INSIGHT

Anticipating the Future... Assessing the Impact

IPRO 341 – Final Report
Fall 2006

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Abstract

In the fall semester of 2006, Illinois Institute of Technology students continued the Insight process of "anticipating the future and assessing the impact on society". This term, the IPRO team collaborated with Ball State University architecture students led by Professor George Elvin. Together these students designed, researched, and evaluated the use of nanomaterials in structural design. In addition they went on to review the technical aspects of the properties of nanotechnology used in conventional building materials as well as to envision new and novel ones for the future. This culminated in the examination of what possible impacts this will have on our society on a national level as well as global scale.

The students had to first familiarize themselves with the definition of what nanotechnology is and how it could be utilized. The Ball State students designed five different structures for the future that might incorporate some of these novel properties. Along with the design process, the IIT students worked closely with their counterparts to review the technical feasibility of using such materials. This led to questions about not just the structural design, but the societal impacts using these materials. Many issues were brought to the fore regarding how we integrate this technology into our society on a global level. One of the major concerns is how to regulate and mentor the progress of how we introduce nanotechnology into our everyday world. The study culminated in areas that need to be further examined and possible recommendations.

In conclusion this IPRO was not only about nanotechnology, but about how we look at accelerated change, emerging technologies, and integration into society.

Forward

IPRO 341 has continued its journey into the diffusion, integration and impact of emerging technologies into society at large. This term added a new dimension as we collaborated with Ball State University architecture students under the direction of Dr. George Elvin. This collaboration provided the platform for students to connect virtually utilizing social networking software (Breeze). The students defined what nanotechnology is and what the possibilities could be. In looking at how it is applied to architectural design, it holds great promise for a world that is concerned with "eco-efficiency". With that being said there are also challenges when dealing with particles on a sub atomic scale. The goal of this team of talented students was to examine the functionality of nano enabled materials and balance the challenges presented with its use.

I commend both the Ball State and Illinois Institute of Technology students for their hard work and tenacity in envisioning the future before it is reality. After observing this group for the period of sixteen weeks it is encouraging to see their enthusing, determination, commitment to excellence, and persistence in looking at nanotechnology through a balanced filter. They have pushed the limits using tools to examine a world we could only dream about a few years ago. It has been a privilege to engage with this group.

As Albert Einstein said:

"We cannot solve our problems with the same thinking that we used to create them."

-Janet Staker Woerner
December 2006

History of Insight

IPRO 341, Insight, is an ongoing project whose purpose is to gather, critically analyze, and synthesize data on the public perception and understanding of emerging technologies. In its first semester (fall 2005) the focus was on Optical Media, Cellular Phones, the Internet, and Video Games.[1] In its second semester (spring 2006), Insight focused on the area of nanotechnology with respect to how the general public attained its information on nanotechnology and also who the major stakeholders in nanotechnology were and how they played a role in the public discourse of nanotechnology.[2] With innovative emerging technologies introduced at an accelerated pace, stakeholder interaction has wide spread consequences that have the potential to affect almost everyone. Thus it is imperative that we understand the potential risks concerning nanotechnology. Spawning from this ideology, IPRO 341 has continued to explore and evaluate these concerns.

With nanotechnology being introduced in commercial and industrial sectors, it is crucial to evaluate its capabilities of enhancing known materials and the impact of these materials outside a protected environment such as a laboratory. Once nanotechnology leaves its controlled environment and interacts with the millions of uncontrollable factors in the world, it is difficult to predict what can happen due to the ability to control nature. Thus it is important to theoretically explore and analyze how nanotechnology might affects the world around us in ways broader than the traditional scientific approach has taught us. Societal implications are more important than ever for emerging technologies but what makes nanotechnology a much more crucial topic is its miniscule size. At the nanometer level where chemical properties of atoms are changed and being manipulated, close inspection is crucial to make sure nanotechnology does not lead to another environmental issue comparable to asbestos or freon.

[1] For more information please visit: http://iKNOW.iit.edu/
[2] For more information please visit: http://www.iit.edu/~ipro341s06/

Another area where societal implications of nanotechnology need to be studied is in architecture and building materials. We need to ensure that building materials with nano-particles are not only safe for the end user, but for those working with the material at all levels. We also need to ensure that our environment will be protected and that nanomaterials will be safe for decades to come. Before continuing this report, we will provide a brief introduction to provide a common platform of understanding. The following is a short introduction to nanotechnology:

What is Nanotechnology?

Nanotechnology is the technology of building things on a microscopic scale, from the smallest particles and increasing in size to the macro level. Nanotechnology creates and uses structures that have novel properties because of their small size. The science builds on the ability to control or manipulate at the atomic scale. Nanotechnology involves research and technology development at the 1 nm to 100 nm range.

Definition of "Nano"[3]

"Nano" in the technical sense means one billionth. A nanometer is one billionth of a meter. To put this into perspective:

· 1 nm = 1/1 000,000,000 m (10-9 m)

· Human hair is 50,000 nm in diameter

· The smallest object visible to humans is 10,000 nm

· 10 hydrogen atoms in line equal 1 nm

NOTE: At any time when a term may seem confusing, a glossary has been inserted at the end of the paper to clarify scientific and nano related terms.

[3] http://www.nano.gov

Introduction

With the rise of nanotechnology at the global scale, it is increasingly important to keep in mind the technical and societal implications that may arise due to the nature of this emerging technology. Currently we are in an influx of research and the implications thereof directly affecting many avenues of human existence. But a critical area that has seen very little research is that of the architecture community and building materials that can be enhanced with nanotechnology. IPRO 341 saw this as an area to explore and initiated a collaborative effort with architectural students as well as many other disciplines within the IPRO team.

As part of this objective, the team closely collaborated with architecture students from Ball State University (BSU) in the process of designing nano-houses in order to evaluate their chosen nano-materials, explore possible risk factors, and offer alternatives where required. Research of the implications were carried out in parallel with the theoretical designs as to develop a more efficient, successful, user friendly and safe final product. The following objectives were identified in order to complete this project.

Objectives

IPRO 341's objectives were to:

1. Identify Nanotechnology

Identify nanotechnology concepts and the properties of the materials that the BSU students planned to incorporate into their designs.

2. Detail obstacles with nanotechnology

Detail the possible technical obstacles when integrating these materials in to real-world architecture designs created by the BSU students.

3. Research societal issues

Research, identify, and analyze the following societal issues:

1. Materials: Recyclability, cost-efficiency, toxicity, etc.
2. Education: Workers' education, insurance agents, etc.
3. Society: Privacy-hacking, responsible parties, governmental concerns, etc.
4. Construction market: Machinery, job force/market, etc.

4. Detail the collaborative process

Detail the collaborative process with off-site team members separated not only geographically, but also in terms of technical and aesthetic knowledge bases.

5. Construct recommendations

Construct recommendations pertaining to the future of nanotechnology and its integration into society.

6. Apply collaboration tools

Apply collaboration and communication tools.

Team Values

The following paragraph documents the team values that were decided upon by consensus of the IPRO team and shared with both BSU and IIT. The values our team hopes to accomplish and the values that we hope to upkeep are to be ethical in our judgments and keep an open mind about different perspectives. We find that having ethics as a top priority will help us deal with the ethical implications of nanotechnology. This is especially important with building materials and architecture. We need to closely look at the ethical and societal implications of nanotechnology to prevent another lead paint or asbestos-like situation. Also, since nanotechnology is such a multi-disciplinary effort and a newly emerging technology, we need to keep an open mind and to think "outside the box".

Values that were identified as being important to all team members include:

1. Trust, hard work, and dedication.
2. Efficiency and time management.
3. Openness to constructive criticism, being open-minded.
4. Team facilitator and flat management team style to incorporate an equal share of work per person.
5. Respect for each other.
6. Avoid plagiarism! Paraphrase information, use proper citations, and ensure that original photo links are stored on the image.

Process

The Beginnings…

The concept of collaboration between Ball State University and Illinois Institute of Technology was discussed between the two faculty members, George Elvin and Janet Staker Woerner in late April at a Nanotechnology conference held here in Chicago. In discussing the issues of the day (primarily societal issues and their impact) they talked about current curriculums and way to address these emerging technologies at the university level. Professor Elvin talked about his NanoStudio, which is composed of architectural students, and Professor Woerner talked about a survey class she was teaching, Emerging Technologies and Society, and also the interdisciplinary approach to education. In discussion the idea floated to the surface about the possibility of collaboration between the two schools. They both felt strongly about the promise of nanotechnology, but what remained was how to integrate this into university level programs as well as the consideration of the much wider societal impacts.

Professor Elvin came to Chicago and met with Tom Jacobius, Director of the IRPO Program and then Professor Woerner traveled to Ball State to visit the campus at which time they agreed to collaborate for the fall. The next step was to introduce the students to their idea and move forward.

IIT/BSU subgroups

To first get a feel for the collaboration, the BSU students and Professor George Elvin made a trip to Illinois Institute of Technology's IPRO Games Day on August 26, 2006. This provided an ice breaker for us to learn more about each other. After this we met in our first collaborative group session via teleconferencing rooms at each University. At this point we were able to formulate our subgroups with respect to the nanomaterials being used in each design and the members within. Five subgroups were decided upon and are as follows:

Teams	Members	Year/Major	Materials
Team 3884	Marta Bastrzyk (IIT)	5th / Mechanical, Materials, and Aerospace Engineering & Applied Mathematics	Quantum dot lighting Carbon nanotube sheets
	Tae Young Kim (IIT)	4th / Biological, Chemical, and Physical Sciences	
	Adam Buente (BSU)	3rd / Architecture	
	Elizabeth Boone (BSU)	3rd / Architecture	
Team Natural Umbrella	Jose Hernandez (IIT)	4th / Mechanical, Materials, and Aerospace Engineering	Nanowire paper Quantum dots Nanosensors
	Nicole Holt (BSU)	3rd / Architecture	
	Emily Perchlik (BSU)	3rd / Architecture	
	Jessica Mullendore (BSU)	3rd / Architecture	
Team NanoSpa	George Skontos (IIT)	5th / Applied Mathematics	Expandable building envelope Nanosensors
	Tyge Sopko (IIT)	5th / Electrical and Computer Engineering	
	Andrew Glass (BSU)	3rd / Architecture	
	Amber Agan (BSU)	3rd / Architecture	
Team Fleischman	Kevin Lerash (IIT)	4th / Political Science & Masters in Public Administration	Carbon nanotube sheets OLED panels
	Crystal Lybolt (IIT)	2nd / Mechanical, Materials, and Aerospace Engineering	
	Eric Gerding (BSU)	3rd / Architecture	
	Paul Ripley (BSU)	3rd / Architecture	
Team NanoShell	Nir Vaks (IIT)	3rd / Electrical and Computer Engineering	Nanosensors Nanosteel-coated fabric
	Brandon Seaton (IIT)[4]	4th / Electrical and Computer Engineering	
	Matt Goyak (BSU)	3rd / Architecture	
	Jessica Coleman (BSU)	3rd / Architecture	

[4] Withdrew from team

Team	Professor Janet Staker Woerner (IIT)
Advisors	Professor George Elvin (BSU)

Communication Methods

We then decided on Macromedia's Breeze to be the primary communicative collaboration tool for the rest of the semester. Breeze is a collaboration software program that allows video/chat communications and also sharing of documents "live" to rest of team while using the program. It was also expected that subgroups would supplement this tool with regular e-mails and phone calls. The team had a special meeting set up to learn how to use Breeze, headed by Tim Paige, training manager of the Indiana Higher Education Telecommunications System (IHETS, which can be accessed at http://www.ihets.org). At this point we were ready to start meeting on our own times with our respective subgroups.

Newsletters

It should be noted that throughout the semester there were five, bi-weekly newsletters posted on iGROUPS and sent to everyone in the collaboration. iGROUPS is an internet project management application developed and hosted by the IIT IPRO office that enables teams to upload their files, create calendars, send email, etc. The purpose of these newsletters was to keep BSU updated on the weekly operations of the IIT team. These five letters were written in an informal fashion and can be viewed in the Appendix following the paper. We decided at the start of the semester that BSU should know what was going on at least bi-weekly, thus we decided upon a newsletter every two weeks.

IPRO Team Member's Responsibilities

The team also assigned individual team assignments and were as follows:

- **Nir (*Marketing*)** – Creating a video that we'll show on IPRO day, general marketing.
- **Kevin (*IPRO liaison / co-editor*)** – Taking care of reflections, handling issues with the IPRO office and keeping track of deadlines.
- **George (*Editor*)** – Final report editor.
- **Marta (*Facilitator*)** – Preparing the agenda, keeping us on track, ensuring we know what we want to accomplish.
- **Tyge (Scribe)** – Recording meeting minutes, taking attendance.
- **Jose (*iGROUPS / iKNOW / website*)** – Administrator for iGROUPS, iKNOW, and website.
- **Crystal (*Publisher*)** – Producing a weekly summary of everything accomplished by IPRO 341 to keep BSU updated.
- **Tae Young (*Research*)** – Finding articles and summarizing the information, acquiring nano-technology related pictures that we can display on iGROUPS or elsewhere on the web.

Societal Dimensions

To stimulate discussion about the issues, we were given a list of questions to answer from our instructors to better facilitate our acclimation to our new process of collaboration. This was the first team assignment. The purpose of this assignment was to get both teams to think about what nanotechnology is and why it is so important to society. Compiled answers are presented in section 4 of this report.

Presentation 1 – Materials and Products Overview

Following the above introductory group assignment, each of the IIT groups researched their respective nanomaterials and gave presentations on each to the rest of the class. IIT students also decided to look at a product incorporating nanotechnology that interested them. This was included in the first presentation (Presentation 1) as presented in section 5 of this report.

Presentation 2 – Technical Issues with BSU's Designs

After identifying and analyzing the nanomaterials selected, we received the first draft drawings from the BSU students for our subgroups. At this point we were able to see how our materials were actually going to be used which allowed us to begin our technical evaluations of each subgroup's design. These findings were presented in "Presentation 2" to the rest of our IPRO, which is covered more extensively in section 6 of this report. (A Sample Presentation 2 is offered in the appendix.)

Technical Recommendations

Each team was able to point out and give a critical analysis of design issues, which can be found in section 7, for the structures provided by the BSU students and was able to voice those recommendations when the BSU visited the IIT campus on Friday, October 6th 2006. Essentially this meeting allowed everyone to get together in a room and discuss the presentations, drawings, and technical concerns that we had with the respective designs. This allowed for the BSU students to properly change some of the problems that we foresaw with the designs. At this point we also made adjustments as needed on how we saw the rest of the semester progressing. That is, we defined our objectives more thoroughly. The consensus was to create a long-standing website on each of the designs hosted on BSU servers that could be looked back at in years to come. We also documented that we wanted to focus on the process of the groups' actions throughout the rest of the semester and keep a close eye on how the collaboration worked. A date was also set in advance for us to visit BSU for a "final review" on November 17, 2006, where IIT would be traveling to BSU.

Product Case Studies

At this point of the semester we found that the technical issues with the BSU designs had been documented accordingly and we wanted to redirect our focus to an approach on societal issues concerning nanotechnology. For a period of time we also discussed the idea of doing product case studies and actually documented four specific products that were going to be researched. Even though the case studies did not get researched extensively, they were decided upon as follows, some only being recognized as broad categories:

- Man-made Diamonds
- Building issues – Nanotechnology being discussed in the building community
- Viva Gel – An STD and HIV preventing contraceptive that utilizes nanoparticles
- Weapons utilizing nanotechnology and their impact on politics on the global scale

The decision of not doing these case studies was decided upon because they would have taken too much time for what we wanted to accomplish. However it did bring to the forefront interesting possibilities of nanotechnology applications.

Societal Issues

Subsequently, we devised a list of issues to research, particularly focusing an eye on building materials, and divided them throughout the IIT group. There was a literature gap concerning some of the selected issues resulting in a lack of information for some issues chosen, but that will be covered extensively in later sections. They are as follows:

Material	Education	Society	Construction Market	Global
• Recyclable • Cost-efficiency • Toxicity • Compatibility • Resourcefulness • Survivability • Life-expectancy • Radioactivity • Sustainability	• User • Insurance agents • Workers • Designers / Engineers • Governing body • Requirements	• Privacy – hacking • Sabotage / attacks • Religious reactions • Malfunctions • Responsible parties • Governing bodies	• Construction time • Material delivery • Job force / market • New hardware / machines needed • Insurance • Test efficiency	• How other nations deal with / what regulations do they have?

<u>Note:</u> This table is NOT indicative of all issues relating to nanotechnology. The issues above where chosen because of their significance to the IPRO team and their research studies. It should also be noted that the five categories are not exclusive. The IPRO team grouped these issues into categories for their own research purposes.

Midterm Progress Presentation

On October 17, 2006 the IIT group had two faculty members, Professor of Chemistry Dr. Lycos and Project Coordinator of Chemistry/Materials/Chemical Synthesis Dr. Friedman, come in and watch a presentation given on what currently occurred on and before that date. The critical areas that were discussed during this presentation included the materials used in the BSU designs and how they were incorporated, the process by which our teams had collaborated thus far, and our future steps – primarily referring to the social research yet to be done.

Societal Impact of Nanotechnology Research

On October 24, 2006 we met in Galvin Library with Jannelle Ruswick, IIT's social science librarian, to discuss options of research for our social issues. At this point we scoured through scholarly journals and completed the necessary research on the topics selected previously. We then met as a class and discussed our findings. Further information about the researched issues and the conclusions made are available in section 8 of this report.

Deliverables

On November 9, 2006 we met with the O'Connor Design Agency to discuss possible designs for deliverables on IPRO Day. It was decided that we would be creating two posters, an abstract, and a movie to have at our booth on IPRO Day. We are still under the process of figuring out other deliverables that may be handed out as supplements such as pens, candy with our brand, buttons, t-shirts, business cards, or bookmarks. Our budget is limited to less than $500, so our options are limited. O'Connor has agreed to price out these items and get back to us regarding what the possibilities are.

List of deliverables

- Project Plan Midterm Progress Report
- Professional Exhibit / Poster
- Abstract
- Deliverables CD
- Final Report
- Oral Presentation / PowerPoint
- Project Plan Midterm Progress Report
- Professional Exhibit / Poster
- Website

Meeting at Ball State University

On November 17, Insight made a trip to Ball State University to watch the semi-final architecture review for the NanoStudio. Each design's website was presented by respective subgroup, and evaluated by architecture faculty. Special guests included the Chair for the Architecture Department and guests from BSU's Center for Computational Nanoscience.

The trip turned out to be very rewarding, as we were able to see the designs we have been contributing to really take their final forms. The BSU teams had been doing a considerable amount of work in the previous weeks, allowing for the Insight recommendations to really be apparent. IIT was also asked numerous times to expand on technical and societal issues that were presented, and did so as much as possible.

The meeting also gave the IIT members a chance to see BSU's campus and interact with each other on a long road trip. Team synergy appeared very strong, despite getting in to a minor vehicle accident with a large deer, somewhere in the middle of Indiana. The trip turned out to be a real success with future promise, as the BSU students plan on attending IPRO Day on December 1, 2006.

IPRO Day

On December 1, 2006 we will present our findings for the semester and display an exhibit for the day to be judged. Our deliverables include two posters, an abstract, a DVD movie about nanotechnology, and several computers showing off Macromedia's Breeze and the websites created by ourselves and our counterparts at BSU. The BSU members will also be in attendance to take in IPRO Day and also be able to answer any questions at our exhibit that pertain to their designs.

Collaboration Process Report

The team collaboration between the groups at IIT and BSU has involved a wide range of experiences for each team. Most of the collaborative obstacles that came up were due to communication. Those obstacles were identified as follows:

- Problems with meeting times. Because the groups were picked at random rather than with an analysis of schedules first, there were huge problems with getting four and five people together at one time to meet and discuss the topics at hand. Also due to time zone differences between CST and EST, teams mismanaged proper meeting times.
- Lack of e-mail usage. There was also a serious problem that has been discussed of e-mails that were replied to multiple days after they were sent. Other e-mail problems included not e-mailing all members of a group: that is, there would be two members of a group communicating over e-mail when everyone in the subgroup should have gotten each e-mail that was sent.
- Issues with Macromedia Breeze. There were some technical issues with Breeze such as microphones not working and speakers not outputting sounds. This did not occur as much as the other issues though and calling Tim Paige may have helped with those problems.
- Differing educational backgrounds made communication on a common platform challenging (i.e. architectural vs. engineering and social science).

The difficulties that arose with the collaboration were issues that may arise in any project and indeed do arise in many projects that take place when geographic separation is a factor. It should also be noted that these issues did arise in some groups, but in other groups these miscommunications rarely occurred and meetings were prompt and regular.

Overall, even when the groups that had faced major obstacles were asked if they thought they could enter a collaboration process with more knowledge in the future, the overwhelming answer was positive. Regardless of hurdles with communication, everyone in the IIT group has said that they were very pleased with the outcomes of the collaboration process and found it to be a great job market learning experience.

Acknowledgements

Thank you for valuable assistance from:

- Jannelle Ruswick, Reference Librarian for Psychology and Social Sciences, for her invaluable assistance with using the Galvin Library databases.
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- Jay Marhoefer – Latham and Watkins, LLC. – legal counsel.
- O'Connor Design for helping us with our deliverables.
- Brandon Seaton, who was a member of 341, but dropped the class about halfway through the semester.

Societal Dimensions

In order to begin a collaboration process with our BSU counterparts we have worked together on answering some of the questions relating to new technology development, the process, the participants and our general thoughts on all these topics. The following are direct quotes from IIT and BSU team members to the proposed assignment which are offered in the following passages:

- **Discuss why you think exploring design issues, materials issues, and the societal implications are important.**

When you are designing a product (whether it be buildings, electronics, etc.), it's critical to explore all the issues concerning your product. You cannot cut any corners or just brush by certain issues, because these could mean a future failure of your product. Especially in the case of nano-materials, there's a much higher health risk in comparison to conventional materials. It has been demonstrated that scientists are only now coming to an understanding of the behavior of molecules at this scale. Given the circumstances, it's imperative to conduct a proper amount of research and testing so that society doesn't have another asbestos problem to handle. By covering all bases and exploring all avenues that the product will go down, it is easier to have a better, well-rounded product.

