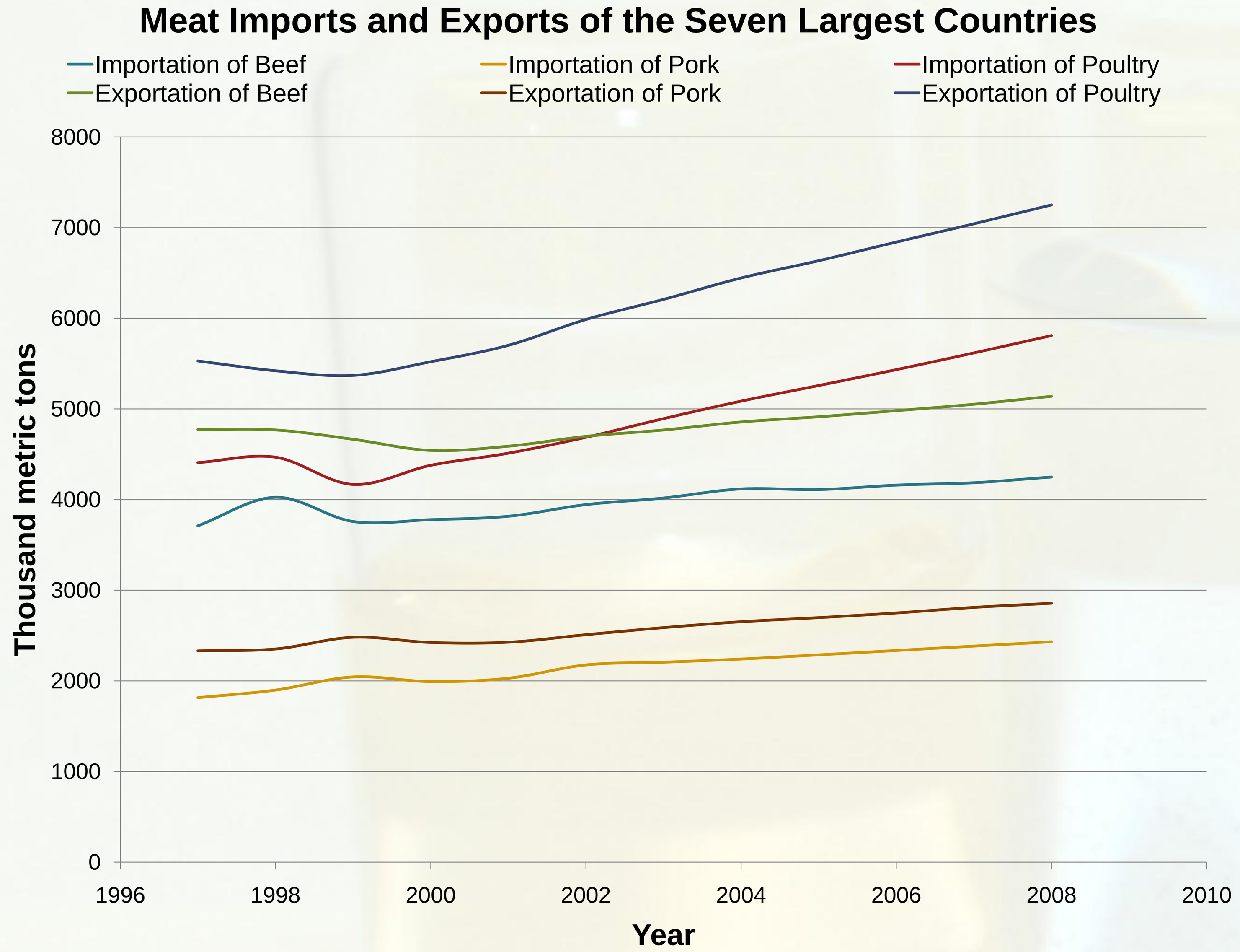
QUICK SILVER 47
IPRO 317

ILLINOIS INSTITUTE OF TECHNOLOGY

Problem


- Maintaining the quality and safety of perishable items during shipping and storage is greatly dependent on maintaining adequate thermal conditions. How can this temperature be monitored effectively and efficiently?



Source: US Department of Agriculture

- A cost-effective thermal-history indicator could greatly improve quality assurance and safety of perishable products.