As Frank Lloyd Wright said: "literature tells about man, architecture presents him." All of these new materials will present society with a new image and create new issues for society to explore. Because nano technology is a vast new subject and its issues and implications are unknown more exploring needs to take place.

- **By using a holistic approach to design, can potential problems be avoided? If so how?**

Yes, problems can be avoided; by taking the holistic approach, you are bringing in other professions and other ways of thinking that you alone could not conceive. By having many hands in the cookie jar, you can avoid more problems. But that is not to say that too many hands in the cookie jar can be a good thing. If too many people are involved your project may never take off due to too many opposing ideas.

The main reason I can think of as to why exploring these issues is important is because we simply don't know enough about nanotech and its possible side effects when used in real world applications. I deal with nano measurements all the time in my engineering classes, but suffice it to say all the theory in the world won't account for real life/real world trial and error.

- **What are the possible outcomes of involving all or many of the stakeholders early on?**

By involving many stakeholders early in the manufacturing process, they become more aware of the many aspects of the handling nano-materials and the potential risks. This can be both a good thing and a bad thing. The good outcome is that, since the stakeholders do own a part of your company, they may assist by offering a different perspective, namely a consumer perspective. Additionally, it may encourage some of the stakeholders to claim the product as their own and pusher harder with investments.

Many times present architecture has a very narrow approach to design, most likely with economics in mind. Clearly this narrow/naive approach can only increase the number of potential problems. With these problems directly affecting the social atmosphere in a negative way, the design is a failure. With nano-technology being as undeveloped as it is, there is a possibility of starting from scratch with an extraordinary building material that is capable of combining all previous knowledge of design and its social implications, in turn creating unprecedented design.

Involving all of the stakeholders early on would allow for the alteration of plans to incorporate the agenda of each. This would increase the productivity and efficiency of the development of the project. We already know that nano science takes the work from people in several different areas of *study, so incorporating as many different stakeholders as possible in the early stages could lead to positive prescriptions earlier than if different stakeholders were brought in to the project a few at a time.*

- **What are the downside risks of early collaboration?**

There can be too many different outcomes – there may be so many opinions that discussion would confound how to begin creating the product, and it may never take off the ground. Also, this might raise fears and doubts due to the uncertainty about potential risks of nano-materials. Stakeholders typically aren't scientists, and might be fearful of early test results that may later be proven wrong.

A handful of people with various background field experiences should thoroughly study and be involved in the whole process but not all the stakeholders, especially early on. Having everyone involved would offer possible positive results since more ideas would be put on the table, but also more problems would surface. As with any new product certain risk factors are always involved and it would be to the company's advantage to pin-point possible problems/law suits early on. Nevertheless, engaging numerous people would greatly reduce the efficiency of the work-in-progress, therefore, delaying the actual developmental process of the product and possibly bringing it to a screeching hold if issues would appear to be too complex. In addition, as more opposition would be raised, team morale could degrade and passion for the project could be lost. For example, many times when a group is influencing an architect during the initial design stages, there are too many specifics and minute issues asked to be resolved. At such an early stage, there are not enough products to collaborate on efficiently.

- **Can using a model of early collaboration with all stakeholders be used as a possible model for other emerging technologies?**

Yes, nanotechnology is a very multidisciplinary effort. Due to the fact that it is so new and not much is known about it, the more perspectives and different approaches we can have into this subject the better. There are important societal, scientific, and legal issues that need to be addressed regarding *nanotechnology. It may be the only model, as many graduates working in nano-technology and other cutting edge fields have very multi-disciplinary backgrounds, often with multiple, unrelated degrees.*

An input from people who might not be scientifically involved with a project but who know the market and could predict not only future success and the road to it, but also possible future issues is a necessary must to any new project being started, any new technology being explored, but they should not take a priority over the actual product. For that reason the model of early collaboration with all stakeholders could be used as a possible model for emerging technologies. Since it would involve those who will be directly using the technology, their influence can allow for free exchange of ideas and create a more successful end product.

- **Does this differ from the past? If so, in what ways? Think about the introduction of the PC, cell phone, media storage devices, and electronic games.**

While all of these devices left a massive imprint on society, nano-technology (on a large scale) will more likely be revolutionary, rather than evolutionary. In the beginning of a new technology, not much is known about that technology; issues arise that are not previously conceived. Nano-technology, however, is dissimilar to the aforementioned technologies in this question. Although the general process itself is the next step in manufacturing, the societal implications and issues around this manipulation will impact society in a much more profound sense than any of the consumer devices mentioned above. Manipulation at the atomic and molecular level could lead to entirely new branches of science, and will result in many issues that will need to be addressed.

I think that nanotechnology is very different than anything else that we have been introduced before. The main difference is the fact that unlike other new technologies that were introduced such as the industrial revolution that affected the mass production of goods and the internet revolution which revolutionized the flow and distribution of information, nanotech will have a global affect on any field one can imagine. I will try and explain by giving few examples:

Imagine that in few years people could make materials that are ten times stronger than a diamond. Imagine a computer chip that will be a thousand times faster and cost fifty times less than the fastest computer chip currently in the market. Imagine the possibility of building an electric power plant for less than $5 millions, which will supply energy to all of New York, and be pollution free. All of this is possible, through Molecular Nanotechnology. It could become the most influential force to take hold since the age of humankind.

Materials and Product Overview (Presentation 1)

In order to familiarize ourselves with each of the materials chosen by the architects, every group has extensively researched these materials, their definitions, characteristics and possible current or future applications within and outside the architectural scope. In addition, to gain better understanding on technology in general, each group has also chosen a nanotechnology based product that is already on the market or could be introduced shortly.

The following section details what was included in the Presentation 1, with relevance to the materials and products being studied for each subgroup.

Team 3884 – Carbon Nano Tubes and Quantum Dots

A carbon nanotube (CNT) is a cylindrical fullerene which consists of rolled up sheets of carbon hexagons. It was discovered in 1991 by researchers at NEC. CNT has two main types. One is Multi-Walled Nanotubes which were discovered in 1991 and the other one is Single-Walled Nanotubes which were discovered two years later. Their diameter is 50,000 times thinner than human hair.[5] Currently CNTs can be found in big screen TVs, ultra-sensitive sensors, high-resolution AFM probes, super capacitors, transparent conducting films, drug carriers and much more. Also, since CNTs have hydrophobic properties, it could be used in waterproof clothes and other applications. Significant advantages of CNTs are also their extensive properties. This material can sustain high temperatures (up to 2000ºC) in the absence of oxygen. When subjected to an electrical field, it emits electrons very efficiently. In addition, the material has high mechanical

[5] www.nano.gov

strength, as well as tensile strength which prove higher than steel.

Quantum dots, also known as nanocrystals, artificial atoms or microscopic beads, have a variety of current and future applications. Since their discovery in the 1970s, they have proven to hold a large promise in many fields ranging from electronics and solar energy applications to medicine. Currently we can find them in the new Play Station 3 and high-definition DVD players. Ongoing research is being performed in the applications of quantum dots in fluorescence spectroscopy and 3D imaging inside living organisms since the nanocrystals proved to be significantly superior to the currently used organic dyes.[6] In the solar energy field, the quantum dots have been found to increase solar cell efficiencies from 15 to 20% (conventional cells) up to 42% conversion of solar power to usable electricity.[7] Their white light emitting capabilities have been confirmed as well, thereby allowing scientists to explore the possibilities of replacing conventional light sources (light bulbs) with much more efficient and human eye friendly tiny artificial atoms.[8]

Product – Artificial Diamond

It's a real diamond, but instead of being forged over millions of years by nature, it's man-made.[9] Therefore, what used to take thousands of years to create can now happen in a matter of days, and at a fraction of the price. These diamonds are almost indistinguishable from mined diamonds. Nanotechnology is used when the diamond is constructed one atomic layer at a time in specially developed machines.[10] These uses of progressing technology in diamond development might have significant implications from technical and societal angles. Lowering the price of the diamond while still providing the exact same capabilities of the hardest known material will allow for much faster computers with increased memory space, as well as improvements in various fields including optics,

[6] http://en.wikipedia.org/wiki/Quantum_dot
[7] http://www.sciencenews.org/articles/20060603/bob8.asp
[8] http://www.vanderbilt.edu/exploration/stories/quantumdotled.html
[9] http://www.cbsnews.com/stories/2004/05/10/60II/main616666.shtml?CMP=ILC-SearchStories
[10] http://www.apollodiamond.com/

electronics, acoustics, thermal management, mechanical applications and weapons. In addition, it will have a great societal impact on the companies that earn money mining and selling diamonds (i.e. DeBeers), as well as countries with big mining industries and the workers.[11]

Team NanoShell – Nanosteel and Nanosensors

Translucent nanosteel[12] is a unique product that when applied to any surface does special things:

1. It allows weak materials to be self supporting and strong.
2. It allows the owner to control the amount of daylight that is entering through the surface.

This unique product usually comes as a powder, a spray, adhesive, or a wire mesh.

The second material that is used in the BSU design is Carbon Nanosensors; generally, the team relies on the nanosensors to have the ability to respond to the environment and change the characteristics of the nanosteel.

When combining the two materials together, BSU's team ***assumed*** that:

- Nanosteel becomes stiff when a certain thickness is applied to the cloth membrane.
- Nanosensors induce a change in the nanosteel from transparent to translucent to opaque.
- A pressure activation system allows the user to control these changes.
- The Nanosteel is strong enough to support dead and live building loads. (4.5 times the strength of the strongest steel)[13]

[11] http://www.usatoday.com/money/industries/technology/maney/2005-05-31-nanotech_x.htm
[12] The Nanosteel Company. *Nanosteel's RADAC*. http://www.nanosteelco.com/
[13] Ibid.

By incorporating these features BSU's team is hoping that thin nanosteel membrane will act as a very thin shell structure, allowing unconventional free-form design options. A traditional core structure, which will contain the stairwell and bedrooms, will tie the building into its semi-urban context. The membrane will wrap and attach itself to the core, ripping away at the traditional building materials and morphing into very fluid shapes. Nanosteel panels embedded with nanosensors will respond to the user's need for different light qualities.

Product – NanoFluids

The main problem with heat dissipation is directly related with the development of new technologies. Computers, Telephones, music players, etc. keep getting smaller and more powerful. The number of transistors on a chip has increased exponentially since the 1970s. Components are getting smaller and the clock frequencies are getting higher. That creates heat - a lot of heat.

Today, currently, the most common ways to dissipate heat in Microchips are the use of:

1. Heat sinks[14] to increase the surface area which dissipates heat.

2. Fans to speed up the exchange of air heated by the computer parts for cooler ambient air.

In addition, when more powerful microchips are being used, the heat that is being generated is much greater and forces us to use water cooling[15] systems which usually consist of a water block, a water pump and a heat exchanger. Liquid Nitrogen[16] systems can also be used by pumping liquid nitrogen on to the chip through a cooling system.

The two main problems with the ways to dissipate heat are:

[14] Wikipedia The free Encyclopedia, HeatSink. Page last modified November 2006. http://en.wikipedia.org/wiki/Heat_sink
[15] Tom's Hardware, CPU cooling with liquid nitrogen. Page last modified November 2006. http://www.tomshardware.com/2003/12/30/5_ghz_project/index.html
[16] Tom's Hardware, CPU cooling with liquid nitrogen. Page last modified November 2006. http://www.tomshardware.com/2003/12/30/5_ghz_project/index.html

1. The ability to dissipate heat has reached its limit for heat sinks and fans.

2. Methods of excessive heat dissipation are very expensive to produce, big and bulky, and uses a lot of energy.

However, recent developments in nanotechnology have created a new and rather special class of fluids, called 'NanoFluids', which appear to have great potential for cooling applications. NanoFluid[17] - a two-phase mixture in which the continuous phase is usually a liquid and the dispersed phase is composed of extremely fine metallic nanoparticles.

Overall, the advantages of nanotechnology are:

1. Heat dissipation is up to 400% better than current technology[18].

2. NanoFluid cooling systems are relatively cheap and easy to build.

3. High reliability and zero maintenance cost.

4. Low energy use while operated.

5. Technology already exists and being used in several labs.

Team NanoSpa – Expandable Building Envelope and Nanosensors

The expandable building envelope is essentially a membrane-like structure that has the ability to expand and contract in all 3 planes of motion. It is constructed with nano-reinforced materials in the shape of honeycombs. The idea behind this shape is that the honeycombs will allows for the stretching and contraction of the membrane. The membrane is reinforced with

[17]PHYSORG.com, Cool nanotechnology can save energy. Page last modified November 2006. http://www.physorg.com/news12190.html
[18] Center for Nanofluids Technology@MIT, Research-Heat Transfer. Page last modified November 2006. http://web.mit.edu/nse/nanofluids/research/heat.html

carbon nanotubes (nanosteel) to provide a light, yet strong structure.

- Nanosensors are able to detect explosive, chemical, and biological agents
- Monitor different gases
    - Check oxygen concentration in the room
    - Monitor for unhealthy gases that can have grave affects on humans
        - Can improve worker safety
        - Decontamination of hospitals
- Low-cost, batch fabrication in comparison to traditional technology
- Small size and low weight leads to easier integration in devices, buildings
- Lower power requirements

Product – Military nano-suit

This product was chosen because of the significant consequences that nano-enhanced weaponry can introduce to the global scale. The nano-enhanced ground soldier will be a very formidable agent of war.

- Suit will monitor soldier's health status
- Nano-bots injected in soldier's body will communicate with suit to help treat injuries
- Suit will change to adapt to certain areas/conditions:
    - Insulation/Porous
    - Camouflage
- Suit will give soldiers super-human strength
    - Ability to jump 20 feet in the air

Team Fleischman – Carbon Nanotube Sheets and Organic Light Emitting Diodes

Carbon nanotube sheets are essentially CNTs that have been fused together in order to create longer strands, or sheets, of CNTs. The idea behind these sheets is that they will be able to reinforce other materials because of the properties CNTs have shown. They are said to be extremely strong, stronger than steel, nearly invisible, very flexible and able to emit light or heat given the right voltage. It has also been discussed that in the very distant future it may be possible to create walls or meter-long sheets of CNTs, but at the current time we cannot make these sheets even an inch long. Current products that are being aided by these sheets include screens that roll up and car windows and aircraft canopies that contain invisible antennae, electrical heaters, and optical displays

Organic Light Emitting Diodes (OLED) are essentially extremely flexible screens that are able to give off light in many different colors. They are extremely more efficient than current LED's because they do not require a backlight to propagate the lighting from the device. OLEDs also have greater portability on same size batteries of comparable technology. These devices are also lightweight, extremely thin, and very flexible.[19]

Product – Self-cleaning Glass

The product that was chosen to study was self-cleaning glass because it is already in use and offers great new benefits for buildings. Essentially the glass is made with carbon nanotubes and works in two steps: first, the surface of the glass reacts with UV rays from the sun to breakdown dirt organisms – this is called a *photo catalytic* process. Then, because the material is *hydrophilic,* the rain does not form droplets on the glass but rather covers the glass uniformly – easily washing the dirt off of the outside of the glass and then drying extremely fast.

[19] Optoelectronics Industry Development Association (OIDA) (August 2002). *Organic Light Emitting Diodes for General Illumination,* OIDA. Washington, DC. http://lighting.sandia.gov/lightingdocs/OIDA_SSL_OLED_Roadmap_Full.pdf

Unfortunately, if the glass is too dirty, then they still must be washed manually – may not be good for the desert where there is no rain![20]

Team Natural Umbrella – Quantum dots, nanowire Paper, Nanosensors

Nanowire paper or more specifically Titanium Dioxide (TiO2), is one of the materials Team Natural Umbrella will be using in their design. The nanowire paper which is essentially just strands of TiO2 woven together,, will be used for the walls and roof for this team's house. So far TiO2 has been created in sizes similar to that of pennies, small bowls and small cups. It is our hope that one day, once technology has progressed far enough, TiO2 can be used for the purposes stated above.

A quantum dot is a basically just a semiconductor crystal that has a diameter of a few nanometers. They have very interesting optical and electrical properties that make them potentially useful in a variety of applications. For those who do not know, a semiconductor is a material that is neither a good conductor of electricity (like copper) nor a good insulator (like rubber). The group hopes to use quantum dots in a variety of ways. One assumption which is still being researched is whether quantum dots can turn the TiO2 walls transparent under the "right" conditions. Quantum dots which produce different colors of light based on their size may or may not be able to be used in a situation such as the transparency case. However, this is still under research.

Nanosensors are simply sensors constructed on the nano scale, 1,000,000,000 of a meter. There are various applications nano sensors could be one day used in. Applications such biosensors, deployable nanosensors and electrometers could all one day be within the realm of the possible due to nanosensors. Currently, very few sensors are made purely on nano technology. However, the group is confident that once technology and society progress far enough they can use these

[20] Jo Twist (June 2004). *Eco Glass Cleans itself with Sun,* BBC News. http://news.bbc.co.uk/2/hi/technology/3770353.stm

nanosensors to detect moisture content in the garden of their home, as well as changing the environment of the house to reflect the user entering a room.

Product – Nano Hockey Stick

Some of the benefits and characteristics of this new type of hockey stick are as follows:

- 4x energy transmission, enabled by nanotechnology
- Nano Epoxy used, which is a carbon nanotube epoxy matrix.
- The new composite stick is 60% - 70% better impact resistant than the traditional composite stick that the company offers.

Technical Evaluation of Architectural Designs (Presentation 2)

As has been seen through the collaboration between BSU and IIT, there is knowledge gaps between the technical issues and other broader issues associated with a system. Issues that seemed negligible for the non-technical members turned out to be crucial and of immense importance. Noticeable knowledge gaps were also found between the call for the utilization of nanomaterials and the adequate knowledge on how to utilize these materials correctly to date.

We, the team, tried to gather as much information and insight in order to successfully estimate the many technical issues that are concerned with BSU's designs. These issues are presented below, according to the designs. A small image of each design is shown in order to give a visual feel for the intended structure.

Team 3884

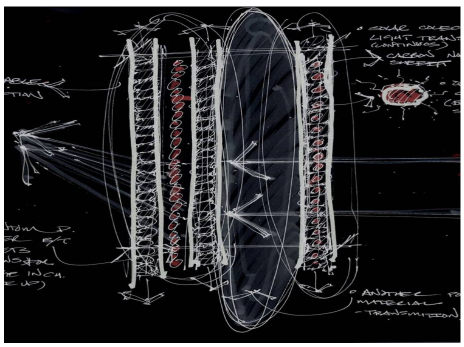
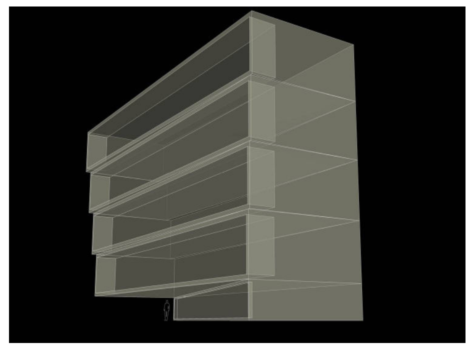
The two nanomaterials that Team 3884 chose to use were single wall nano tube sheets (SWCNT) and quantum dots (QD). SWCNT is being used as the outer shell due to its good ratio between strength/weight, and quantum dots as an artificial source of light and energy storage/transfer devices.

This design, even though more feasible than other designs has few technical issues with current technology, mainly:

- Limitation in length
    - It is difficult to produce long CNTs formed basically from hexagonal graphemes

- In the process of generating CNT, pentagonal and heptagonal graphemes are also created[21]
- Resulting with closed ends or with ends that spread out[22]
- Maximum length of 6 millimeters, to date[23]

- Limit in synthesis
  - Cannot control chirality[24]
  - Carbon Nanotube can be either metallic or semiconducting depending on different chirality

Team NanoShell

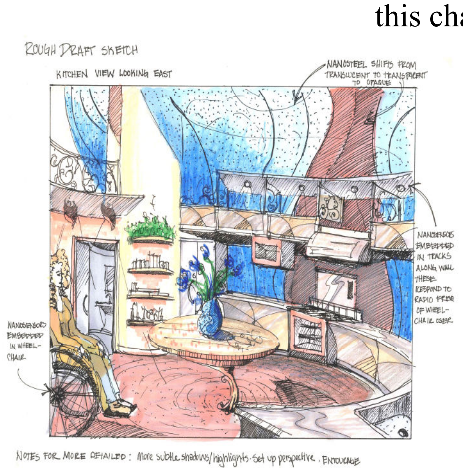
The BSU team implemented two different nanomaterials in their design: translucent nanosteel, which from one hand allows weak materials to be self supporting and strong, and from the other, it will allow the owner to control the amount of daylight that is entering through the surface. The second nanomaterial is carbon nanosensors which will allow sensing and control of the nanosteel characteristics.

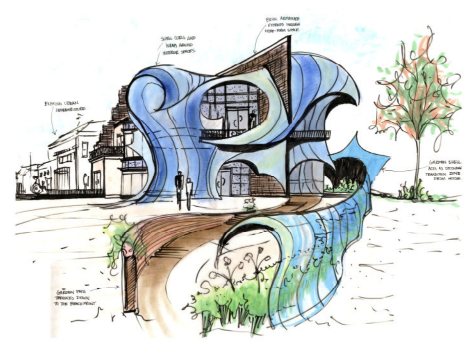
The use of these materials raised few technical issues:

- Limitation in size

[21] NEC laboratories - Innovative Engine. In the first issue, Dr. Iijima introduced recent developments in Carbon Nanotube Technology
[22] Ibid.
[23] Ibid.
[24] http://www.applied-nanotech.com/cntproperties.htm

    - Nanosteel as not been proven efficient on large scale structures;
    - The structure relies on nanosteel as the sole material to support it.
- Acoustics and heat[25]
    - Nanosteel is a very good heat conductor, which means that when sunlight is strong the steel structure may reach temperatures that are even higher than the outside environment.
    - Due to the use of nanosteel, the structure will be exposed to sound and noise from the outside.
- Electromagnetic effects[26]
    - Lightning will be attracted to the steel structure due to its ferromagnetic characteristics.
    - The structure will act as a capacitor (two conductors with dielectric material between them) and might cause a lot of static voltage inside the house.
    - The change in the characteristics of the wall will be induced by change in voltage on the Nanosteel plates. This means that it would be hazardous to be in contact with the wall when this change happens.





25 Heat Transfer and Transport Phenomena in Microscale-Heat Transfer. Gian Piero Celata
26 Introduction to Condensed Matter Physics- Electromagnetism, Feng Duan, Jin Guojun, Duan Feng, Guojun Jin

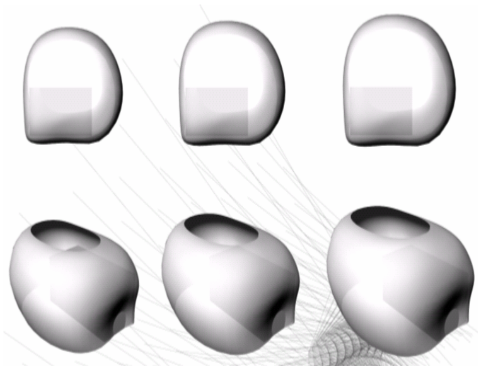
Team NanoSpa

Team NanoSpa used a carbon nano tube reinforced building envelope and CNT reinforced liquid crystal displays (LCD) attached to the inside of the envelope. Entire envelope is based on unproven kinetic architecture – moving walls and floors.

The utilization of these materials in the design raised the following technical issues:

- Elasticity of envelope screens
  - Not only does CNT have limitation of length (please see Team 3884 section), but CNT is not a very elastic material[27].
  - Even if the CNT will be elastic, one will have to use immense power (1TPa force for ~10% of stretch)[28] in order to achieve adequate stretch.
- Elasticity of screens
  - The use of LCD screens, mounted on the walls is quite problematic due to the fact that LCD screens, even though flexible, are not very stretchable. So when the envelope will expend, the LCD screens will be destroyed.
- Structural issues
  - No reason to believe that the structure will support its own weight, especially during and after stretching.
  - The inside and outside walls will be made from the same material, which makes even greater dependability on the CNT material and its ability to stretch and support itself at the same time.
- Aerodynamics
  - The structure, which is a bubble like shape might have aero dynamical problems and might not be able to handle strong winds.

[27] E. Hernández, C. Goze, P. Bernier, A. Rubio. (1999). Elastic properties of single-wall nanotubes. Applied Physics A: Materials Science & Processing, 68(3), 287-292.
[28] Ibid.



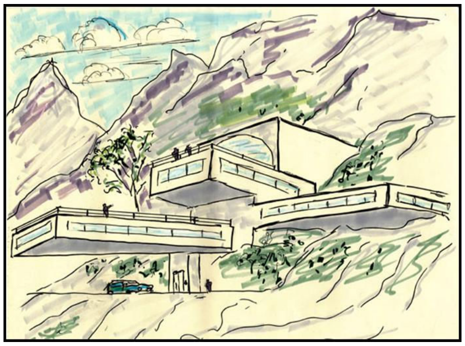
Team Fleischman

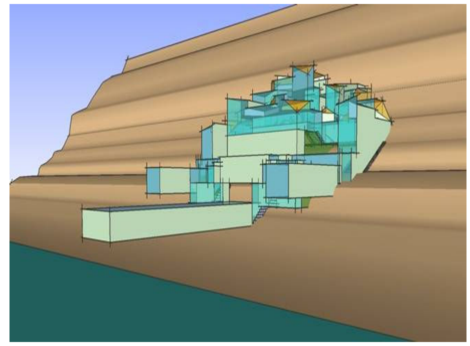
The design is using two nanomaterials: carbon nano tubes and organic light-emitting diodes (OLED). The house is filled with many multi-angled ceiling panels to catch as much natural light as possible. The idea behind this is to reflect normal lighting conditions in response to the Alaskan day-light cycles. The house is also supposed to offer seclusion from the rest of society with a three-layer design.

The utilization of these materials in the design raised few technical issues:

- Structural limitations
  - Huge torque on the building due to the protruding lap pool.
  - Torques applied by the extruding swimming pool: combining the weight of the lap pool with the existing torque may become unreasonable. The mountain landscape will also offer some limitations because erosion, snow and melting ice will certainly affect the structure of the house.
- Transparent walls concept limitation
  - Concerns with the nanomaterials becoming more stable while changing the composition of the rock
  - Heat may arise due to the transparency of the walls and the intense day-light offered in some parts of the year. (20+ hours of daylight compared to 20+ hours of darkness)

- Privacy issues - the inefficiencies that may result from the transparent walls and ceilings and the possibility of malfunctions making the walls transparent or opaque at undesired instances.





Team Natural Umbrella

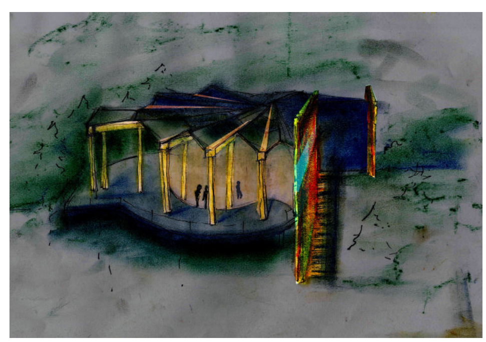
The group is using three nanomaterials in their design: nanowire paper, quantum dots, and nano-sensors. Nanowire has potential applications from armor and flame-retardant fabric, to bacteria filters and chemical warfare agents. It can withstand temperatures up to 700 degrees Celsius (about 1300 degrees Fahrenheit)[29]. The group plans on using quantum dots as display images on the nanopaper. Also, they would like to use the quantum dots' magnetic properties to aid in nanowire paper wall movement and manipulation. Lastly, the group would like to use their nano sensors in two ways. Sensors in plants to detect soil and water content, which would automatically turn on the sprinkler system when the moisture content is low is the main use for their sensors. However, the group would also like to place nano sensors in the house to detect and change that rooms environmental settings to match the preprogrammed preferences of the person entering that room.

The utilization of these materials in the design raised a few technical issues:

- Materials Limitations

[29] Physorg.com Science:Physics:Tech:Nano:News, Nanowire-Paper Offers Strength, Flexibility. June 2007.

- The roof and walls may melt after when coming into contact with water. As an area of the wall is exposed to UV light for longs period of time, if it becomes wet it might dissolve. UV light causes Titanium Dioxide (nanowire paper) to become hydrophilic, which could be very bad for the TiO_2 walls and roof.[30]
- To date nanowire paper has only been made into penny sized shapes, as well as small cups and bowls. The group assumes that one day once technology advances far enough walls and roofs could be constructed from TiO_2
- When exposed to sunlight it has been observed that some types of quantum dots act as solar cells. This could be bad for the Titanium Dioxide (nanowire walls) as having solar cells on your wall may cause it to produce electricity which could cause it to combust, as well as possibly electrocute passers by without proper protection/insulation.
- With current technology, pure nano sensors are not feasible. The group would like to use these sensors in to detect users entering a room then set the environmental settings of that room to that particular individuals preferred temperature, humidity etc. It is still unclear exactly how this will be accomplished using these sensors.



<u>Note:</u> For those interested, please refer to the appendix for updated model pictures.

[30] Wikipedia The free Encyclopedia, Titanium Dioxide. Page last modified October 2006.

Technical Recommendations

Upon completing the technical evaluation of architectural designs presented to us by our BSU counterparts, as outlined in section 3 of this report, we have also presented them with recommendations on design improvements. The purpose of this was to provide some evaluative recommendations to our teams and further the development of their houses.

The proposed suggestions are outlined below, accordingly to the design.

Team 3884

Although acknowledging certain limitations to the proposed building design based on the current scientific capabilities of the materials or lack of certain information about them, no technical recommendations have been given. The limitations on length of carbon nanotube sheets were researched and presented. While brainstorming within the group, a possibility of reinforcing known materials (i.e. cement) with the CNTs have been brought up, but this solution would take away the capabilities of this nano-material, its characteristics, on which the building structure relies. We have also informed the designers about possible health risks, providing them with current scientific findings on toxicity effects of single walled Carbon nanotubes and Quantum Dots.[31] In summary, it is our opinion, that the concept, in its

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[31] www.cdc.gov

Shvedova AA, Kisin ER, AR Murray, Gandelsman VZ, Maynard AD, Baron PA, Castranova V [2003]. Exposure to carbon nanotube material: assessment of the biological effects of nanotube materials using human keratinocyte cells. J Toxicol Environ Health *66*(20):1909–1926.

simplicity and similarity to existing buildings will prove to be feasible relatively soon and it will provide a great transition between current and future buildings.

Team NanoShell

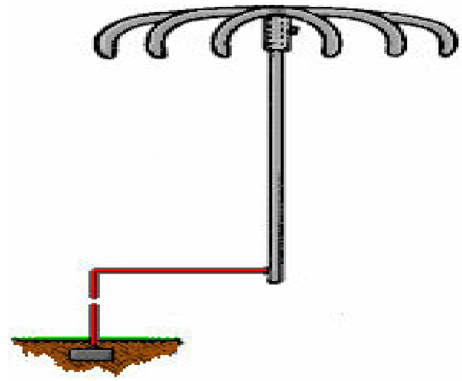
The structure suggested by the team was composed of translucent nanosteel that was used as the material for the outer walls of the building. While evaluating the design, we have realized that since the house was made of a large metallic structure, lightning which occurs quite often in areas next to the ocean, would be very likely to be attracted to it. We have found and recommended to the designers, that the most efficient solution, meaning one that would require very little structural/design changes and would be inexpensive, is the use of a lightning rod. By placing a lightning rod connected via a low-resistance wire or cable to the earth or water below, where the charge may be safely dissipated, one will significantly increase the probability of lightning to go through the rod into the ground, instead of it going through the house itself.[32]

Shvedova AA, Kisin ER, Mercer R, Murray AR, Johnson VJ, Potapovich AI, Tyurina YY, Gorelik O, Arepalli S, Schwegler-Berry D [2005]. Unusual inflammatory and fibrogenic pulmonary responses to single walled carbon nanotubes in mice. Am J Physiol Lung Cell Mol Physiol

Lam CW, James JT, McCluskey R, Hunter RL [2004]. Pulmonary toxicity of single-wall carbon nanotubes in mice 7 and 90 days after intratracheal instillation. Toxicol Sci *77*:126–134.

Lam C-W, James JT, McCluskey R, Arepalli S, Hunter RL [2006]. A review of carbon nanotube toxicity and assessment of potential occupational and environmental health risks. Crit Rev Toxicol *36*:189–217.

[32] Physics Today, your daily news & research source, Benjamin Franklin and Lightning Rods. Page last modified November 2006



33

Another technical problem we have acknowledged was based on the fact that the structure of the building resembled two conductors separated by a dielectric material (mainly air).[34] This would cause the structure to act as a capacitor and generate flowing charge in its interior, thereby putting the people within it in danger. In order to resolve this issue, we have recommended using the already proposed lighting rod.[35] By connecting the rod cable to the translucent nanosteel in a certain spot, we will connect the "capacitor" metal plates to the ground. This connection should be made between the metal structure and the rod as close as possible to the ground, so the lightning will have the least effect (shortest way to the ground). Since the ground has an absolute potential of zero, the potential between the plates should be also equal to zero. Zero potential means zero charge and so we will have a constant state of a discharged capacitor.

Team NanoSpa

Since CNTs are not malleable at the molecular level[36], it was recommended that our team implements some type of accordion-like structure to accommodate the expansion and contraction of the envelope. This accordion structure will allow the envelope to physically move without concern for the

[33] This figure is displaying a lightning rod, which is used to take excess electricity from a structure and channel into the ground.
[34] Wikipedia The free Encyclopedia Capacitor. Page last modified October 2006
[35] Ibid.
[36] E. Hernández, C. Goze, P. Bernier, A. Rubio. (1999). Elastic properties of single-wall nanotubes. Applied Physics A: Materials Science & Processing, 68(3), 287-292.

elasticity of the material; this also provides a means to control the envelope, as movements of the electromechanical joints in the accordion can be controlled via monitoring hardware. By controlling angles of the joints, the total size of the envelope is easily managed. Aesthetics becomes the next hurdle, as this accordion joint is not especially pleasing to look at.

Another issue will be the substantial amount of heat radiating from the motors and servos that will be used to contract and expand the house. We have proposed that a fire prevention system be installed that will constantly monitor all the heat emanating from the servos and motors at all times. This will help prevent a fire by shutting off certain motors that are about to over heat. To prevent all motors from overheating and thus paralyzing the building envelope, the motors will run in intervals of each other. This will allow for the cool down of one set of motors as the secondary set comes into service. Thus by alternating motors we above the problem of completely shutting down the dome in the event all the motors overheat.

Team Fleischman

The unique design of this Alaskan home has introduced a few possible problems. First, the house is built into a rock cliff with huge cantilevers hanging over the land below. These unsupported extrusions were designed to show the possible strength of CNTs, however one of them holds a lap pool which will apply a tremendous weight on the 'lever' of the building section – torque – that could pry the house away from its foundation over time.[37] Making sure that the house is anchored far into the rock should solve the problem of it being pulled away. Also, the cantilevers will unlikely be stable without some extra supports near the connection to the rest of the house where shear forces will be the strongest; diagonal beams from the house to the cantilever should be sufficient and still futuristic.

Secondly, the possible inefficiencies (loss of energy and heat) that could result from the transparent walls and ceilings are a problem. In order to be transparent, the only insulations that

[37]http://www.physics.uoguelph.ca/tutorials/torque/Q.torque.intro.html

could be used would have to be transparent as well. This might simply mean using glass or very clear plastic along with air as insulation. Again, in the future when this house is to be viable, CNTs might be incorporated into other materials (like glass or plastic) which would solve this problem.[38]

The third issue was the possibility of malfunctions concerning privacy issues when making the walls transparent or opaque. If they are controlled by a central computer system, they could be susceptible to intruders with hacking abilities. So, there should be security measures implemented such as protective software, alarm systems, over-ride panels inside the house, and backup power supplies/generators.

Team Natural Umbrella

In order to help resolve the issues with the Titanium Dioxide roof and walls dissolving after being exposed to UV light then having water applied to it, one possible solution could be simply coating the roof with a paint that is resistant to water. There are elastomeric coatings[39] currently available on the market. Simply coat your roof or wall with something such as this, and it is possible it will reduce the chances as well as possibly prevent it in general from dissolving the walls/roof with water after it's been exposed to UV light.

One way to help prevent quantum dots from causing the TiO2 walls to combust as well as to prevent passer bys from being accidentally electrocuted could be to coat it in a similar manner to coating the TiO2 to prevent damage due to moisture. Simply applying some kind of an insulator either in the form of paint or an epoxy can be all that is needed.

Seeing as there are rarely any sensors built purely on nano technology, a very simple alternative to this would be to use micro sensors. There are "tons" of micro sensors available on the market that can do what the group is looking for, and are

[38] Kazuo Minami (2005), *Large Scale Simulation on the Properties of Carbon Nanotube.* http://www.es.jamstec.go.jp/esc/images/annualreport2002/pdf/3project/chapter4/2minami.pdf (November 2006)

[39] Definition from the EPA online Glossary: *Elastomeric coatings* have elastic properties, and can stretch in the summertime heat and then return to their original shape without damage. Elastomeric coatings include acrylic, silicone and urethane materials.

relatively inexpensive. A sensor such as an "irrometer watermark sensor" from Gempler's[40] can be used for exactly what the group needs, and only costs $35. So while a nano sensor could be more efficient say 25 years from now, right now for a relativity low price, the same solution can be achieved using micro technology.

[40] http://www.gemplers.com/a/shop/product.asp?T1=R38101&UID=20061113193518718829047

Societal Issues

The potential of impact that nanotechnology can have on society is, without a doubt, enormous. Unlike previous, revolutionary technologies, nanotechnology is an evolutionary and disruptive science that will impact many disciplines in society. Nanotechnology is defined to be the manipulation of matter at the smallest level[41]; materials produced with nanotechnology behave quite differently than materials on a conventional scale. The phenomena observed at this level are not yet entirely understood. This science is still evolving and there is great potential for disaster if proper, precautionary steps are not taken before nanotechnology becomes widespread in society.

Material	Education	Society	Construction Market	Global
• Recyclability • Cost-efficiency • Toxicity • Life-expectancy • Sustainability • Durability	• User • Insurance agents • Workers • Designers / Engineers • Governing body	• Privacy / hacking • Malfunctions • Governing bodies	• Material transport • Job force / market • New hardware / machines needed	• How other nations deal with / what regulations do they have?

<u>Note</u>: This table consists of the revised and final issues that were researched and wrote upon, as decided by the group. These issues are not categorically exclusive and do not attempt to suggest the wide range of issues associated with nanotechnology.

[41] www.nano.gov

As depicted above in table above, several categories of societal issues as they related to nanotechnology were be examined. These included material issues, educational issues, issues within society and government, challenges in the construction market, and global issues. Safety of nanomaterials is just one aspect: considering previous material catastrophes such as asbestos, DuPont's Teflon, or even leaded paints, it is important to understand the behavior of these materials as they interact with the human body. Unfortunately, as will be explained in this section of the report, there is currently very little to stop companies from producing and selling nanotechnology products because of the lack of regulation. We have discovered these products are generally not fully tested (or tested properly for nanotechnology-related concerns) or not regulated by government agencies. A lack of consumer education does little to pacify potential fears of nanotechnology. Our research will provide insight into what the possible risks associated with nanotechnology are and recommendations will be provided on how those can be integrated as we move forward.

Global Issues

Global Issues in Nanotechnology

Written by Kevin Lerash

In the article "Who's Minding the Nano's," the funding from the U.S. Federal government toward the nanotechnology initiative is investigated. George Bush has been behind the increased funding for nanotechnology promotion and has increased the 2004 budget up to $1 billion, more than double that of the 2001 budget. The article states that there are growing concerns because this money is apparently going to the most proactive in the nanoscience community and there is the threat that the majority of this money is going to the wrong people overall. Some people are even saying that by 2015, we could see as much as $1 trillion dollars invested in nanotechnology, about 10% of the economy's current income.[42]

About $10 million of the $1 billion will be going toward researching "toxicity issues" concerning nanotechnology, but

[42] Munro, Neil & Vaida, Bara (2004). "Who's Minding the Nanos?" National Journal, 36, 2033-2034.

there are advocacy groups speaking out that this may not be enough and with the rise of under researched products already hitting the market, many people are starting to get very alarmed on the issue. Another great issue that is being talked about now is the fact that scientists may be directed to undertake research that they do not necessarily agree with, and in turn may have to promote it. All though, there is faith that scientists are human beings too and it would take a great number of them to incorporate any type of gigantic change in they way science is taking place.[43]

The public is also expressing their concerns about nanotechnology and the safety that it harnesses because we are seeing people already getting hurt from some products. The German product "magic nano," a nano glass sealant sparked a number of concerns last year when many consumers who had tried the product received abdominal pains after use. It turns out that there are really no nanoparticles in the glass sealant, but it led many consumers to believe there were, thus taking a different look at this new technology.[44]

This has sparked some action in the private sector because of a lack of regulation on the part of government. DuPont is working with a nonprofit company to assess its current products and research development on nanotechnology, as are other firms in Europe. The FDA and the EPA are now becoming concerned as well because certain products that do contain nanoparticles in them, such as cosmetics and mineral supplements, are out of the reach of these organizations. Many venture capitalists are now saying that using "nano" in a companies name is unwise because it may show a vulnerability to risk management.

The EPA has created an act concerning its first nanoproduct though, a carbon nanotube that has been enacted under that Toxic Substances Control Act, which they have said that any other products will have to be subject to the same guidelines in the future. DuPont and other companies are calling for the U.S. government to provide $100 million per year in assessing the risks of nanotechnology, annually. So why is this not happening? The administration earmarked almost $40 million on 2005 for

[43] Gewin, Virginia (September 2006) "Nanotech's Big Issue." Nature, 443, 137.
[44] van Calster, Geert (Aug/Sep2006) "Regulating Nanotechnology in the European Union." European Environmental Law Review; 15, 238-247.

these concerns, but only about $11 million could actually be traced in to direct concerns.

In the European Union, we are seeing many of the same policy decisions as in the United States. Essentially, that there are none. There are certainly some toxicity acts, chemical restrictions, and molecular restrictions that have been in place for many years which could be used to regulate nanotechnology. But the problem is greater than that. The biggest problem is that none of these regulatory acts or agencies has enough knowledge about nanotechnology. Next, there is not a distinct, uniform vocabulary for talking about nanotechnology.[45] This is dire to standardize how these laws will be made globally. And the greatest problem of all is that nanotechnology behaves differently than particles on the molecular scale, which in turn affects the scope of the current regulatory provisions because they just do not cover enough of the behaviors that we have currently seen nano particles exhibit.

Overall, the European Union wants to see regulation come from a process-based initiative rather than a product-based initiative, but the current frameworks for chemical, biological and other processes do not cover the wide-ranging scope of nanotechnology.[46] But, the United States currently is running a product-based campaign as they have in the past. This product-based process is clearly seen with the FDA who regulates new prescription drugs based on when they come out, and the recent passing of a specific carbon nanotube, the first nano product that has been approved by the FDA.[47] It must be noted as well that we could not expect these policies and agencies to be able to adopt a process-based structure for regulation because we as a human race are not even sure the capabilities of nanotechnology at this point. One of the main similarities between the U.S. and U.K. is that there needs to be regulation on the issue, but it is of dire concern that there are not too many agencies fighting for control over the issue because it could allow for too many industrial safety concerns to come before the more important civic health and environmental concerns, which will affect the most people. Finally, in the current administrations, they are saying until more in-house cleaning and provisions can be made

[45] van Calster, Geert (Aug/Sep2006) "Regulating Nanotechnology in the European Union." European Environmental Law Review; 15, 238-247.
[46] Ibid.
[47] Ibid.

to current acts, the market will have to decide on its own which way nanotechnology will lead. The current governments expect the population to make concise efforts when debating on nanotechnology. They are also putting their faith into companies putting products on the market that may have questionable outcomes. Essentially, it is on the private sector to control these issues and be accountable for any mishaps occurring because of the pervasiveness of the technology.