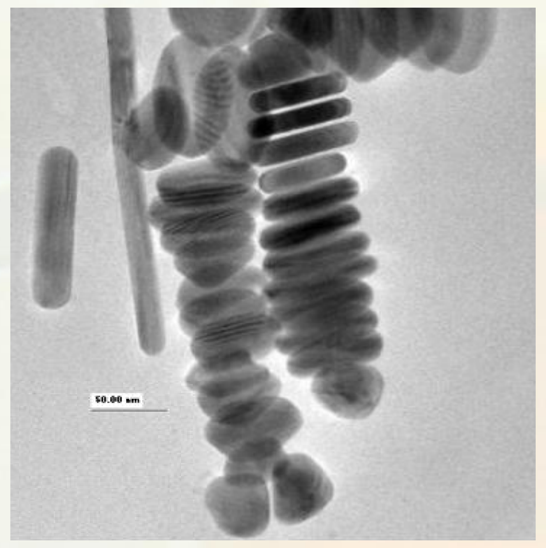
Opportunity

- Because of their shape dependent optical properties and morphological instability, **silver nanorods** could be used as a convenient and cost-efficient thermal indicator to determine if packages have not been stored under adequate thermal conditions.

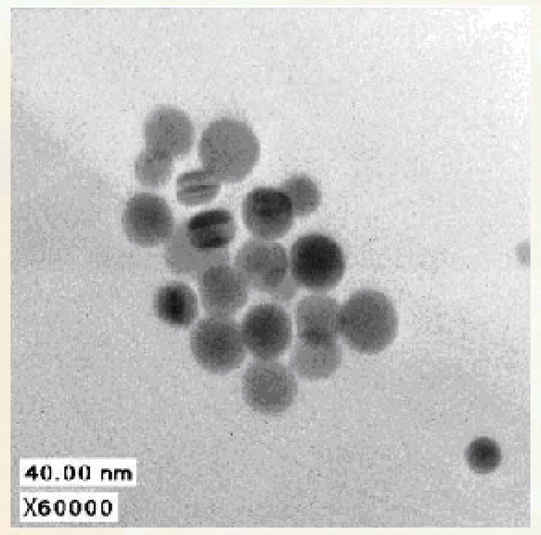
- If a **continuous process** for producing **silver nanorods** could be established, the **cost** could be sharply **reduced**.

Background

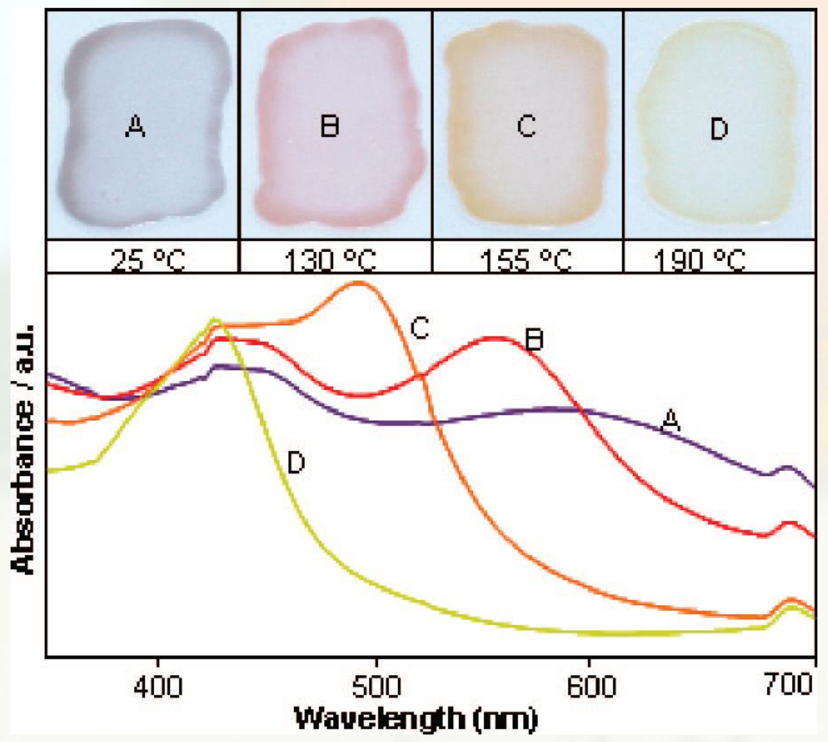
- Nanoparticles are smaller than the size of a of dust particle.
- It has a unique **color changing property** which is directly dependant on **changes in both temperature** and **time**. This color change is due to morphological changes of nanoparticles.
- One significant application involves the use of **silver nanorods** as **thermal history indicators** as they have the unique property of changing color as ambient temperature changes.
- Work is being done on the **development** of a **continuous flow process** for large scale and **commercial use** of silver nanorods.