The Canadian based Action Group on Erosion, Technology and Concentration is assessing the impacts of farmers and nanotechnology because there are several new ways that food can be genetically modified using nanotechnology. They believe that the entire way the food chain currently works will be under scrutiny after we see a massive change in the way food is processed, manufactured and delivered. They are also saying that farmers may be in a great deal of trouble concerning these actions because there is a great number of unknown foreseen consequences concerning the environment when nanoparticles are infused in the crops we plant. The group is currently calling for all foods with nano-based particles to be taken off the shelves and regulated before they come in to the market.[48]

In Asia we are also seeing major investments in nanotechnology, especially in China and Japan. Currently, Japan remains one of the world leaders in promotion of nanotechnology initiatives and is the number one supplier of carbon nanotubes to the rest of the world. Japanese scientists have been working with nanotechnology since the 1980's and are responsible for the first carbon nanotubes. They are currently part of the top 3 countries investing in nanotechnology and appear to be regulating this pervasive technology similarly to the rest of the world: relying on private business's accountability.[49]

In China we are seeing a massive effort to become part of the new nanotech world. They are currently investing in new infrastructure every year, including two new massive facilities: National Center for Nanoscience and Technology in Beijing and the National Center for Nanoengineering in Shanghai. The regulation efforts in China have been a troublesome topic for research because there is little information to be found. But, we

[48] (January 2005) "The Big Down: Food and Nanotech." Outlook on Science Policy; Vol. 27, 2-3
[49] Chen, Hsinchun, Chen, Zhi-kai, Huang, Zan, & Roco, Mihail (August 2004). "International Nanotechnology development in 2003: Country, Institution, and Technology." Journal of Nanoparticle Research; 6, 325-354.

may believe that their government is closely watching the efforts of their scientists and heavily watching any private business ventures that may be taking place.[50] We may also want to keep a close eye on China's developments because their government is powerful and very aware of the operations in the country. It may also be a possibility that they may be working much more diligently than presented on the issue. Also with their political influence now becoming much more prominent in the globe we may find that China's efforts could soon start setting the pace for global regulation.

One promising option for regulation could come from an independent organization that oversees government activity in an international arena setting. One such option is the International Risk Governance Council (IGRC) based out of the European Union. The IGRC is a Swiss-based initiative that started in 2003 to identify risks in current government initiatives. A paper put out in February 2006 on nanotechnology risk governance is calling for the IGRC to be at the forefront of nanotechnology regulation, at least a process there of. They have devised models for risk governance which include how to regulate nanotechnology, increase transparency in research and governmental work, and they also provide a list of recommendations for academia, industry, government and non-governmental organizations on how they should be approaching the topic at hand.[51]

The current way that the rest of the world is looking at nanotechnology is very similar to the United States' approach. That is, there is very little that can be done for a few reasons. First, there is yet to be a standardized approach to looking at nanotechnology and regulating it. This is because we are not exactly sure the capabilities of nanotechnology and we are still attempting to have our old regulations apply to this new, pervasive technology. Second, money talks especially loudly. There is a great deal of venture capitalism going in to this technology as well as a great deal of monies being spent by the governments in promotion of this technology, which could potentially stymie regulation efforts in turn. Third, consumers

[50] Bai, Chunli (July 2005) "Ascent of Nanoscience in China." Science 309 (5731), 61.
[51] Renn, O. & Roco, M. C. (February 2006). "Nanotechnology and the Need for Risk Governance." Journal of Nanoparticle Research, 8, 153-191.

love new technology and ways to utilize it, and generally do not research what they use accordingly prior to using it.

It is extremely important that we as a globe look at this issue with great care and precaution so as to not spoil the new technology or put any part of our environment in danger. Looking for an independent organization to carefully monitor the globe's efforts and keep transparency at the top of the list of priorities is dire. Only time will tell whether or not the globe can work together, effectively, to benefit mankind or whether this new technology will indeed be the detriment of mankind.

Societal and Government Issues

Regulatory Agencies

Written by Marta Bastrzyk

Structure

Thus far, the way the new technology has been approached by the government was to establish organizations and provide research money for those researching the capabilities, improvements and risks of nano-products. However, no organization to provide control, establish regulations or set limitations that would be tailor-made for nanotechnology has been created, according to the author's knowledge. That is not to say that the technology is unregulated. The principles of the law, as applied to any technology or product still apply here, in general. All the products released to the public still fall under the product liability laws or the current environmental, health and safety laws (consumer protection law, liability for environmental damage) to some degree at least since they have not been drafted with the intent of nano-particles in mind[52].

However, it appears that allowing established government organizations to take a lead in nanotechnology control and regulating it will not be sufficient. With previous technologies, the general rules, as drafted by the Food and Drugs Administration (FDA) or the Environmental Protection Agency

[52] van Calster, Geert (Aug/Sep2006) "Regulating Nanotechnology in the European Union." European Environmental Law Review; 15, 238-247.

(EPA) through its Occupational Safety and Health Acts (OSHA) or Toxic Substance Control Acts (TSCA), seemed to keep the technologies in check, being able to successfully protect the public.

Nanotechnology is not just a new technology; it's a field of many converging technologies. Not only does it have application in a variety of scientific domains, but it also is based on many expertise fields, making it far from singular. That leads to the conclusion that nanotechnology requires its own, tailor-made regime[53] since current regulatory regime may just not be sufficiently prepared to address all the environmental, health, safety, economics concerns of the technology and its wide areas of application. In addition, this regulatory framework should be arranged soon, in order to keep up with all the new emerging information and to be in place prior to full technology deployment, which, according to a survey of 600 manufacturing companies, as conducted by the National Center for Manufacturing Sciences (NCMS), will occur within the next five years (80% of responders)[54] . Time is, definitively, of essence.

Referring to the latest events, we can clearly see that what influences one part of the world, also influences the other too, but in a lesser or stronger manner. One might call it a "butterfly effect", more commonly known as chaos theory.[55] Governing of nanotechnology in U.S. would certainly have to account for its world-wide implications. What we decide, as a nation, no longer influences just us. Same goes for other countries. Possible economic collapse of any large nation would shake all the rest. At the same time, totally preventing the nanotechnology development in any country would cause a colossal technology gap in that country, leaving it inferior to others and exposing its allies. Additionally, each country drafting its own regulations would have to satisfy a number of previously made international agreements and insure that friendly countries don't establish conflicting regime. Based on these problems and many others, it appears that it would be the most productive if an international administration would be established in order to impose tight control over the technology.

[53] Ibid.
[54] Allan, Roger (June 2006) " The Little Nano Went to Market… Eventually." Electronic Design; 85-86.
[55] Bradbury, Ray "A Sound of Thunder" *A Sound of Thunder and Other Stories* (2005)

This is not a novel concept.[56] Organizations like the United Nations, World Trade Organization, NATO and others, which bring many nations together, already exist. However, the way these work is not perfect, to say the least. Often, the organizations have to satisfy too many competing interests, have to stand their ground, although shakily, against big nations and experience numerous communication problems. It is not to say that they are not working. It is definitively better to settle a number of the issues they face arguing while sitting at a table, than in any other circumstances. Their structure should be considered as a building block for the international nanotechnology administration. Since this emerging technology is expected to change the things as we know it, why not change the way we govern matters as well, lead to invention of new forms of administration.

The questions on the type of organizational structure are one of the first ones to surface. Based on centuries of wars and power-hungry individuals the option of dictatorship based organization is quickly rejected. Democracy, although proven in existing societies to be superior to many others, might not work either[57]. It would require that people who make the decisions would be extremely well educated in science and technology and free of biased agenda (isn't that contrary to the definition of a politician?)

This leads to another possible system type, or rather a concept of "network democracy" proposed by Jim Garrison in his *America as Empire: Global Leader or Rogue Power?*[58] That might just be the best option currently available, however it's not without its faults. It assumes that nations, especially the powerful ones, would be willing to step down and be equal with all the others. That would require a major shift in the minds of the citizens of these countries, who could feel their identity, although not literal, is being taken away. Better concepts, if available, are hopefully being drafted and explored.

Independent of the type of structure, as explored in above paragraph, another question that comes up pertains to the way laws or regulations would be drafted and implemented. The idea

[56] van Calster, Geert (Aug/Sep2006) "Regulating Nanotechnology in the European Union." European Environmental Law Review; 15, 238-247.
[57] Phoenix, Chris "Thirty Essential Nanotechnology Studies." Center for Responsible Nanotechnology.
[58] Ibid.

of prohibiting the technology from development should be crossed out from the start.[59] The technology is already way too far into the development and whatever administration is established to control and regulate it will first have to concern itself with catching up. Both the governments and privet companies have invested too much money into advancements and the technology holds too much promise to just drop it. Even if laws were made that would extensively limit the progress, these legal regulations, either national or international, may not have much effect on the secret military programs. In addition, tight regulations would only encourage black market developments and uncontrolled research or product applications. For that reason, a balance has to be obtained between insufficient and crushing regulations. This partially leads to the question of decision execution. If laws are drafted, how are they implemented in the society, through force? The concept of police forces might have to be adjusted. Commercial self-regulation might prove very useful, since the companies do not want to expose themselves to future liability action law suits. But it would still require a threat of government regulations. Other scenarios seem more science fiction than realistic (hopefully) and include surveillance or human modification. Unfortunately, both sound as an attractive solution. Would nanotechnology, or rather we ourselves, go as far as *Brave New World* type of Utopia[60]?

The definition of governing nanotechnology, as defined by Eric Drexler and Chris Peterson, suggest that the challenge is basically to “find ways to maximize research freedom while preventing serious abuse and making it stick worldwide is a social challenge of the first rank.”[61]

Education of Members of Regulatory Agencies

Due to the extremely wide field of nanotechnology applications, the governing organizations would have to be composed of members with educational backgrounds in numerous fields and be able to fully understand what nanotechnology is, on both scientific and societal levels. Diversity should be the core of the requirements expected of those in power. People from different

[59] Ibid.
[60] Huxley, Aldous “Brave New World.” Harpercollins, September. 1998
[61] Drexler, Eric and Peterson, Chris “Unbounding the Future: the Nanotechnology Revolution.” Gayle Pergamit William Morrow and Company, Inc., New York 1991

nations, with various technical and societal backgrounds should make the decision, as a collaborative organization. This is a notion that the IPRO team holds strongly because nanotechnology involves so many stakeholders that communication between them is imperative.

In addition, beyond the deep understanding of the technical concepts of nanotechnology in various fields as acquired from science classes, the administration representatives should also be required to complete a series of political science, history, geography and overall cultural awareness classes while still in school.

The group that would govern first will not have the expected backgrounds and understanding in nanotechnology, but as the years go by and the student educational system would be adjusted (or rather completely changed), the groups would become more as desired.

Nanotechnology Hacking / Privacy

Written by Crystal Lybolt

Computer hackers share a “fundamental belief that information should be free and that the pursuit of knowledge is an essential human right.”[62] These are people who are interested in computer security; however, the public is only aware of those few hackers who use this knowledge to cause damage. Without the hackers who are looking for and finding avenues that are insecure, there will be no way to protect ourselves against the hackers with bad intents. In “Academic Freedom and the Hacker Ethic,” it is clearly discussed how the hackers who look for security issues to solve cannot share these issues with everyone because the other hackers trying to cause damage will be able to use that information and be a step ahead.

There is a small private online store for “The Hacker Quarterly” that sells a subscription to “Hack Nano” which is actually people brainstorming about new ideas and products and what could go

[62] Cross, Tom. (June 2006). Academic Freedom and the Hacker Ethic. Communications of the Association for Computing Machinery (ACM). 49.6, 36-41. ACM Digital Library. 1 Nov. 2006 <
http://delivery.acm.org/10.1145/1140000/1132498/p37cross.pdf?key1=
1132498&key2=0001242611&coll=portal&dl=ACM&CFID=3582724&CFTOKEN=81479690>

wrong. These are (mostly) going to be the 'good hackers' that society needs. They say the content of "Hack Nano" is "theory and thought driven" to lay out the "realities of nano hacking," and why this "is an important area of exploration."[63]

One website directed specifically against the malicious types of hackers called the Center for Responsible Nanotechnology put this potential issue very well by asking what is going to happen "when the world's hackers shift their focus from turning your computer against you to turning your nanotech devices and implants against you..."?[64] Imagine the world when society realizes that the products they are so proud of because of their efficiency, self-automation, and capabilities can be controlled by malicious hackers (even more likely, governments). There might be just as much potential for disaster and chaos as for advancement of our way of life through nanotechnology.

In a scholarly journal by the Association for Computing Machinery (ACM) already used in the beginning of this section, an essay by the co-founder of Sun Microsystems, Bill Joy, is mentioned. In his essay, he argued "that advancements in biology, nanotechnology, and robotics will soon give rise to technological capabilities beyond our control, threatening the survival of all humanity."[65] This is a heavy, compelling statement, but it could very well be true; this man is very knowledgeable in the field of advancing technology. This leads to the associated point of future nano-warfare. There were metal knives, then guns, then explosives, then chemical warfare, and then nuclear warfare: is nano-warfare next? Would there be any way to hide or protect ourselves? These particles can easily go through the molecular holes in solid materials – including our bodies. Imagine self replicating nano-bots as soldiers to destroy life. Consider the idea of nanoparticles being distributed into the atmosphere as a war mechanism. Science fiction movies like "The Matrix" and "The Fifth Element" seem to be coming closer to reality.

[63] Cipz, Jim. (2006). Hack Nano. 2600 The Hacker Quarterly. 1 Nov. 2006 <http://2600hacker.stores.yahoo.net/hacknano.html>.

[64] _____. (29 Oct 2006). Hacking Nanotechnology. Center for Responsible Nanotechnology. 1 Nov. 2006 <http://crnano.typepad.com/crnblog/2006/03/hacking_nanotec.html>

[65] Cross, Tom. (June 2006). Academic Freedom and the Hacker Ethic. Communications of the Association for Computing Machinery (ACM). 49.6, 36-41. ACM Digital Library. 1 Nov. 2006 <http://delivery.acm.org/10.1145/1140000/1132498/p37cross.pdf?key1=1132498&key2=0001242611&coll=portal&dl=ACM&CFID=3582724&CFTOKEN=81479690>.

Societal Reactions to Malfunctions with Nanotechnology

Written by Ty Sopko

Given the uncertainties and stigma associated with nanotechnology and nanomaterials, there's a clear potential for problems with societal diffusion and integration. Deemed by some as "the next big thing" because of the revolutionary changes it can allow, there are many that are concerned about the profound effects this technology can have on many aspects of society. Since nanotechnology has a much larger breadth than some previous technologies, it's reasonable that there's a proportionally large concern. Considering previous product disasters which include asbestos, leaded gasoline, leaded paints, chlorofluorocarbons (CFCs), and (most recently) Teflon we need to make sure that nanotechnology will not cause such a disaster again. Some companies such as DuPont have addressed this concern and have started questioning integration of nanotechnology products into society and alarm over their malfunction is a solid concern.

Currently, toxicity data on specific nanoparticles is somewhat slim; generic nanoparticles (including CNT) have been tested for toxicity multiple times, with discouraging results. Materials on this scale behave much differently than their larger counterparts, resulting in some unique (and appealing) characteristics. Unfortunately, these qualities imply that they can have "unusual" toxicity[66]. Their effects on cells when they enter the body are different, depending on the viscosity of the material and where it enters the body. As a result of these complexities, toxicologists and chemists are working to establish a new field of nano toxicology. Unlike conventional materials, nano-sized particles have a much higher chance of producing toxic effects; smaller sized particles can reach more parts of the body. This is a two-fold problem, as smaller amounts of a harder to detect particle can produce equally toxic effects as larger particles; the toxicity of nanomaterials is primarily due to their larger surface area compared to their volume[67]. Indeed, nano-Teflon fumes are much more acutely toxic than their normal-sized counterparts[68].

[66] Science News, 5/6/2006, Vol. 169 Issue 18, p280
[67] Annals of Occupational Hygiene; published October 14, 2006, p1-12
[68] Bulletin of the Atomic Scientists; Mar/Apr2006, Vol. 62 Issue 2, p23-24

Unfortunately, the U.S. government is woefully unprepared for nanotechnology education and is devoting minimal funds to the establishment of this field. The introduction of GMO was an immense public relations disaster; seed data and the explanation of the GMO technology was concealed from farmers and consumers[69]. Nanotechnology isn't following the same specific route, but similar trends are being observed. Toxicity of some nanomaterials has already been proven, which is not the case for GMO: there's much potential for a grassroots movement that would attempt to exclude nanotechnology from products. If the companies producing nanomaterials do little to educate the consumers buying their products, it is conceivable nanotechnology will receive the same perception as GMO. Parallel to the GMO outburst, nanotechnology "organic" movements will follow, and this potential technology may never reach its full potential.

Issues in Education

Nanotechnology Impact on Student Education

Written by Marta Bastrzyk

Nanotechnology, in theory, has the capability to affect everything we know from medical and engineering fields to building industries, food growth and processing, to education. It can shape a new world, a world full of nanoscale inventions.[70]

The question is, how do we prepare for it, how do we understand it and how do we introduce our kids to it? The last question, although simple, is very complex, as all of them are when dealing with nanotechnology. The whole educational system will have to adjust in order to prepare young people for this change and, later, to keep the progress going while not leaving many behind. This new educational system would have to encompass all students and cover all the vast fields where nanotechnology applies. Starting from toddler years, some classics of Andersen and Grim Brothers would have to be either altered or replaced

[69] Scientific American; Apr2000, Vol. 282 Issue 4, p42, 2p
[70] Drexler, Eric and Peterson, Chris "Unbounding the Future: the Nanotechnology Revolution." Gayle Pergamit William Morrow and Company, Inc., New York 1991

with new stories and cartoons incorporating nanotechnology to make the new generations more comfortable with it. Similarly as the new generations are not scared of computers, future ones should not be of nano inventions. The systems employed in elementary and high school would be crucial to shaping the young people. The existing one would have to be significantly revised. One proposed approach is the just-in-time education (JITE) tactic[71] which suggests that in order to develop multidisciplinary and collaborative skills, the students would have to learn:

- to identify the disciplines intersecting a complex problem;
- to acquire the necessary pieces of information and understanding from each intersecting discipline;
- to synthesize the various parts into a whole that denotes an acceptable, if not desirable, level of accomplishment;
- to assess requirements for further developments; and
- to establish the values of their accomplishment in the cultures of their surroundings, nation and the world"[72].

This would be accomplished through a number of mid-term or term projects. The point is to integrate different topics and develop a multidisciplinary mindset. The curriculums would have to be adjusted as well to include more integrated classes, where problems refer not only to math and physics, but also history, literature and communication, i.e. "using word problems in mathematical courses to model scientific phenomena"[73]. The goal of these projects would be to make young students open to new possibilities, to encourage self-education on various topics, to collaborate with others and to become enthusiastic about the technology. They would also help to conquer what many report as the one of the top fears of American adults, with many people experiencing tremendous suffering due to it – fear of public speaking.

Interestingly enough, this is exactly what the goals of the IPRO program we are currently participating in are. Therefore, the system is already being put in place.

[71] Lakhtakia, Akhlesh (Jan. 2006) "Priming Pre-University Education for Nanotechnology." Current Science 90; 1
[72] Ibid.
[73] Ibid.

The new system, however, would not only encourage more innovative thinking from students, but also would incorporate a stronger basis in science and communication. And that's what might cause problems. First of all, the teachers would have to be become lifelong learners, adapting to all the new information surfacing and be able to guide the young minds. This would require a total transformation of the certification system. In addition, since much more material would have to be learned by the students, possibly more days and hours would have to be spent learning. That would mean shorter vacations, but also more school taxes (someone has to pay the money for it) and possibly more mental breakdowns of young children unable to handle the pressure. Currently, young teenagers are often spread thin between school activities and extracurriculars. One solution could be making people choose their careers in elementary school and making them experts in what they choose, but giving them just enough information about other things, so that they are able to understand other areas of interest. But how can such a young person make a successful lifelong decision? They cannot and later transitions would be impossible due to large amounts of crucial missing background knowledge.

On the college level, similarly on high school, students would be encouraged to participate in collaborative and interdisciplinary projects. Scientists would not only be taught in depth scientific information, but also sociology, economics, communication and ethics, to understand how their future discoveries affect the world.

College education, however, would no longer be the last stage of the educational system. In order to keep in touch with the advances being made and the changes implied, the scientists, architects, economists, politicians, sociologists, engineers and all the other professionals would have to be re-certified every few years to ensure their knowledge of the fields. We would become lifelong students. Not keeping up would mean falling far behind, often losing the possibility to catch up again.

All the mentioned changes would affect not only curriculums and teaching methods. Among many things, they would also affect the way schools are built in order to accommodate for the interdisciplinary collaborative efforts. Initial signs of it can be observed in the difficulties associated with the design of Birck Nanotechnology Center at Purdue University. Twenty-four departments are represented in that center. In the design of it, architects had to account for all the interdisciplinary science labs for both research and undergraduate levels.[74] These disciplines often had opposite specific needs thereby creating a challenge for the designers.

Now the question is how many people would be willing to go through all these steps, barriers and challenges? Would it be worth it? Would it be too much? Are our expectations for the new technology or for ourselves too high? For example, realizing how many different courses would architecture students have to take during their undergraduate education (extended over the current 5) and the need to re-certify on regular basis, how many people would actually go into it? We can only speculate on the numbers.

Therefore, in summary, the need for a new educational system that accounts for the nanotechnology impact is necessary. Classes need to be more multidisciplinary and collaborative, yet still providing students with the "dry information" about all the things not yet known to them. The hope is, since we have adjusted to everything that has been thrown at us already, we will be able to do so again? If this is true, what costs will be incurred to see such results?

User Education Issues Regarding Nanotechnology

Written by Ty Sopko

In its current state, user education about nanotechnology and products containing nanomaterials is poor and difficult to locate. Some companies have chosen to avoid safety testing or are keeping what is known confidential[75]. This is a pitiful state of affairs when considering previous disasters regarding introduction of new materials or manufacturing technologies that were deemed revolutionary; plenty of new "miracle" materials were later shown to have adverse health effects. To illustrate this, DuPont was recently hit with the largest penalty in the EPA's 35-year history for hiding toxicity data for 20 years

[74] J. Kinkade and M. Jamison (Nov. 2005) "Collaborative Research: Integrating Nanotechnology for multi-disciplines." American School & University,

[75] Bulletin of the Atomic Scientists; Mar/Apr2006, Vol. 62 Issue 2, p23-24

concerning Teflon-related perfluorochemicals which can cause birth defects[1]. Two months prior to this, DuPont announced that they want "an open and early examination of potential risks"; what is the public to believe? Money talks, but the line between profitability and consumer safety needs to be drawn.

Unfortunately, this is only one scenario of poor user education from corporations: the company hides potential toxicity data to ensure high sales. Another, more troublesome situation is deception concerning nanotechnology toxicity. The Green People company produces a type of sunscreen which contains nano-sized titanium dioxide[76]. A concerned consumer wrote the company to inquire about the use of nanotechnology in the sunscreen. Green People affirmed that they did indeed use nanoparticles, as they claimed that these particles are the only size with effective protection against UVA rays. However, there is no evidence that these titanium dioxide particles are the only effective means of UV protection. Green People fails to mention, however, that these nanoparticles allow their product to be transparent instead of leaving a white film on the skin: the problem is purely aesthetic. New evidence suggests that exposure to these nanoparticles may lead to neurodegenerative diseases such as Parkinson's and Alzheimer's, as their small size can potentially allow them to penetrate the blood-brain barrier[77]. Considering there are more than 300 manufacturer identified[78] products containing nanotechnology on the market, everything nano may receive a stigma unless proper safety testing is conducted.

Since the companies cannot be trusted, it seems critical for consumers to search for other mediums to obtain their nanotechnology information. Government agencies such as the EPA are currently overwhelmed, and the current administration is not actively involved in spending money to enforce regulation of nanotechnology. At present, 4% of federal nanotechnology funding is spent on research in health and environmental effects, and another 4% is devoted to social implications and education about nanotechnology. This 4% spent on education is practically meaningless, as 42% of the U.S. population has never heard of nanotechnology[79]. The situation doesn't improve in other

[76] The Ecologist, Nov2006, Vol. 36 Issue 9, p65
[77] Science News, 5/6/2006, Vol. 169 Issue 18, p280
[78] http://www.nanotechproject.org/93/nanotechnology-next-big-thing-or-much-ado-about-nothing
[79] http://www.nanotechproject.org/78/public-awareness-of-nano-grows-but-majority-unaware

countries: a German cleaning product known as 'Magic Nano' was recalled after dozens of users suffered from lung problems[80]. Primarily, this was due to the fact that this product contains fine particles delivered by aerosol; it is currently unknown if nanotechnology is used in this product.

Since it has been shown that corporations cannot be trusted to inform the general populace about potential dangers and benefits of nanotechnology, the burden is placed on the government and non-profit companies. In the current state of affairs, it seems unlikely that the administration is likely to devote any serious funding to user education. Short of the change in cabinet in two years, it seems that non-profit institutes such as the Woodrow Wilson International Center for Scholars, the NRDC (National Resource Defense Council), and Foresight should extend their focus to consumer education. Labeling products that contain nanotechnology and allowing consumers to research the company's test data would also be a major step forward; there are no clear standards regarding test methodologies for nanotechnology products.

Difficulties in Educating the Workforce

Written by Crystal Lybolt

With respect to architecture, the primary workers involved in actually building structures are, of course, construction workers. Construction is already one of the most dangerous and abundant jobs in the U.S. Between 1980 and 1995, there were 17,000 construction workers who died from work related injuries.[81] Construction has existed throughout human history, and still it is this dangerous. So, in the accelerated age of nanotechnology, adding nanomaterials with unknown implications could be catastrophic if not dealt with appropriately.

Some of the leading programs that have taken initiatives in educating society and future professional workers in the US are the NIOSH (National Institute for Occupational Safety and

[80] http://www.nanotechwire.com/news.asp?nid=3178
[81] Brunette, M. J. (2004). Construction Safety Research in the United States: Targeting the Hispanic Workforce [Electronic Version]. Injury Prevention, 10, 244-248. 26 October 2006 <ipbmjjournals.com>.

Health), the NNI (National Nanotechnology Initiative) by the US government, and the NNIN (National Nanotechnology Infrastructure Network).

The NIOSH is the leading federal agency researching and providing recommendations for occupational health implications from the use of nanotechnology. It has listed ten critical areas to focus on as part of the strategic plan to fill the knowledge gaps about nanotechnology in society: 1) exposure and dose 2) toxicity 3) epidemiology and surveillance 4) risk assessment 5) measurement methods 6) controls 7) Safety 8) communication and education 9) recommendations and 10) applications.[82]

The three primary questions the NIOSH is addressing are the following:

- How might workers be exposed to nano-sized particles in the manufacturing or industrial use of nanomaterials?
- How do nanoparticles interact with the body's systems?
- What effects might nanoparticles have on the body's systems?

Some of their goals in education are "Establishing partnerships to allow for identification and sharing of research needs, approaches, and results," and "Developing and disseminating training and educational materials to workers and health and safety professionals." [83]

One very important product of the National Nanotechnology Initiative (NNI) so far has been its recent publication of a document meant to identify the government's research and information needs with respect to the risks that nanomaterials might present: Environmental Health and Safety Research Needs for Engineered Nanoscale Materials. It seems that in this report the basic idea for the regulation of worker safety is to collect, analyze, and interpret data on exposure to nanomaterials in the workplace over time. This would be in addition to research aimed at verifying the amounts of present nanoparticles and their byproducts, as well as determining the corresponding effects in a given environment. Any issues or correlations in the

[82] ---. Nanotechnology at NIOSH. CDC. National Institute for Occupational Safety and Health. October 30, 2006. <http://www.cdc.gov/niosh/topics/nanotech/default.html>.
[83] ____. Nanotechnology at NIOSH. CDC. National Institute for Occupational Safety and Health. October 30, 2006. <http://www.cdc.gov/niosh/topics/nanotech/default.html>.

closely monitored health data will serve as new issues to research, and thus will allow companies to make the work environments safer[84].

This approach of 'do it first and ask questions later' seems quite rushed at first, but because nanomaterials are already eagerly being used in products around the world, it is vital that the workers and consumers of those products are protected as soon as possible. So, the best way to do that is to monitor the health of people already exposed to the nanomaterials, and also monitor the environment around them.

In this report, four areas of needed research/ information have been identified.

1) "Collect health information" – This would include keeping medical histories and questionnaires on file, and flagging suspicious illnesses or injuries that could be related to the exposure to nanomaterials.

2) "Collect exposure information" – Exposure information would be used to categorize people into groups with similar amounts of exposure so that any commonalities could be examined. The NNI recommends highly quantitative personal data (i.e. a sensor that would record levels of exposure over time).

3) "Understand workplace processes and factors that determine exposure to nanomaterials" – In order to classify workers into exposure categories, the processes that involve the nanomaterials must first be understood.

4) "Analyze injury and illness reporting" – Just keeping countless health records is not enough. There must be a program to find correlations so that any issues can be studied and addressed[85]

The National Nanotechnology Initiative (NNI), which is a federal level R&D program aimed at promoting nanotech research, also identified four "possible research approaches".

[84] ____. (2004) National Nanotechnology Infrastructure Network (NNIN). NSF. 1 Nov. 2006 <http://www.nnin.org/>.

[85] ____. (2004) National Nanotechnology Infrastructure Network (NNIN). NSF. 1 Nov. 2006 <http://www.nnin.org/>.

1) "Injury and illness reporting" – The existing systems for reporting occupational health problems will not be sufficient for identifying any adverse effects of nanomaterials. Problems could be missed until many people have already been endangered.

2) "Occupational Exposure Registry" – An exposure registry could be developed to use employment and health records to more easily determine possible correlations. This would then be supplemented by research studies to provide quantitative data on the subject. The exposure-medical correlated data could then be joined with other recent research and toxicity analyses. \The NNI recommends the "Nanoparticle Information Library" as an important comparative source of information.[86] This registry would allow for "more accurate risk assessment and risk management processes."

3) "Cohort epidemiology studies" – These studies could be used to examine hypotheses made about possible correlations in illnesses and exposure. They would determine if something actually is caused by exposure to a material, exactly which material, and quantify the relative risk.

4) "Nested case-control epidemiology studies" – These studies are much like the cohort studies, but they are more advanced. Participants become part of these studies on the basis that they do or do not actually have a certain disease or illness. It is a more in depth look at the exposure levels and risk factors involved. Also in these studies, the "findings can be extrapolated to the population from which the cases and controls came." The risks are communicated in terms of the odds of getting the disease.[87]

The NNI plans to collect and use all of this surveillance data to allow for improved safety in workplaces where nanomaterials are present.[88]

The National Nanotechnology Infrastructure Network (NNIN) is helping to develop "educational outreach programs designed to ensure that tomorrow's workers have the right skills for nanotechnology industries – and that the public will be able to

[86] Nanotechnology Coordination Office. (2006). Environmental Health and Safety Research Needs for Engineered Nanoscale Materials. National Nanotechnology Initiative.
[87] _____. (2004) National Nanotechnology Infrastructure Network (NNIN). NSF. 1 Nov. 2006 <http://www.nnin.org/>.
[88] _____. (2004) National Nanotechnology Infrastructure Network (NNIN). NSF. 1 Nov. 2006 <http://www.nnin.org/>.

separate nanotechnology fact from fiction."[89] The NNIN is a network of facilities that are leading much of the research in nanotechnology, and is focused most directly on college students that will soon be entering the workforce.[90]

This shows that the structure for regulating and preventing illnesses and other adverse health affects is already being developed. But, it is although in the very early stages, while the nanotechnology industry seems to be on the move without the reassurance of adequate exposure and health research.

Insurance Agency Education in Nanotechnology

Written by Brandon Seaton and George Skontos

The insurance industry and related financial industries also need to be educated in nanotechnology risks so they may understand potential problems with nanomaterials. As with all other building materials, insurance is a key issue when dealing with nanotechnology. Many insurance companies want to know the best way to insure buildings/structures that are constructed with nanomaterials. Currently, many companies are attempting to determine if their old infrastructure will apply to nanotechnology: can the existing coverage plans be modified, or are new ones required specifically for buildings that incorporate nanomaterials. In addition, the insurance companies are attempting to calculate the contributions that nanomaterials can bring, in addition to the risks posed by these materials.

One appealing fact of nanomaterials is their purported strength; some nanomaterials for the construction industry can withstand large amounts of force and are very durable materials. As a result, these materials can potentially save insurance companies billions of dollars by allowing buildings to maintain their structural integrity in extreme conditions. Buildings built with nanomaterials may be able to survive natural disasters with minimal to no damage; since this translates to less payout from

[89] Toon, John. (October 30, 2006) Explaining Nanotech: Education Programs Focus on Building the Work Force for Tomorrow's Nanotechnology Industry. Georgia Tech Research News. Atlanta. February 4 2006.
[90] _____. (2004) National Nanotechnology Infrastructure Network (NNIN). NSF. 1 Nov. 2006 <http://www.nnin.org/>.

insurance firms, this is very desirable. Despite these factors, insurance companies are reluctant to act on nanomaterials due to the lack of knowledge about potential health risks in nanomaterials. Personal injury from these materials could easily offset the cost benefits of stronger buildings; given previous litigation from asbestos, it is clear that the building industry is proceeding with caution.

Swiss Re, one of the world's leading and most diversified reinsurers, who provides reinsurance products and financial services that enable risk taking essential to enterprise and progress has this to say about nanotechnology:

The insurance industry is concerned because scientific evaluations of potential risks for human health and the environment are few and remain inconclusive. Nor are there regulatory guidelines that address potential risks in an adequate manner. The industry community has only begun to evaluate potential "nano-risks" and there is no global approach towards finding a solution satisfactory to business, scientists and regulators alike.[91]

Material Issues

Toxicity and Recyclability of Nanomaterials

Written by Taeyoung Kim

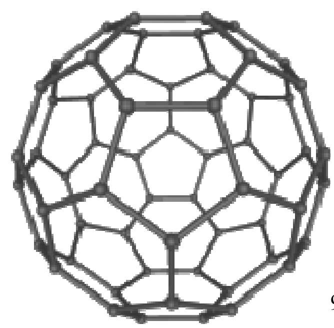
Toxicity

Nowadays a lot of nanomaterials and devices are formed from nanometer-scale particles (nanoparticles) which are initially made as aerosols or colloidal suspensions. When people are handling nanometer scale particles in manufacturing or use, it is possible that they were exposed to nano-sized particles. The nano-sized material can enter the body through inhalation, dermal contact, and ingestion[92].

[91] Nanotechnology – The Insurers perspective. www.swissre.com
[92] Center for Disease Control and Prevention-National Institute for Occupational Safety and Health

There is not much information available but some research indicates poorly soluble, ultra fine particles are more toxic than larger particles on a mass for mass basis; the toxicity of ultra fine or nanoparticles is greater than that of the same mass of larger particles of similar chemical composition[93].

The fullerenes are a recently-discovered family of carbon allotropes named after Buckminster Fuller. They are molecules composed entirely of carbon, in the form of a hollow sphere, ellipsoid, or tube. Spherical fullerenes are sometimes called buckyballs; the C60 variant is often compared to the typical white and black soccer football, the Telstar of 1970. Fullerenes are similar in structure to graphite, which is composed of a sheet of linked hexagonal rings, but they contain pentagonal (or sometimes heptagonal) rings that prevent the sheet from being planar.


[94]

Molecules made up of 60 carbon atoms arranged in a series of interlocking hexagons and pentagons, C60 is actually a "truncated icosahedron", consisting of 12 pentagons and 20 hexagons. It was discovered in 1985 by Professor Sir Harry Kroto, and two Rice University professors, chemists Dr. Richard E. Smalley and Dr. Robert F. Curl Jr.[95] It is the only molecule composed of a single element to form a hollow spheroid. A team from Rice University and the Georgia Institute of Technology, US, has found that the toxicity of buckyballs to human cells depends strongly on whether any molecules are attached to the buckyball surface.[96]

93 Oberdörster et al., 1992, 1994a,b; Lison et al., 1997; Tran et al., 1999, 2000; Brown et al., 2001; Duffin et al., 2002; Barlow et al. 2005
94 http://en.wikipedia.org/wiki/Image:C60a.png
95 http://scifun.chem.wisc.edu/chemweek/buckball/buckball.html
96 http://nanotechweb.org/articles/news/3/9/16

There are strong indications that particle surface area and surface chemistry are primarily responsible for observed responses in cell cultures and animals. There are also indications that ultra fine particles can penetrate through the skin, or trans-locate from the respiratory system to other organs. In addition to particle surface area, other particle characteristics may influence the toxicity, including solubility, shape, and surface chemistry.[97] This means that the people working in nanotechnology related industries have the potential to be exposed to uniquely engineered materials with novel sizes, shapes and physical and chemical properties, at levels far exceeding ambient concentrations. To understand and discover the impact of these exposures on health, and how best to devise appropriate exposure monitoring and control strategies, much research is still needed. Until a clearer picture emerges, the limited evidence available would suggest caution when potential exposures to nanoparticles may occur.

Experimental studies in rats have shown that at equivalent mass doses, insoluble ultra fine particles are more potent than larger particles of similar composition in causing pulmonary inflammation, tissue damage, and lung tumors[98]. These studies indicate that for nanoparticles with similar properties (e.g., PSLT), the toxicity of a given mass dose will increase with decreasing particle size due to the increasing surface area. For example, in CNT, single-walled CNTs (SWCNT) have been shown to produce adverse effects including granulomas in the lungs of mice and rats at mass doses of carbon that did not produce these adverse effects[99]. We do not exactly know why CNTs are toxic, but we can assume that CNT contain metal catalysts as byproducts of their production, which could also contribute to their toxicity.

Recyclability

Nanomaterial wastes may present regulators with unexpected and unique questions[100]. Researchers are trying to assess how

[97] Duffin et al. 2002; Oberdörster et al. 2005a; Maynard and Kuempel 2005; Donaldson et al. 2006
[98] Lee et al. 1985; Oberdörster and Yu 1990; Oberdörster et al. 1992, 1994a,b; Heinrich et al. 1995; Driscoll 1996; Lison et al. 1997; Tran et al. 1999, 2000; Brown et al. 2001; Duffin et al. 2002; Renwick et al. 2004; Barlow et al. 2005
[99] Shvedova et al. 2005; Lam et al. 2004
[100] E. V. Barrera, L. P. F. Chibante, B. Collins, F. Rodriquez-Marcias, M. Shofner, J. D. Kim, and F. D. S. Marquis "Recycling Nanotubes from Polymer Nanocomposites." Powder Materials Current Research and Industrial Practices, F. D. S. Marquis, E. V. Barrera, and N. Thadani, edts., TMS Pub. (2001): 267-282

nanomaterials and nanoparticles released into the environment will migrate through groundwater, adhere to soil, move through air/water and water/sediment partitions, and become available for bio-uptake. Ironically, the use of these nanomaterials to solve environmental problems may collide with concerns that releasing these same nanomaterials into the environment raises unknown and unacceptable risks. Hazardous wastes will also likely apply broadly to solid and hazardous wastes containing nanoscale constituents.

EPA's RCRA regulations should apply to wastes containing nanomaterials that are discarded onto land, burned, or recycled as a means of disposal[101]. These broad categories of "discard" should cover actions that would typically occur with wastes containing nanomaterials[102]. Since there is not much information about nanomaterials, it will be hard to determine if the nanomaterial are reusable. Currently, we know advantages of using nanomaterials, but we lack data on how it can affect us later. I do believe it is a little early for us to tell if we can recycle the nanomaterial that we have used. We're only able to get the conclusions that some nano-size particles are toxic. Therefore, I think it is wise to wait until we have more information regarding the behavior of nanomaterials.

Durability and Sustainability of nano-enhanced building materials

Written by George Skontos

With conventional building materials nearing their maximum performance, architects and construction firms are looking for new materials that will outperform and be more cost-efficient than traditional materials. These common traditional materials include: wood, coatings, concrete, steel, and glass. With the benefits of nanotechnology, we will be able to take these materials and enhance them. These enhanced materials will not only benefit the structure they will be used on but also the users and society on an environmental and economical level.

[101] 40 C.F.R. § 240 et seq
[102] American Bar Association Section of Environment, Energy and Resources 2006 Jun

Wood will be able to be preserved much better by coating it with nanotechnology. Due to the discontinuation of CCA wood preservation in 2003 because it was found to be poisonous, the wood industry has been looking for a safer alternative.[103] Since nanoparticles are so small, they are better able to penetrate into the porous surface of wood, thus sealing the wood better. With current wood sealants, the sealant adheres to the surface of the wood but does not go deep into the grain as nano-sealant would do. Thus nano-sealant creates better surface adhesion which means better longer lasting wood. This nano-sealant would also be cost effective, long lasting, and anti-microbial thus keeping the wood in top condition, regardless of whether it is used in humid climates or dry climates.[104]

Nano-treated wood also has major environmental benefits. By volume, wood is the most widely used construction material in the US. Of the 1.9 million housing units constructed in 2004, wood compromised 80% of the building materials in the residential sector.[105] Reasons for the desire of wood include: cost, ease of fabrication, and the ability to produce a variety of architectural designs. Consumers want structures that maintain their value over time and are safe and secure, healthy, comfortable, long-lasting (durable), low maintenance, affordable (lower in cost and providing more value for the dollar), easily adaptable to new and modified architectural designs, and allow for personalized customization, have smart system capabilities, and reduce costs for heating and air conditioning.[106] Nano-treated wood will allow for this to occur while also keeping wood production and usage down; this is very important on an environmental scale. US consumption of wood is roughly 400 million cubic meters per year. Now, if we consider that nano-enhanced wood will last longer and not be susceptible to the problems that traditional wood faces today, the amount of wood consumption will drop. Environmental groups will find this favorable.