Silver nanorods after one week

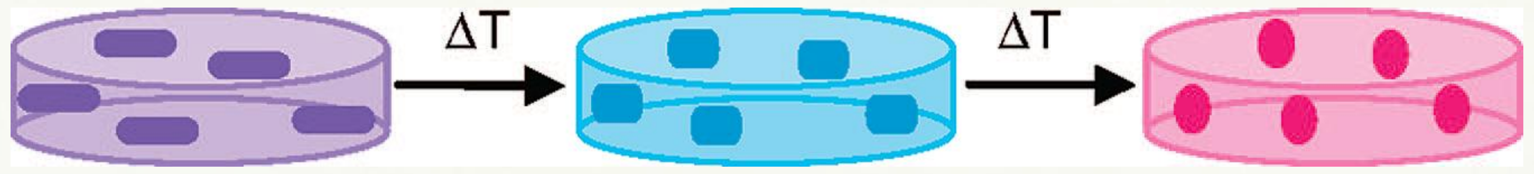


Silver nanorods after 4 weeks



Nanorod Color and Absorption Changes

- Using spectroscopy, the changes in morphology was recorded in the form absorbance as a function of wavelength generated by **changing temperatures** and **time**.
- Clear visible **color changes** can be **observed** which is indicative of morphology changes.

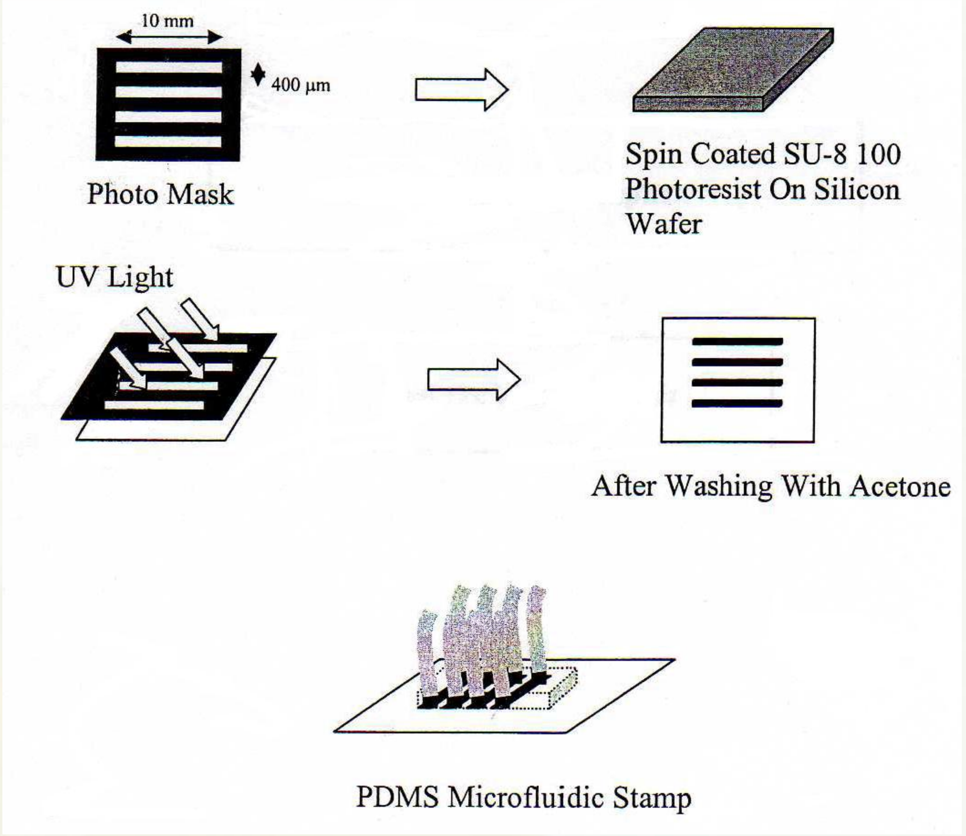


Artist's Conception of Nanorod Shape and Color Changes

Source: Tollan, C.; et al. /ACS Appl. Mater. Interfaces/ 2009, *1*, 348

Objectives

- Optimize the existing batch process for creating silver nanorods.
- Develop a continuous process for producing silver nanorods.
- Explore the use of silver nanorods as thermal indicators and prove the economic viability of the nanorods
- Tailor silver nanorods for their use at different conditions of thermal history.
- Design and build a microreactor for continuous nanorod production.