Current building coatings fade due to time. Some coatings can become brittle and washout when exposed to the sun for a

[103] Copper Oxide – NanoArc Copper Oxide Nanometerials from Nanophase Technologies Corporation. Retrieved 11/04/06 from AZoNanotechnlogy. Website: http://www.azonano.com/Details.asp?ArticleID=1728
[104] Theodore H. Wegner, Jerrold E. Winandy and Michael A. Ritter. (2005) NANOTECHNOLOGY OPPORTUNITIES IN RESIDENTIAL AND NON-RESIDENTIAL CONSTRUCTION. USDA Forest Service, Forest Products Laboratory, USA
[105] Ibid.
[106] Ibid.

prolonged period of time. Nanotechnology proposes to help this issue with chemically enhanced nano-coatings. Nano-enhanced coating can lead to high diffusivity, improved toughness and strength, better thermal expansion coefficients, with lower density, elastic modulus, and thermal conductivity.[107] These coatings will provide long-term antimicrobial protection and protect against the sun's UV rays. Also due to the high strength of nanoparticles, nano-coatings are very durable and add to the sustainability of the structure they are coating. Because nano-structuring increases the number of active sites, (there are many more atoms per grain boundary) the enhanced surface area leads to a reduced material requirement, which in turn can lower cost.[108] This is very cost-efficient: due to the durability of the coatings, exterior maintenance fees can be minimized. These coatings will also be able to help the environment by eliminating the need for hazardous chemicals and solvents that are used for paint-stripping and resurfacing worn exteriors. By eliminating hazardous wastes, nano-coatings can both reduce a company's disposal costs and improve its environmental position.[109]

Concrete has greater potential once enhanced with nanoparticles; concrete is a very strong, but also very heavy material. Cement enhanced with nanomaterials will have the same strength to weight ratio but will be much lighter, thus allowing it to sustain more load forces. Nano-structured titanium dioxide (TiO_2) is the key chemical to nano-cement. Due to its strong oxidizing power under near-UV radiation, its chemical stability when exposed to acidic and basic compounds, its chemical inertness in the absence of UV light, and its absence of toxicity, TiO2 has proven to be very effective in the reduction of pollutants such as NOx, aromatics, ammonia, and aldehydes.[110] Once again, this is very important in dealing with environmental issues. Buildings built with these materials will be far less toxic to the environment. Another advantage from using this nanomaterial is that it will greatly help construction workers who handle and have to breathe the toxins given off by traditional cement. With nano-enhanced cement, there are less toxins, which translates to a safer environment for construction workers

[107] John Mendel, Chap 3. Dispersions and Coatings. Eastman Kodak Company
[108] Ibid.
[109] Ibid.
[110] Kaneko, M. and Okura, I., Photocatalysis: Science and Technology (Springer, Berlin, 2002).

Cement enhanced with photo catalysts will also retain the exterior color of cement for a longer period of time without fading. Cement discoloring is due to the accumulation on organic compounds on the surface of the cement.[111] Photo catalytic degradation of organic pollutants is aimed at maintaining the aesthetic characteristics of concrete structures, particularly those based on white cement.[112] Photo catalysts will prevent this organic material from forming on cement, brick, road, mortar, and any other cementitious materials. This is certainly a positive achievement, as it will save costs on structure maintenance and aesthetic maintenance.

With the urge to construct buildings of dizzying heights, steel has become the main material of choice. Steel's preeminent position in modern society is a result of several favorable criteria, including the abundance and low cost of iron, its manufacturability, and its recyclability.[113] Similar to wood, steel compromises 80% of all metallic alloys used on the industrial scale.[114] Although there are 25,000 different types of steel worldwide, only a handful are based off nanomaterials; nano-steels, though still in their infancy, show great promise. They allow for a combination of ultra-high strength with good formability, corrosion resistance, and a good surface finish. A high elastic modulus and extreme strength can result in thinner, lighter components than those made from aluminum and titanium.[115] In nano-structured steel alloys, measured tensile strengths have exceeded 4 GPa at 20 °C, and strength levels of 1.8 GPa at 750 °C have been obtained; these are stronger than conventional steels at room temperature.[116]

Combined with nano-coatings, nano-steel has great corrosive resistance; this means no anti-corrosive treatment is needed.[117] Once again, we see nano-steel's cost-efficiency. Money need not

[111] L. Cassar, NANOTECHNOLOGY AND PHOTOCATALYSIS IN CEMENTITIOUS MATERIALS, CTG Italcementi Group, Italy
[112] Ibid.
[113] D. J. Branagan, Enabling Factors Toward Production of Nanostructured Steel on an Industrial Scale, ASM International. 2004.
[114] W.C. Mack, Worldwide Guide to Equivalent Irons and Steels, 4th ed., ASM International, 1993, p iii
[115] Copper Oxide – NanoArc Copper Oxide Nanometerials from Nanophase Technologies Corporation. Retrieved 11/04/06 from AZoNanotechnlogy. Website: http://www.azonano.com/Details.asp?ArticleID=1728
[116] D. J. Branagan, Enabling Factors Toward Production of Nanostructured Steel on an Industrial Scale, ASM International. 2004.
[117] Furbeth, W; Nguyen, H-Q; Dettenwanger, F; Schutze, M, New developments for corrosion resistant coatings for light metals and steel based on chemical nanotechnology,. EUROCORR 2001: The European Corrosion Congress; Lake Garda; Italy; 30 Sept.-4 Oct. 2001. 8 pp. 2001

be wasted on corrosion treatment, which again reduces building maintenance. Society can benefit from nano-steel because buildings will no longer be susceptible to rust: buildings will be stronger and have greater structural integrity. The elimination of rust will also benefit the environment. Water pipes will no longer form rust, resulting in a potential contamination of the water supply; there will be no rust runoff into lakes and streams.

Another component of skyscrapers, and most any other building, is glass. Nanotechnology has some a promising future in glass applications; self-cleaning glass is one such possibility. Using a special nano-coating that is activated by UV rays and rain, organic dirt can be broken down by photo catalysts in the coating; this is the same concept as the self-cleaning concrete. Nano-glass will also provide greater thermal protection and noise insulation. This is a great concept, as self cleaning glass requires less maintenance which again results in cost efficiency. Window washers no longer have to risk their lives – especially when cleaning glass on skyscrapers. Self-cleaning glass also helps the environment by preventing ground contamination from window cleaning solutions and solvents and in general the release of noxious gasses into the atmosphere.[118] Since nano-glass will have better thermal protection than traditional glass, it will be able to retain heat and thus create a better insulator. This implies less spending on heating and cooling, while being more environmentally friendly due to reduced natural gas usage and lower production of dangerous hydro chlorofluorocarbons for air conditioners.

As nanotechnology slowly integrates its way into society, it presents a tool to extend structural performance and serviceability by orders of magnitude. Nanotechnology will allow engineers and scientists to manipulate and systematically eliminate the formation of random defects that now dictate the properties, performance, and serviceability of traditional materials as we know them today.[119] The ability to see materials at nanoscale dimensions and control construction at this level is providing the opportunity to develop new materials and products

[118] Jo Twist, Eco glass cleans itself with Sun. BBC News Article. (2004) Website: http://news.bbc.co.uk/1/hi/technology/3770353.stm
[119] Theodore H. Wegner, Jerrold E. Winandy and Michael A. Ritter. (2005) NANOTECHNOLOGY OPPORTUNITIES IN RESIDENTIAL AND NON-RESIDENTIAL CONSTRUCTION. USDA Forest Service, Forest Products Laboratory, USA

in previously unimagined ways.[120] Nano-enhanced materials will allow for the integration of more environmentally friendly materials into society. With many environmental groups claiming that human recklessness and industry are destroying the earth, nanotechnology seems to provide and answer to their concerns.

Nanotechnology will also provide a cost-efficient solution to the rising prices of natural materials. As shown from the table below:

OUTLOOK FOR CONSTRUCTION COSTS IN 2006

Product	Projected 2006 Increase
PVC Pipe	20-50%
Insulation	20-50%
Roofing Materials	20-50%
Brick and Glass	5-10%
Cement/Concrete	10-15%
Steel	Stable
Gypsum	5-10%
Wood Products	Down 10%
Labor	4%

SOURCE: AGC CHIEF ECONOMIST KEN SIMONSON

the rising cost of construction materials is a big issue. The Associated General Contractors of America (AGC), which is the largest and oldest national construction association in the US, expects demand for cement will continue to increase in 2006 and beyond. U.S. production will increase little, if at all, because few new plants are being built.[121] Therefore, higher prices and shortages are likely to persist and a push for a cost-efficient and longer lasting alternative will ensue. The global building boom has strained supplies of key construction components and may continue to produce large increases in demand for a wide variety of building components in the future.[122] With the value of

[120] Ibid.
[121] Ken Simonson, Cement Shortage Fact Sheet. Chief Economist, Associated General Contractors of America
[122] Ken Simonson, Between a rock and a hard place, Constructor Magazine. Jan/Feb 2006

construction totaling to roughly $1.2 trillion in the month of August 2006 (4.4% increase over the August 2005 spending), nanotechnology could step in and help alleviate these costs. [123]

Construction Market Issues

Nanotechnology and Machines

Written by Jose Hernandez

"The United States, in conjunction with the multi-national community as a whole, can better maintain its own security and a global security by exploiting scientific discovery and invention for two vital purposes: to develop thriving markets within and among nations, and to utilize innovation to resolve problems and to address the rising expectations of the world's people.[124]" The United States' current job market is in jeopardy. With rampant outsourcing, downsizing, and decrease in scientific and engineering related professions, we are in serious trouble.

"Consider, today, the rise of nanotechnology. Nanotechnology is a quintessentially multi-disciplinary field, with a wide variety of promising applications resulting from the fundamental research.[125]" Anyone interested in taking a job related to nano-technology needs to be "multi-disciplinary", this could bring up a larger issue. Issues such as what changes need to occur in training the current work force: do they need to become skilled in handling nano-materials? This also raises other issues, which include educating the nation about nano-technology, as well as providing a program of learning that allows students of all ages to experience this "multi-disciplinary field?"

In order to better educate our workers that may one day be displaced, we will first need institutions that teach these skills. While nanotechnology is not at the point where such drastic measures are needed, it is foreseeable that it will be one day. As such, America will need to take changes to our educational

[123] Value of Construction Put in Place - Seasonally Adjusted Annual Rate, U.S. Census Bureau News, U.S. Department of Commerce.
[124] Woodrow Wilson International Center for scholars, Funding the Foundation: Basic Science at the crossroads, January 2006, p. 7
[125] Woodrow Wilson International Center for scholars, Funding the Foundation: Basic Science at the crossroads, January 2006, p. 9

system under serious consideration. Not only will education at K-8, high school, or even college aged students need revamped, but we will need a curriculum or program that can cater to people who are now in their 40's and 50's and in need of a second career.

According to some, in order to achieve such goals, "America's nanotechnology effort must be nothing less than the equivalent of President Kennedy's commitment to landing a man on the moon.[126]" I completely agree. We as Americans have lost our competitive nature; I have fallen victim to this as well. For example, should I push myself to get a 95 on my next exam, or do I study enough just to meet the group average, typically around 80? Now multiply this scenario across our university, then the city, state and country. The problem is now more apparent.

It has to start in the classrooms. If we're worried about losing jobs in America, then equip current American students with the tools, experience, and knowledge that successful individuals (like a Donald Trump or a Bill Gates have) have used to create and secure their empires. How did they become so successful, how did they create so many jobs for so many Americans? Is it such a mystery that it can't be taught to freshmen level college students? Is it so complicated to understand, we can't teach 8th grade students, or kids in high school? Of course it's not: the problem is it's not being done on a large enough scale.

One way to achieve this can simply be "securing funding for specific research projects, naming the several nanotech centers authorized by the legislation and preparing America's workforce to fill the nanotechnology jobs of the future.[127]" It sounds so easy, and it really can be. Consider companies like AP&C (Advanced Powders and Coatings). "AP&C Advanced Powders and Coatings have received orders totaling $600,000 for the supply of its spherical titanium powders from a major US orthopedic implant company.[128]" This is a nano-material. By taking basic business practice and applying it to an emerging technology like nanotechnology, you now have increased revenue, possible future jobs, and a better economy in general.

[126] National Nanotechnology Initiative, Sen. Allen Announces Congressional Nanotechnology Caucus, April 2004.
[127] National Nanotechnology Initiative, Sen. Allen Announces Congressional Nanotechnology Caucus, April 2004.
[128] Nanotechnology Now, Raymore announces $600,000 Order, November 1, 2006

In reference to nanotechnology machines, and how they can be produced, what effects will they have on society, what type are being worked on, etc., some believe "if cleanliness can be maintained, it may be possible to take advantage of super lubricity between stiff surfaces. Mechanical transport may be faster and more predictable than diffusive transport. Absence of fluids could reduce drag, increasing efficiency and improving performance through higher speeds. High density of strong covalent bonds in some materials implies superior material properties. Although it is too early to say with confidence which of these theoretical benefits will be practically useful, they are certainly attractive targets.[129]"

What this means is "wow, we've got nano-machines on the horizon!" This isn't a big deal: we had horses in the 1800's, steam engines in the early 1900's, nuclear power in the mid to late 1900's. Nanotechnology is just the next step forward. It's really not something that deserves awe. It's humanity striving to improve upon what their predecessors created before them; while nanotechnology has the potential to be the greatest threat and boon to man kind, so did spears to the Romans. So did the wheel to Grog the caveman. Nano-technology is just another tool mankind will one day use to further ourselves as the species progress. Like any technology before it, it will have its "ups", it will have its "downs", and then one day it to will be replaced.

Delivery / Transport of Nanotechnology Construction Materials

Written by Ty Sopko

All commercial nanotechnology currently involves the addition of nano-sized particles into existing products to enhance their properties. At present, no nanomaterials are being used in construction materials. Therefore, everything presented here in regard to delivering nano-based construction materials to the construction site will be speculation. Additionally, since some laboratory tests have shown nanomaterials to be toxic, these construction materials will be treated as hazardous materials (HAZMAT) to ensure the highest safety of construction workers and users of the building.

[129] Center for Responsible Nanotechnology, Developing Molecular Manufacturing, February 2005.

Due to their small size, nanomaterials are easily airborne; one potential route into the human body is through the lungs. It is therefore imperative that nano-based construction materials should have a protective chemical coating; this coating will prevent the unwanted release of nanomaterials into the environment[130]. Unfortunately for the transport industry, automobile accidents happen. If a fire results from such an accident, there's a great potential to release nanomaterials into the environment from combustion. In this scenario, it would be desirable to surround the construction materials with a fire-resistant gypsum wallboard, similar to what is used in HAZMAT containers.

While in transport, it's critical that these nano-material enhanced construction products are isolated from the environment. Any exposure with moisture can result in potential contamination[131]. Although the chemical coating is designed to protect an accidental contamination from the nano-technology construction product, the utmost caution must be used when dealing with HAZMAT materials. Therefore, isolation from moisture is desirable to provide an extra layer of protection. Not surprisingly, these guidelines can also be applied to the nanomaterial once it is within the building. If nano-enhanced steel is used in a building frame, it should be protected from users to prevent accidental exposure to employees within the building. Although it is unlikely that the users will come into contact with the building frame, fires could spread to the frame and potentially release the nanomaterials into the air. Fire-resistant gypsum surrounding the actual frame would be desirable.

Since the construction industry is in its infancy with nanotechnology products, it would be most beneficial to set safety standards and guidelines before products reach the market. Unlike consumer goods, people will be exposed to these buildings regardless of their perspective toward nanomaterials. For example: if a government building is built with nanotechnology created construction materials and an individual is required to enter that building by law, how can that individual protest? Additionally, special regulations for nanomaterials in transport overseas will need to be determined: in a shipping

[130] Pollution Engineering; Jul2006, Vol. 38 Issue 7, p51
[131] Journal of Environmental Engineering; Aug2004, Vol. 130 Issue 8, p834-835

accident, it's near impossible to prevent release of the materials into the environment when in water. Additionally, the basic HAZMAT specifications covered here are very general; undoubtedly, nanotechnology specific provisions need to be established once these materials are better understood.

Note: In November 2006, Nanoforum.org – European Nanotechnology Gateway, released a report titled: Nanotechnology and Construction. For those interested for a more detailed and comprehensive report on nanotechnology and its integration with the construction industry, please review this report.

Recommendations

In order to prepare our society for the implications related to nanotechnology, we have come up with action steps that should be undertaken within a short period of time from now. Some of them might be already in progress, but most are still overlooked. We have to realize the extent of these implications, the ways it will revolutionize the world. Below, we detail certain societal issues we have looked into (section 8) and draw conclusions on what should be done.

Regulatory Agencies

- Establish an international governing agency over nanotechnology made of members from different countries and fields.
- Launch tailor-made organization for nanotechnology within U.S. Government.
- Draft laws controlling nanotechnology development within each country and on an international scale.
- Require members of the governing body to have backgrounds not only in politics and social sciences, but also diverse number of scientific fields. They need to have well developed communication and cultural (history, political science, geography, overall awareness) skills.
- Require members of the governing body to constantly increase their knowledge on the rapidly developing technology
- Allocated more research grants into investigation of nanotechnology based materials' effect on our environment and our health.
- Develop marketing tools to inform the public about nanotechnology and provide them with the ability to make educated choices.
- Standardize vocabulary relating to nanotechnology.

Education

Student Education

- Significantly revolutionize school curriculums with nanotechnology education and collaboration methods in mind.
- Incorporate disciplines intersecting complex problems.
- New curriculums must promote math and science.
- Require teacher to be well educated and have a positive attitude towards the subject they are teaching.
- Require better screening process for educators and more re-certifications.
- Balance educational systems throughout the world.
- Start educating our nation at a younger age, for example through educational cartoons and activities.
- Include programs similar to our IPRO programs early on in elementary schools

User Education

- Create more public, user friendly, reliable information sources
- Require companies to include on their websites and all product labels'
- Make specific testing requirements and prohibit the concealment of those results
- Use of RFID to tag all products that are NANO enhanced so there is a national data base.
- All statements made by companies must be approved by specified, reliable regulatory bodies.
- If companies do not have approval, they will be subject to fines (to discourage false claims)

- Legal recourse will be dire to see these changes take effect

Job Market

- People interested in working with nanotechnology materials must be diverse in different educational backgrounds such as chemistry, engineering, and biology to name a few.
- Introduce changes gradually in order to prevent sudden crashes on the job market.
- Encourage workers already in a given field to expand their scopes of knowledge, possibly by undertaking more education.
- Should a workers' current job change to one related to nano, provide the worker enough time to educate his or herself in order to meet the new requirements for their new nano job.
- Establish a new type of union for workers dealing with nanotechnology, as well as workers whose jobs might be converted from their current type of job to a nano job. Nano workers will need a new type of union to better represent them, a union that is themselves diverse in different educational backgrounds.

Workforce Education

- The leading regulatory bodies seem to be focusing on a passive approach to finding issues in the workplace. Instead of depending on predictions of risks before people are exposed to the possibly dangerous materials, they seem to be making systems to find correlations in health problems in workers who have already been exposed. This is a very dangerous approach, but maybe it is because nanomaterials are already being worked with in industry. There should be more research to identify the risks before many people are affected.

- Workers should have classes or other training by properly educated professionals who understand nanotechnology.
- As with delivery and educating the public, there should be set requirements that companies must legally follow pertaining to the explanation to employees of the risks involved (the forms and wording of this information should be approved by certain reliable regulatory bodies/y)
- Proper safety equipment for each type and composition of nanomaterial should be specified and all workers should be required to use that equipment.

Privacy/Hacking

The issues that might arise in this area are still quite theoretical.

- We should encourage and use the work of all of the hackers that have a real interest in finding security breaches to develop a more secure electronic and virtual security infrastructure as nanotechnology develops. This would potentially be a high security job because information that they develop should not be leaked to people who might use the knowledge to do damage.
- When the time comes, there might have to be 'nanocops' to track and punish dangerous hackers that specialize in interfering with the controls of nanodevices and systems.
- Also, people should have the right to be informed of possible hacking/control issues before they buy mechanical nanoproducts or allow mechanisms to be used for medical purposes.

Durability and Sustainability of Nano-building Materials

- Test nano-enhanced materials on a practical level

- Through research in controlled labs predict if structures will be safe to use
- Use miniature models incorporating various materials to observe how they behave and if they react with each other. This would allow for research and testing to be conducted while cutting down costs by eliminating the need for life-size structure
- Use modeling tools to project pitfalls and dangerous issues

Cost Efficiency & Resourcefulness

Nanotechnology has the potential to be very cost efficient and revolutionize society and industry in unimaginable ways. At the present time, this technology is in its infancy, and therefore production is still in small and specialized scales. Recommendations and action steps are really not necessary for this topic because it is the nature and purpose of new technology to improve efficiency in every way including that of costs. Products built with nanomaterials have the potential to be more cost effective than anything we have had before as long as precautions are taken to insure that there will not be massive side effects involved.

One thing that is quite certain about nanotechnology and the utilization of nanotechnology to replace current products… nanotechnology's impact on current commodities will probably be very small.

In the age of globalization and mass production a normal commodities is close to zero cost (in western world standards). The commodity world works by a simple rule of thumb; One dollar per one pound. For instance, a pound of cement will roughly cost about one dollar. A pound of Twinkies will roughly cost also one dollar. In such case, even if nanotechnology will enable to lower these costs of production by say 90%, which is a huge percentage reduction, its shear savings will be 90 cents, which is actually not very much and can be considered negligible[132].

Compatibility

To solve the many compatibility problems that are going to appear once nanotechnology matures and is integrated into most technological products, the following should be done.

First a regulatory board/organization should be created to encourage and enforce a uniform compatibility between similar technologies. This board/organization must be universal so the technology or at least the I/O ports will have a similar protocol all over the world and not only in certain countries or regions of the globe.

Another thing that must be done is to make all manufactures of any new nanotechnology based product to make it compatible with there old non-nano based technology, so the transformation from conventional products to products that are based on nanotechnology be as smooth as possible.

Societal Reaction to Malfunction

- Efforts must be made to continuously inform consumers everywhere as the technology progresses so that when malfunctions occur, people will have been warned of risks and at least given the educated choice of whether or not to buy these products. Also, by educating the majority of society early on instead of surprising them when something malfunctions, people will be given the opportunity to voice their opinions and make policy changes that might prevent such disasters.
- There should be regulations or even prohibitions on the use of materials before extensive toxicity research has

[132] Foresight Nanotech Institute . "Foresight Update 40." 24 Oct. 2006 <http://www.foresight.org/Updates/Update40/Update40.1.html>.

been conducted. There is very little toxicity data at present, but companies are free to use these materials in products.

- This toxicity research should have quantitative requirements that must be satisfied to move progress to the next stage.
- There should a set of stages or levels of safety confidence with respect to toxicity knowledge and prevention so that as research progresses on certain materials, they can be classified into these stages. This way, a material can be required to meet the criteria for a minimum level of safety confidence before it can be legally implemented into products or manufactured in large quantities.

Material Delivery

- Specifications on proper containment of nanomaterials – specific HAZMAT transportation regulations – with respect to each type of material. This would include one or more of the following: chemical resistant, fire resistant, isolation from moisture, isolation from the environment, and possible further measures developed particularly for nano particles.
- Specifications on allowable amounts to be delivered at a time, and possibly extra regulations/precautions for international and overseas deliveries.
- Extensive research needs to be done to determine the short and long term effects of these materials on all aspects of our environment in order to place specifications to protect life. (One example of such an effect is the depletion of our atmospheric ozone from CFCs.)

Recyclability

Right now there is little data or even speculation on the recyclability of nanomaterials. Theoretically though, if nano sized particles can be taken and assembled to build things, then those products could be disassembled into the original particles again, in many cases at least. From what little we know about these materials, it seems that because they are such basic building blocks, it might be very easy to recycle old products that contain them. The cost of this at first might be unreasonable, but very possible, and when these materials are integrated into all kinds of products, they will probably be easily reactivated or reused in new products.

Toxicity

- First of all, when dealing with any nanomaterials, workers and developers should be required to wear safety goggles, a respiratory mask, long sleeves, and gloves.
- Guidelines for labs and manufacturing should be developed in order to create a 'standard' procedure for handling nanomaterials
- There should be a designated international organization as well in national internal regulatory bodies that first identify the primary risks and secondary risks that will be involved with each material in all stages of production and use.
- Once these factors are identified, special measures can be taken to protect whoever might be exposed to danger. For example, CNTs researchers, factory workers, and construction workers might need a specific type of respiratory mask or skin & eye protection because the standards right now may not be sufficient or even make much of a difference due to the particle size.
- Other or complimentary nanomaterials and methods should be developed that actually will filter the air or water (even our bodies) to either expel dangerous particles or make them harmless and non reactive. So, we can use nanotechnology to protect ourselves and our environment from dangerous side effects from other forms of nanomaterials.

Conclusions

Based our extensive research on the societal implications of nanotechnology we have decided that there are many changes in our society, such as the organizational makeup of administrations and the perspectives of the citizens within need to be ongoing as we continue on this path. Due to rapid development of the technology through out the globe through diffusion and integration, an international governing administration needs to be established to control the progress, preferably one outside of the UN and protect the health and well being of the humanity by preventing technology abuse, as well as significant technology gaps between countries. This administration should resemble the known international organizations like United Nations, World Trade Organization or International Risk Governance Council.

Law making and enforcing agencies tailor-made for nanotechnology have to be launched to safeguard the consumers, within each country, as well as on the international scale to insure uniformity through out the nations. This regulatory framework has to be arranged soon, in order to keep up with all the new emerging information and to be in place prior to full technology deployment. The groups responsible for governing should not be made of politicians or army personnel, but of a diverse group of people with backgrounds in the fields where nanotechnology would have an impact, meaning all. The educational process through which these future administration members would have to be revolutionized, in order to provide them with not only scientific information in related fields, but also communication, collaboration and cultural skills. The major shift in education would actually be required for everyone, not just the governing body members. Since the impact of nanotechnology appears to be inevitable, the public needs to re-adjust. And this starts at school from early ages. The educational curriculums should include more multidisciplinary and collaborative classes and projects, as well as deeper scientific insights on nanotechnology and related fields. That would be independent of your future career. Engineers, architects, politicians, as well as construction workers, virtually anyone would have to acquire these skills in order to prosper in the shifting society.

Nanotechnology is yet another tool mankind will soon use to further ourselves as humanity progresses. However, in order to proceed successfully, we need to insure that the new technology will not prove to be a slow killer to us. Initial finding on toxicity and health effects of certain nanomaterials appear to point towards possible problems. However, not enough research is being conducted and the products are being released to the public. We recommend that a significantly more funding should be devoted to the research of health risks due to nano-based products. Again, this should be done on an international scale, especially in the countries where advanced nano-products exist already. Certain national organizations have already realized this problem, however their approach is passive. They plan to react to occurring health problems and adjust accordingly. That, we believe, is not the path to follow. An active, preventive approach should be undertaken. A way to be able to test out the nano-enhanced materials on a practical level is needed for both, their health hazards and material capabilities. From all the research currently being done, the results are based on uncontrolled lab environments. If these nano-enhanced building materials are to be implemented in residential and non-residential structures, there needs be a way to predict if these structures will be safe. One way to test this out would be to build a miniature model of a residential or nonresidential structure that incorporates all the nano building materials. Through this approach we would be able to observe how the different materials behave and if they react with each other. The miniature model would help cut down costs by eliminating the need to build a life-sized structure while still allowing research and testing to be conducted.

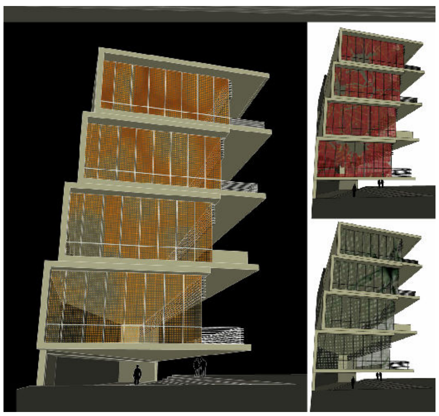
Like any technology before it, nanotechnology will have its up's, it will have it's downs, and then one day it will be replaced. However, if we quickly look through the history of inventions and new technologies we notice that many of them complemented each other, filled in the gaps and advanced our lives. That might not be the progress with nanotechnology. Due to its entirely new concepts it might strive to completely change the existing products and tools. That said, abrupt changes to the economic markets should be prevented by insuring compatibility between old and new products and gradual replacement. In order to accomplish that, a regulatory board/organization should be created to encourage and enforce a uniform compatibility between similar technologies. This board/organization must be universal so the technology or at least the I/O ports will have a similar protocol all over the world and not only in certain countries or regions of the globe. In addition, all manufactures of any new nanotechnology based product should be required to make it compatible with the old, non-nano based technology, so the transformation from conventional products to products that are based on nanotechnology be as smooth as possible.

While thinking and exploring nanotechnology, one should see it as a way for humanity to improve upon what its predecessors created before them. People should not be afraid as science is man's attempt to be curious about his surroundings. The public must be quickly introduced to this technology and ideas behind it in order to allow for educated choices. Public perception needs to be shaped by unbiased sources. We are entering an era with the knowledge world before us. The question to ask now is, will we leverage that knowledge for the good or will we end up destroying ourselves? The choice is ours.

Appendix

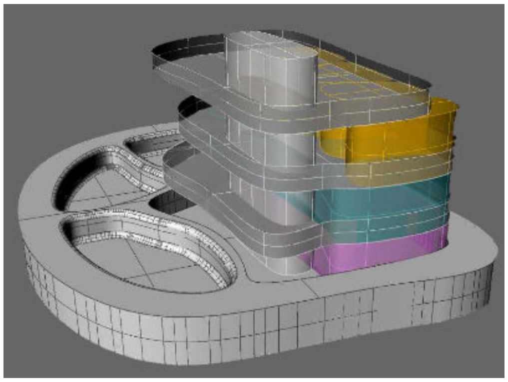
Updated Pictures of Models

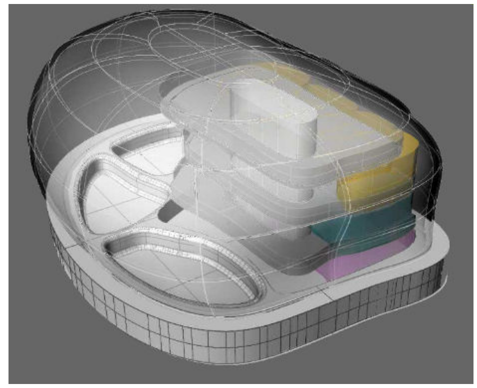
Team 3884



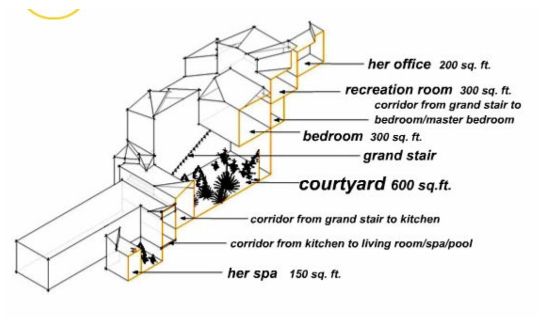
Team NanoShell

Team NanoSpa

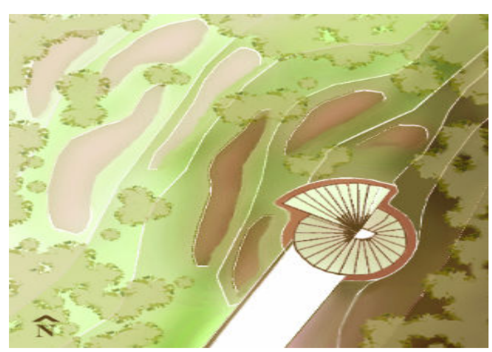




Team Fleischman



Team Natural Umbrella



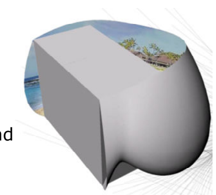
Sample Presentation 2

Expandable Building Envelope

George Skontos
Ty Sopko

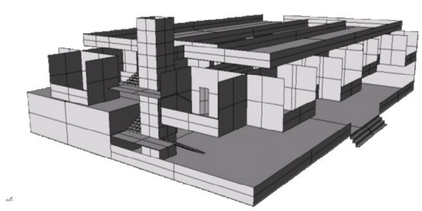
The Real Deal

- Actual concept model
- Building surrounded by nanomaterials
- Building contains nanomaterials and nanosensors



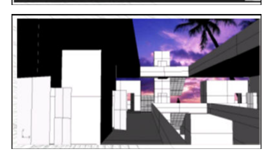
Interior and Purpose

- Spa
- Desire to build with nanomaterials

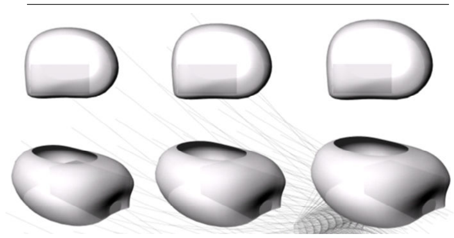


Expandable Screen

- LCD screen that is stretchable
- Conforms to the expandable building envelope
- Can be translucent

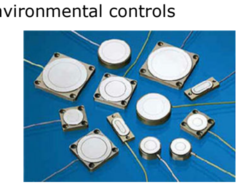


Expansion of the Building Envelope



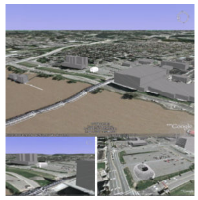
Nanosensors

- Incorporate nanosensors to detect amount of people and expand building envelope as necessary
- Environmental controls



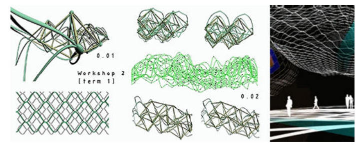
Location

- Cincinnati area, Kentucky side of river
- Commercial area

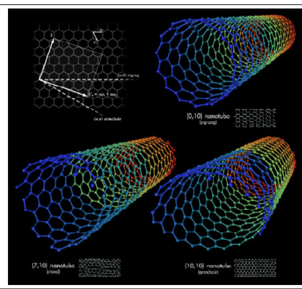


Proposed Material Structures

- Material structure for expandable envelope will be based on “honeycombs”
- Idea from website (p-shifter.org)



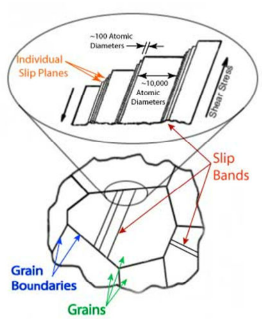
Honeycombs?



Elasticity of Materials

- Elasticity in plastics due to molecular chains folding / unfolding
- Elasticity in metals due to bonds stretching
- Plastic deformation in synthetic materials due to bonds breaking
- Plastic deformation in metallic materials due to planes slipping

Metallic Plastic Deformation



Issues

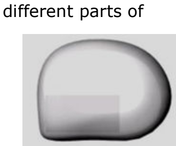
- Elasticity of the envelope
- Elasticity of the screen
- Safety issues

Elasticity of the Envelope

- BSU team proposes using electricity to manipulate the envelope
  - How is it guided
- CNT should be elastic
- Movement issues
  - Immense power requirement
  - 1TPa force for ~10% of stretch
  - IMMENSE HEAT

Envelope (continued)

- Extra matter?
  - Doesn’t deform like a metal or a plastic
  - Bonds will only stretch to a point
  - Zoning laws
- Different forces on different parts of the bubble
  - Some stretching
  - Some bending
  - Some contracting



Elasticity of the Screen

- Proposed CNT LCDs
- No LCD is stretchable
- Some flexible displays have been created (e-Ink)
- Even if envelope expands, LCD will rip apart

Safety Issues

- Drag
  - Acts as a giant sail
  - During strong winds, will it rip off?
- Aerodynamics
  - Will nanosensors allow the building to conform to maximum aerodynamics
- Structural issues
  - Will the envelope support its own weight
  - Same structure used in building and envelope. Huh?

Conclusions

- Design based on an unproven "kinetic theory of architecture"
- Molecular dynamics considered a design liberty
- Design may be possible, but not in its current state
  - Unrealistic expectations of nanomaterials

Newsletters

Newsletter 1 – September 4 ~ 8, 2006

Dear BSU students,

We have elected to create this weekly update of our progress and questions that directly relate to our collaborative project with you to insure that you are all informed. The IIT students feel that we may not be communicating as well as we should be, but this communication is integral in allowing us all to work together because we must know where each other stands. (The update will be basically a summary of our minutes with only those things pertaining directly to you.)

[9-5-06] Our first assignment (the six conceptual questions) was discussed and we were pleased with the insight applied by everyone. We also noted that you – being architecture students – answered decisively differently because of your contrasting perspectives, which is good.

We talked about your part in the collaboration, mentioning that you are building designs using CAD/CAM and that our purpose is to present the pros and cons of your decisions. We will consider ourselves as primarily consultants but also evaluators, depending on when you allow us to be involved. Often, products are pushed to market before they can be fully evaluated, so our goal is to work together to minimize the debilitating issues that would otherwise come forth too late. What is your interest in this topic? Since there is no truly smart building in existence, our collaboration will attempt to determine the sustainability, production, design, and construction of a house constructed with nano-materials. It might also add long-term value to your architecture careers because you will already have experience in this area.

Professor Woerner noted that (looking at Google Trends) there is a tremendous race for information on nanotechnology. This seems to be a huge competition between the nations of the world, going far beyond the borders of capitalism. (The top ten countries in searching for information on nanotechnology were

India, Iran, Singapore, Malaysia, South Korea, Thailand, Australia, US, Canada, and Taiwan – in that order).

[9-7-06] We each have specific roles that we defined in the meeting (I will list these at the bottom in case any of you need something, you will know who to ask). The website location is currently undecided. Where will it be and who is in charge? We were to make short presentations on our nanomaterials as well as a random interesting product that does or could use nanotechnology. (These are on iGROUPS under assignments/presentations).

We talked about public awareness. There is not enough information circulating. Where are people getting there information? How can better public awareness benefit society?

We decided that everyone should at least take a look at last semester's final paper. (I think that would be on iKNOW.)

Maybe we can eventually publish an article as a deliverable for the project. We should, therefore, identify the politics behind getting something published. Also, the IIT students need to ensure that our materials are in an appropriate medium for multimedia (displaying on plasma TVs). Producing a video worked very well in an IPRO Nir was previously involved with. The final models will have to somehow be incorporated into something we can put together in video form. So, we will need your help with this.

It is not clear if BSU is required to make design changes if IIT finds difficulties with their designs. (Is it only to be reported as a downside?) We need to know how much you expect from us, specifically. Also, how much of this advice will be followed? Are you going to create actual physical representations, 3-D electronic renderings, and/or what?

We encourage you all to consult us (your team members) when you get an idea or start doing anything, because otherwise we will not be involved in your decisions. It is important for us to maintain contact with you so that we know what you are working on; this is essential to avoid last minute corrections and for this project to succeed.

This weekly newsletter should keep everyone up to date with us, and we encourage you to maybe do something similar or find some way to respond to us. You can do this individually, by teams, or by group. We would love hear something. Also, maybe your teams could send samples of their pin-ups to us. Actually, uploading them to iGROUPS would be great, we will create a folder right away if you are okay with doing that.

Sincerely,

The IIT Group, a.k.a. Insight

Preliminary description of our team roles:

- **Nir (*Marketing*)** – Wants to create videos that we'll show on IPRO day and create flyers to get our names out.
- **Kevin (*IPRO liaison / co-editor)*** – Takes care of reflections, handle issues with the IPRO office.
- **George (*Editor*)** – Final Report editor.
- **Marta (*Facilitator*)** – Prepare the agenda, keep us on track, ensure we know what we want to accomplish. Keep track of deadlines with Kevin.
- **Ty (Scribe)** – Record meeting minutes, take attendance. Will float around with George to help others.
- **Jose (*iGROUPS / iKNOW / website*)** – Administrator for iGROUPS, iKNOW, and the website. Can do modifications to iGROUPS and iKNOW, such adding and deleting team members as well as adding and deleting information in iGROUPS and iKNOW.
- **Crystal (*Publisher*)** – Produce a weekly summary of everything accomplished.
- **Tae Young (*Research*)** – Find articles and summarize the information, get nano-technology related pictures that we can display on iGROUPS or elsewhere on the web.

Newsletter 2 – September 11 ~ 15, 2006

Dear BSU Students,

I know we just sent you one of these, but this one is for this week that just ended. Don't worry, it's pretty short.

[9-12-06] Most of us still do not know the reasons for which each of you chose your nano-materials or the environment that your building will be in. So if you have some kind of summary and have not shared it with your team, please drop it in an email or maybe on iGROUPS for everyone. Oh, the same goes for samples of your pin-ups.

If you have determined how you might want to use your specific nano-materials, it would be great to fill us in on your progress and ideas because we really can't do a lot until we are given something to work with. This way we can give you some pros and cons that might save you a lot of work.

We just did some short presentations on the materials that our teams are using, just so that we are more likely on the same page. They are posted on iGROUPS if anyone wants to take look (some of them would not upload…we are working on that).

[9-14-06] So you guys are going to come see us in October? We picked a time that may or may not work – 4:30PM on Friday, the 6th. I guess the professors will work this out further.

That's about it for this week. We really need everyone to respond at least to their teams. Maybe we can make a folder in iGROUPS where you can upload a response to this newsletter with any ideas or new info. Just let us know what you think.

Sincerely,

The IIT Group, a.k.a. Insight

Newsletter 3 – September 19 ~ October 3, 2006

Dear BSU Students,

[9/19, 21, 26/06] We had to deal with some IPRO specific stuff during these three classes, but we did discuss a few things pertaining to you all. These things included deciding that we should commit to team values for the whole IIT/BSU team, and also talk about deliverables and the website when we see you on Friday, October 6th. The first Breeze meeting was assigned. We also clarified the structure of the websites: you are hosting a page that will exist beyond these projects, Insight's page will link to your website so that we can maintain IIT's identity, anything outside the collaborative project will also be included in our site (our case studies, etc.), and we can possible present our findings as a story of the implications behind nanotechnology.

Professor Woerner sent out some articles and a report that includes many issues and studies on nano including toxicity, etc. that would be beneficial if you guys want to skim over it for some extra understanding of the materials and such. [*The National Nanotechnology Initiative: Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials* – filename on iGROUPS 'NNI_NHS_research_needs']

Please make sure your group has posted their PowerPoint presentations for assignment 2 so that we can try to analyze the problems and possible issues.

[9/28/06] The Breeze discussions had a few problems like time zone difference and audio equipment. I guess we noticed that there have been several changes since the initial information, probably just much more detailed as intended. Your designs were found to be very creative, and definitely took a lot of time. We have to really study the materials more with your designs in mind so that we can provide you with information regarding the practicality of the specific uses of your nanomaterials. Communication between the groups at this point seemed to be on track.

We started talking about how societal implications and sustainability are important to your projects as well as our specific case studies. For example: Zoning issues around the houses – safety / toxicity, what happens to the workforce? Real estate agencies? Someone brought up the question "Are there industries that want to stop the progress of nano technology?" (Like the diamond, medical, and construction industries, etc...)

By Thursday, October 5th we will have some short preliminary presentations to provide information about your stuff, just some ideas, questions, possible solutions, etc. I think we will probably work on them further for next week so that they will be more in depth and complete.

[10/3/06] The issues mentioned above were extended in an assignment for each of us to come up with more issues, and then they were listed for our meeting on this day. These were split up between us for investigation of answers. At least some of these issues should come into our meeting on Friday. Also for Friday, everyone needs to define what we want to discuss in terms of the full Insight / NanoStudio teams and our individual sub-teams as well. (Consider it as a team agenda.)

Thursday, October 5th, Janelle Ruswick will be stopping by to talk about research and scholarly journals. She is here to help us find any information that is hard for us to get to because of copyrights and such. If you guys think of anything at all that you need, just let you team members know and we will get help from Janelle.

Jose will be meeting you on Friday at the MTCC campus information center at 12:30PM. Kevin will be the backup in case something comes up for Jose; Kevin will be at the Office of Admissions. We'll meet in the IPRO office building at 4:30PM. The food has been ordered and is ready.

Sincerely,

The IIT Group, a.k.a. Insight

Newsletter 4 – October 5 ~ 14, 2006

Dear BSU Students,

[10/5/06] This was the Thursday before you came to see us. We decided that we probably will research 3 other case studies to be secondary to the primary architecture case study. If we do not have time for all of this, then they will just be mentioned in our report for perspective without further depth. We also went over our presentations about each of your designs in preparation to give you feedback.

[10/6/06] We agreed to discuss global issues before splitting into groups (I guess we ended up doing everything as a whole group). I think it is important to recap on our meeting thoroughly so I just pasted most of those minutes in here. Please try to read over it all because it is necessary that we do not forget what we got from the meeting…

Global issues and BSU presentations

- Production capabilities? Advancing even throughout the semester (surfboard made with strands of titanium dioxide nanomaterials).
- Hydrophilic issues with titanium dioxide? Use of quantum dots as water repellant.
- Nanowire paper fatigue? It has similar properties as paper, shouldn't be an issue.
- Moisture detection, person detection using nanosensors? Unsure if they'll still use nanosensors in at least one sub-team.
- Lots of energy implies lots of heat.
- Stretching the distance between two plates of an LCD will change the distance.
- Molecular dynamics versus conceptual behavior on a conventional scale.
- Controlling the transparency of the walls? Controls in rooms.
- Resonance in structures that are supported on only one side.

- Energy conservation benefits from new materials versus consuming more energy to bend these advanced materials to our will.
- Carbon nanotube lengths and production capabilities – irregularities occur and 5- and 7-rings are produced.
- Micro scale vs. macro scale – demonstrated technologies that work on the micro scale do not always work on the macro scale.
- Health issues – laboratory tests on SWCNT indicate that they can be extremely toxic once they enter the body.

IIT concurs that BSU has done amazing work so far.

- BSU's main constraint is that their materials should be available in 20 to 25 years, but the technology behind what they're proposing has to already be viably demonstrated in lab.
- What do we want from BSU?
  - We want to show different steps, potentially how our information could affect their decisions.
  - BSU's reviews can extend well past IPRO day.
  - Timeline and comparison of technical feasibility, including changes they considered.
- What does BSU want from us?
  - Our research materials, comments, concerns.
- Website
  - *Purpose is to raise societal awareness.*
  - BSU already has an infrastructure in place, including a blog.
  - Perhaps every week or every other week – each team should get together and work on what they want to see on the website.
  - Most of our work will go on BSU's website – we have a website to satisfy the IPRO requirement.
  - Brand, image, and presentation are important: our websites should be consistent, or else it could be confusing to someone looking in. How do we

keep the image the same? Consistency is important.
    - Do we want the website to separate the technical from the non-technical, or are we going to use this as a marketing tool?
    - Interactions should occur group by group: there's no single contact person.
- The bulk of our work should be complete by November 17th.
- Is there any standards organization that is looking into potential nanotechnology building codes? There is no specific body currently pursuing this
    - Global standardization can lead to inhibition of the technology's adoption.
    - Consider that we're already 30-40 years behind health issues of Teflon: how long will it take for a similar revolution to occur with nanotechnology?
- BSU will also give an architecture presentation to architecture faculty at IIT?
- It should be important for BSU to deliver architectural data before IPRO day – our presentation is ahead of their final review.

[10/10/06] We defined our goals as of now to be 1) document the progress of design changes and our suggestions, and 2) focus now on societal issues now that the scientific/technical aspects have been discussed.

Most of the rest of what we did was related to our midterm presentation on Tuesday, October 17th . You are welcome to see the things we talked about in the minutes because they still apply to the joint project, but sometime next week you can also look at our midterm presentation after we have noted the responses of our judges. Actually, I will just put all that in the newsletter for you. Our evaluators are going to be knowledgeable in the nanotechnology field, and will provide some useful feedback.

In what ways will architecture require more preparation in the engineering fields with respect to nanotechnology? Or will this be compensated for by building larger more multifaceted teams?

The technical issues that were discussed the other day can be translated to the societal issues that we are now going to study. The table of issues that was in the last letter will be our roadmap for the remainder of the semester as far as research goes.

IPRO day:

1) We will try to make a video,

2) Poster x2 with screen in center of one?

3) Or plasma TV? Both?

4) Final report

5) Final presentation

6) Flyers/pamphlets w/ abstract.

[10/12/06] Potential social science question: If nanotechnology is a new industrial revolution, how will we prepare millions of people to work in this field? What about poorly educated construction workers that need to know about nanotechnology? Won't construction managers push away from these projects because of the significant changes in the process that they are used to?

Use an example like outsourcing? Facts are different from the public perception US public very upset, but less than 5% of the jobs have moved. What about nanotechnology / globalism / teamwork?

(Sidetrack: MIT atoms and bits lab – fabricate small things at home. Search this on Google).

Public's perception: 50% of Americans haven't heard of nanotechnology. How will society learn about it?

[10/14/06 Saturday] We met today to work on our midterm presentations and such.

Stay tuned for next week's progress.

Sincerely,

The IIT Group, a.k.a. Insight

Newsletter 5 – October 17 ~ 26, 2006

Dear BSU Students,

[10/17/06] We had our midterm presentation with a couple of faculty members as our audience.

One of them had an issue with the fact that we are working with your school instead of the IIT or other Chicago architects, but I think it was clarified that there are some reasons for that. (A couple of those reasons being the nature of your more "cutting-edge" goals and the experiment with our distance collaboration).

It was decided that there is no time for in depth additional case studies because there will only be 6 more classes from this date before we need to be finished. The presentation went great though; it really seemed like everything was more coherent when all of us were presenting together. We all compiled the notes and older presentations into a written form to be used in our final paper <iGROUPS-assignments-project summaries>

[10/19/06] 'Fall break'

[10/24/06] We need to be finished by November 14th in order to go over everything again before IPRO day, and we need to figure out exactly how we should introduce why and how we are working with BSU. Each of us researched some societal issues from the table we made a couple weeks ago and wrote about 4 pages on them due Oct. 29th. <iGROUPS assignments – issues about nanotechnology – Progress report 1>.

[10/26/06] There are only five more classes left so everything is getting urgent. We need to adjust our project plan. The final report was discussed. We need an outline:

1) An "impact statement"

2) Describe our nanomaterials (technical aspects). (IIT – Self-learning)

3) (IIT / BSU – Collaborative)

4) Bigger issues (the societal issues we brainstormed / presented on) and how it relates to architects.

5) Recommendations and action steps. etc. about the final.

Is everyone communicating with his or her teams? We should address this in the next class. I know that my team has had a lot of trouble finding a time good for everyone. How are your projects going? And the web pages? Keep in touch.

Sincerely,

The IIT Group, a.k.a. Insight

Glossary[133]

Amorphous Computing: See ***Swarm Computing***.

Amorphous Polymers: Polymers that do not form a crystalline structure, but are disordered in the solid phase (e.g., polystyrene in cups).

Analytes: Chemical species, in solution or in the gas, whose presence and concentration are to be analyzed or sensed.

Antibody: Proteins produced by the immune system to neutralize or destroy antigens.

Antigen: A foreign substance that, when introduced into the body, becomes harmful because of immune response.

Artificial Photosynthesis: Application of molecular or solid state structures to imitate natural photosynthesis by using light to cause electrical current to flow. Artificial photosynthesis is one approach to photovoltaics.

Atomic Force Microscope: A scanning probe instrument that measures the force acting on a tip as it either slides along a surface or moves perpendicularly to a surface.

Bio-availability: The term used to describe the local availability, within a large biological entity like a human body, of a particular drug or therapy molecule.

Bio-inert Materials: Materials that do not react with the biological environment. Normally, bio-inert materials are not rejected by the human immune system.

Biosensor: A sensor structure that targets biological analytes or a sensor based on the use of biological molecules.

Bistable: A system that has two stable resting states, like a coin that can rest either on heads or on tails.

Bottom-Up Nanofabrication: The building of nanostructures starting with small components such as atoms or molecules.

[133] This glossary has been used for academic purposes from Mark Ratner's Nanotechnology: A gentle introduction to the next big idea. 2003, Prentice Hall.

CAD: Computer Aided Design, referring to the use of computational algorithms and tools to design switches, computers, memories, and other technology devices.

Catalyst: A substance that causes a chemical reaction to proceed more rapidly; for example, the crystallization of sugar on a wooden stick occurs more rapidly than it does in simple liquid water, so the stick acts as a catalyst.

Ceramics: Hard, refractory materials often based on oxides.

Chaperones: Small proteins used within cells to carry metal ion species
from one place to another (this facilitating is quite opposed to the usual meaning of chaperones, whose business it is not to facilitate).

Cholesterol: A large molecule very widespread in biology (e.g., it provides much of the mass in human livers and brains); it is hydrophobic.

CMOS: Complementary Metal Oxide Semiconductor, referring to a technology commonly used to make contemporary silicon-based microchips.

Colorimetric Sensors: Sensors that work by changing their colors when the analyte appears. A simple example is litmus paper.

Coulombs Law: The fundamental law of electrical interaction: the force between two charges is proportional to the magnitude of each charge and inversely proportional to the square of the distance between the charges.

Cross-Linked Polymers: Structures consisting of linear polymer strands with chemical bonds between them that act to link one strand to the next.

Crystal Growth: The formation of crystals by growth from solution, a kind of self assembly. Examples include the formation of snowflakes in the atmosphere and the formation of rock candy from sugar solutions, showing that sweet and beautiful are both forms of nanotechnology.

Decoherence: The loss of controlled entanglement. For example, when two entangled pieces of information (in quantum computing) become separated by the loss of relative phase, they are said to decohere.

Dip-Pen Nanolithography: Method of fabrication that uses a scanning probe tip to act essentially as a fountain pen to draw nanostructures on surfaces using arbitrary molecular structures as inks.

DNA Computing: The use of DNA hybridization and replication processes to solve computational problems.

DNA Molecule Therapy: Therapeutic scheme in which DNA molecules are introduced into the cell, where they can combine with, for example, pathogenic DNAs within infected cells.

Electrochemistry: The science that combines chemistry with the flow of electrical current. Examples of electrochemical processes include silver plating and aluminum manufacturing.

Electron: The subatomic particle with one negative charge and a mass that is roughly 1/2000 the mass of a proton.

Electron Beam Lithography: Method of fabrication that uses electron beams to form structures on surfaces. It is widely used to make extended large nanostructures.

Electron Microscopy: The measurement of structures of solids and surfaces using electrons rather than light to see small features (down to the nanoscale).

Electroosmosis: A method for moving liquids using electrical fields. Electroosmosis moves a sample at a constant rate, so it is used when a sample should not separate into components. Compare to *electrophoresis.*

Electrophoresis: A method of using external electric fields on electrically charged species to move either particles or liquids. Electrophoresis moves samples at a rate proportional to inverse mass of the components of the sample and is therefore often used for separations. Compare to *electrosmosis.*

Encapsulated Nanomaterials: Structures in which a nanomaterial is enclosed in an outer covering or coat.

Entanglement: In quantum computing, the process of combining two separate pieces of information so that they can be treated as a single entity.

Enzyme: A protein catalyst used to facilitate chemical reactions in biological species.

Fab: Abbreviation for fabrication, used to refer to a plant that manufactures semiconductor devices (microchips).

Field-Effect Transistor: The most common sort of transistor used in semiconductor chips. It employs a gate to control (turn on and off) electrical current.

Finite State Machine: A device that operates by switching among a series of states according to a set of rules (see *Transition Rules).* An example of a Finite State Machine is an elevator controller. Each position of the elevator (first floor, second floor, etc.) represents a state and how the elevator reacts to users pressing the call buttons is encoded in the Transition Rules.

Gene Therapy: A specific sort of DNA therapy

Giant Magneto Resistance: A phenomenon in which the resistance of a substance is changed very strongly by application of a magnetic field. It is used as a read-out mechanism in current magnetic computer memories.

Graetzel Cell: A photovoltaic cell, first developed by Michael Graetzel in Switzerland, that uses nanoscale titanium dioxide and an organic dye to obtain electrical current from incident light.

Head Groups: Part of the structure of some long molecules wherein one end of the molecule can be called a head group and the other end a tail group. In soap, the hydrophilic head groups are soluble in water, while the hydrophobic tails cause solubility in oils and greases.

Histamine: A small molecule that, although always present in the body, is increased in concentration by the presence of antigens and antibodies. Histamines often cause allergic responses.

Hybridization: In DNA science, the formation of a second strand from the first, by complementary binding of the G with C or A with T.

Hydrogen Bond: A specific sort of weak bond between molecules caused by a hydrogen atom bridging between (say) an oxygen to which it is covalently bound and another oxygen that interacts more weakly with it by electrical forces. Hydrogen bonds are crucial for the structure of water, proteins, and DNA.

Hydrophilic: Water loving, refers to materials or molecular structures that interact strongly with and are soluble in water (e.g., ethyl alcohol).

Hydrophobic: Water hating, refers to materials that do not dissolve in water (e.g., salad oil).

Inhomogeneous Structures: Materials that are not the same throughout.

Macroscopic examples are a western omelet and reinforced concrete.

Insulators: Materials that do not permit electricity to flow (e.g., the rubber lining on extension cords).

Ion: An atom or molecule that is electrically charged.

Light-Emitting Diodes: Structures in which an electron and a hole combine to form an excited state that subsequently emits light; these devices permit direct transformation of electricity into light.

Light-Harvesting Complex: The part of the photosynthetic apparatus that actually captures and stores the light energy (as molecular excited states) before passing it on to other structures within the photosynthetic apparatus.

Liposome: A microscale or nanoscale artificial globule consisting of layers of lipid or phospholipid enclosing an aqueous core. It can be used both as a model for membranes and as a delivery vehicle for particular molecules or biological structures.

Lithograph: Originally meant a pattern or structure formed on paper using ink or painted stones to form the image.

Lithography: The formation of structures of any size (including nanoscale), generally by transferring the pattern from one structure to another.

Logic Gates: The fundamental logic structures that, combined, lead to digital computing. The three most common logic gates are AND, OR, and NOT. Logic gates were first discussed by George Boole.

Luminescent Tags: Molecules or nanostructures that luminescence (emit light) when illuminated and that are used to identify structures to which they are bound.

Macromolecule: Another word for polymer; it refers to single molecules consisting of many (thousands or more) atoms.

Magnetic Force Microscope: A scanning probe microscope in which a magnetic force causes the tip to move. This motion allows the user to measure the magnetic force..

Magnetic Resonance Imaging: A form of magnetic resonance spectroscopy that indicates the presence of particular atomic nuclei. Used to image sections of the body or particular biological structures.

MEMS: Microelectromechanical Systems, referring to structures at the micron scale that transduce signals between electronic and mechanical forms.

Metastasis: The process by which certain cancers can spread from one organ or structure within the body to another.

Microfluidics: The process of moving liquids or fluids along a channel whose characteristic cross-sectional dimension is microns.

Micro Imprint Lithography: Lithographic method for making small structures (originally at the micron, now at the large nanoscale level) using a sort of ink pad, usually made of a plastic material.

Microtubules: Extended rigid linear structures found in cells; they are used by molecular motors such as actin to move cargos of molecules or other structures within the cell.

Mirroring: A method for keeping stored data consistent among two or more digital storage media, such as computer hard drives.

Molecular Conductors: Molecules that can conduct electrical current.

Molecular Electronics: Electronics that depend on or use the molecular organization of space.

Molecular Motors: Complex nanostructures (sometimes slightly larger than nanostructures) that work to transform chemical energy to mechanical motion within biological structures.

Molecular Recognition: Fundamental self-assembly scheme wherein one molecule has the ability to bind in a specific way to another molecule or a surface.

Monomers: Small molecules that bind together into longer structures to form polymers.

Nanocomposites: Composite structures whose characteristic dimensions are found at the nanoscale. An example is the suspension of carbon nanotubes in a soft plastic host.

Nanodots: Nanoparticles that consist of homogeneous material, especially those that are almost spherical or cubical in shape.

Nanofabrication: The manufacture or preparation of nanostructures.

Nanofiltration: The filtering of particles of nanosphere dimensions

Nanofluidics: The process of moving liquids or fluids along a channel whose characteristic cross-sectional dimension is nanometers.

Nanorods: Nanostructures that are shaped like long sticks or dowels, with a diameter in the nanoscale and a length very much longer.

Nanoscale: Refers to phenomena that occur on the length scale between 1 and 100 nanometers.

Nanoscale Biostructure: A biological structure whose characteristic properties change on the nanometer length scale (e.g., a cell wall).

Nanoscale Synthesis: Another word for nanofabrication, referring to manufacture of structures at the nanoscale.

Nanoscience: A discipline in which the authors of this book work, involving scientific understanding and investigation of nanoscale phenomena.

Nanosphere Lift-off Lithography: A nanofabrication method in which small spheres of nanoscale dimension are used to form a pattern on a surface, which then acts as a mask to block some areas of the surface during subsequent deposition of a nanomaterial from the vapor phase. It is a nanoscale version of letter stencils that are used to spray paint signs.

Nanostructures: Structures whose characteristic variation in design length is at the nanoscale.

Nanotechnology: The application of nanoscience in technological devices.

Nanotubes: Almost always carbon nanotubes, referring to the wires of pure carbon that look like rolled sheets of graphite or like carbon soda straws.

Nanowires: Another term for nanorods, especially nanorods that can conduct electricity.

Neuro-Electronic Interface: A structure that permits transduction of signals between nerve fibers and external computational resources.

Neurotransmitters: Small organic molecules that carry signals and information from one part of the brain (neuron) to another.

Neutron: A subatomic particle with no electrical charge and a mass slightly larger than a proton; it can be thought of as a combination of a proton and an electron.

Ohm's Law: Fundamental law of electrical charge flow in macroscopic circuits stating that the current is equal to the voltage divided by the resistance.

Oligonucleotides: Small subunits of DNA consisting of a few bases on each of the hybridized strands. "Oligo" means few.

Optics: The science of light and its propagation and interaction with matter.

Pervasive Computing: A futuristic scenario in which essentially all the functional structures of life ranging from door locks to kitchen stoves to raincoats to humidifiers are computer controlled and in mutual contact.

Photodynamic Therapy: A remediation scheme for several diseases, including cancer. It depends upon the use of molecular or quantum dot structures to transform light energy either into heat or into highly reactive excited oxygen molecules that subsequently attack the tumor tissue.

Photorefractive Polymers: Polymeric materials that exhibit both charge motion and nonlinear optical response so that patterns of information can be written and read using them.

Photosensor: Usually, a device for measuring the presence and frequency of light. The most common photosensors are macroscopic, work by emission of electrons from photoexcited metals, and are used, for example, in the emergency openers for elevator doors.

Photosynthesis: The process by which plants and bacteria transform light energy into chemical energy, molecule synthesis, or proton gradients. It is the fundamental means by which nearly all energy sources are powered by the sun.

Photovoltaics: Artificial systems that transform light energy into electrical current; they can be based either on semiconductor structures or on molecular complexes.

Pipelining: A microprocessor design approach that involves breaking up each individual processor instruction into smaller subinstructions. Each subinstruction requires only part of the processor, so multiple instructions can be processed at the same time.

Polymerization: The process of making polymers from monomers, thereby making very large macromolecules from small molecular precursors.

Polymers: Extended molecules made by bonding together subunits called monomers. Examples include polystyrene and polyethylene, as well as DNA.

Polysaccharides: Polymers whose subunits are sugars.

Prestin: Molecular motor structure found in the inner ear and important in transducing sound into neural signals.

Protein Engineering: The manufacture and manipulation of proteins by synthetic chemical routes.

Proteins: Biological macromolecules assembled from amino acid units.
They are the functional structures in biology.

Proton: A subatomic particle with a positive charge of one unit and mass slightly smaller than a hydrogen atom. The number of protons in a given nucleus determines which element the atom is.

Quantum Computing: A computing scheme that depends upon the wave-like properties of matter and that works in a way that is fundamentally different from digital computing.

Quantum Dots: Nanostructures of roughly spherical or cubic shape that are small enough to exhibit characteristically quantum behavior in optical or electrical

Quantum Mechanics: A description of the mechanical behavior of atomic and subatomic particles such as electrons and protons. Quantum mechanics is a generalization of classical mechanics, which describes basketballs and horseshoes.

Qubit: The smallest unit of information in quantum computing.

Quinones: Small organic molecules containing double bonds between carbons and oxygens. They are important as intermediate acceptor species in photosynthetic structures.

Rodcoils: Medium-size molecules containing hundreds to thousands of atoms that are arranged with a stiff tail and a soft, hydrophobic, space-filling bulbous head. They self-assemble into extended round and cylindrical structures.

Scanning Probe Instruments: Tools for both measuring and preparing nanostructures on surfaces; they work using the interactions between a scanning tip structure and the nanostructure on the surface, which can be either manipulated or measured.

Scanning Tunneling Microscope: The first of the scanning probe instruments, invented by Binnig and Rohrer. It works at the scale of nanostructures and measures electrons tunneling between a scanning tip and a conducting surface.

Self-Healing Structures: A form of smart material in which the structure responds to a physical stress, break, or fracture by repairing itself back to the original structure.

Siderophores: Small molecules containing oxygen, nitrogen, sum, or phosphorous atoms that can bind to (capture) particular metal ions.

Species: In chemistry refers to a particular atom, ion, or structure.

Spectroscopy: The science of the interaction of radiation with matter.

Suicide Inhibitors: Synthetic molecules that, upon reacting with an enzyme, produce a product that binds to the enzyme and therefore causes the enzyme not to function (to commit functional suicide).

Swarm Computing: An alternative computer architecture based upon a very large number (a swarm) of very simple devices instead of a small number of megalithic microprocessors. Each device can perform only a few elementary tasks and each can fail without disrupting the system. Swarm algorithms are complex and are designed to take advantage of both limited strength and the possible failure of a given computational element.

Tail Group: See ***Head Groups***

Top-Down Nanofabrication: The process of making nanostructures starting with the largest structures and taking parts away. It is analogous to classical sculpture and to CMOS chip fabricating. To make David, it is said that Michelangelo started with a block of marble and took away everything that wasn't David.

Transduction: Process of changing energy or signals from one form to another.

Transition Rules: A scheme of instructions that tells a finite state machine (a form of computing device) to move from one particular state (e.g. on or off) to another. An example of a transition rule is "Turn on when the power switch is thrown."

Ultrafiltration: The filtering of very small (micron-scale) particles. It is not a precise usage, and sometimes people refer to nanofiltration as a form of ultrafiltration.

Zeolite: A framework ceramic material built of aluminum oxide and silicon oxide, with other possible additions. Used for water softening and for several catalytic structures, they comprise a very elegant set of nanoscale materials.

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