Microfluidics Channel Design

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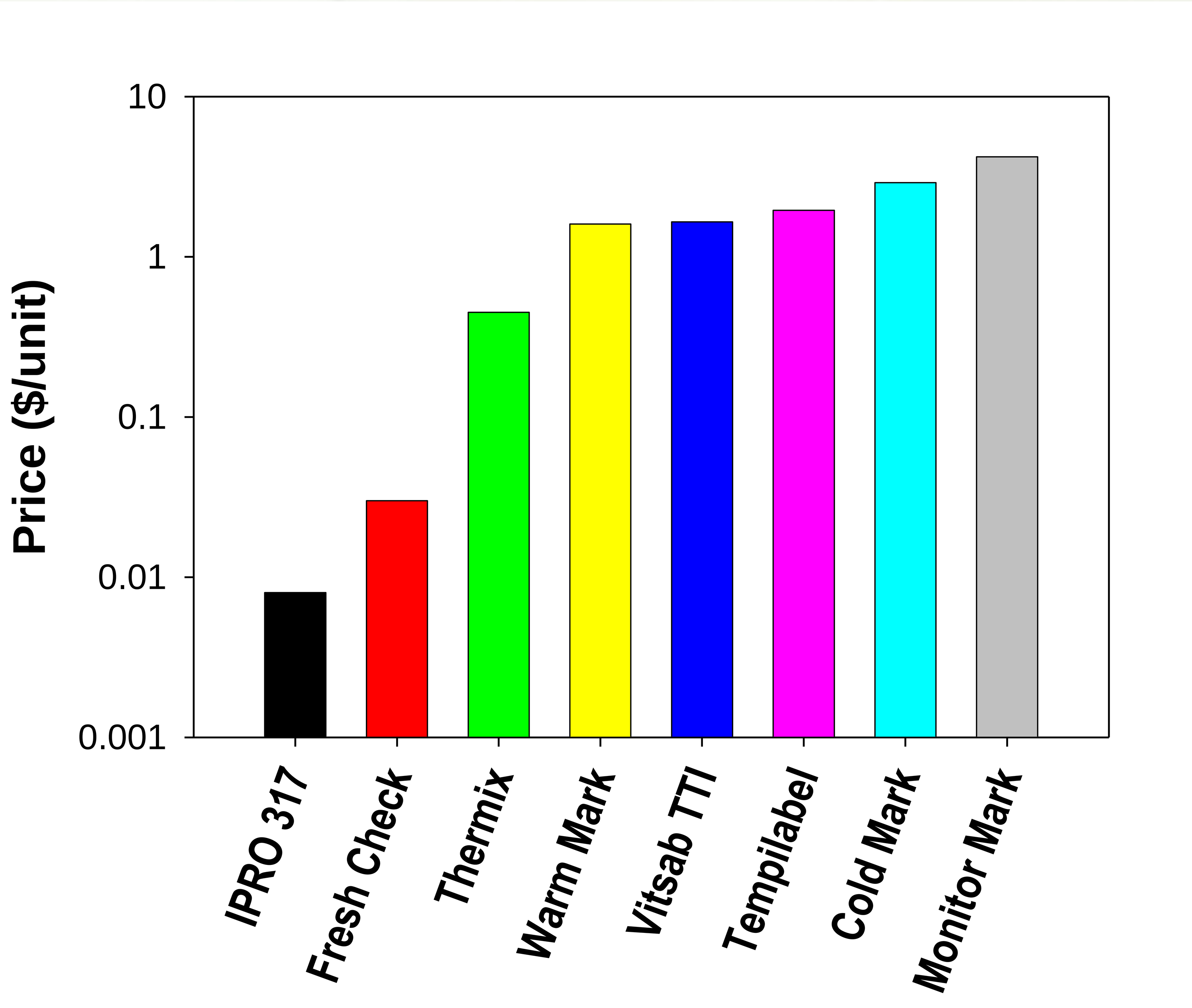
Methodology

The team was divided into the following groups.

- **Research Team:** Compiled information about the batch process presently being used for the production of silver nanorods and also the feasibility of a continuous process.
- **Lab Team:** Conducted experiments using the batch process to make silver nanorods and designed a method to convert the process from batch to continuous with a microfluidic reactor.
- **Economics Team:** Researched the cost and benefits of converting the process from batch to continuous process and concluded that it was economically feasible (see below).

Economics

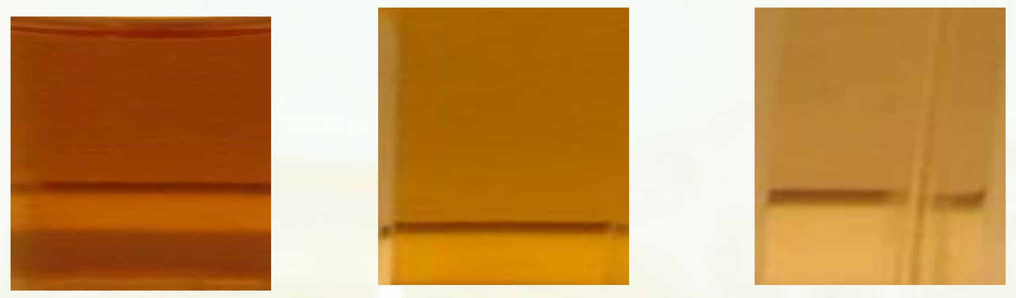


- The Price axis is set at a logarithmic scale to demonstrate the difference in costs by order of magnitudes (factors of 10).

Results

Time : 0 10 90 150 210
(Mins.)

Silver Nanorod color change over Time (held at 60˚ C)

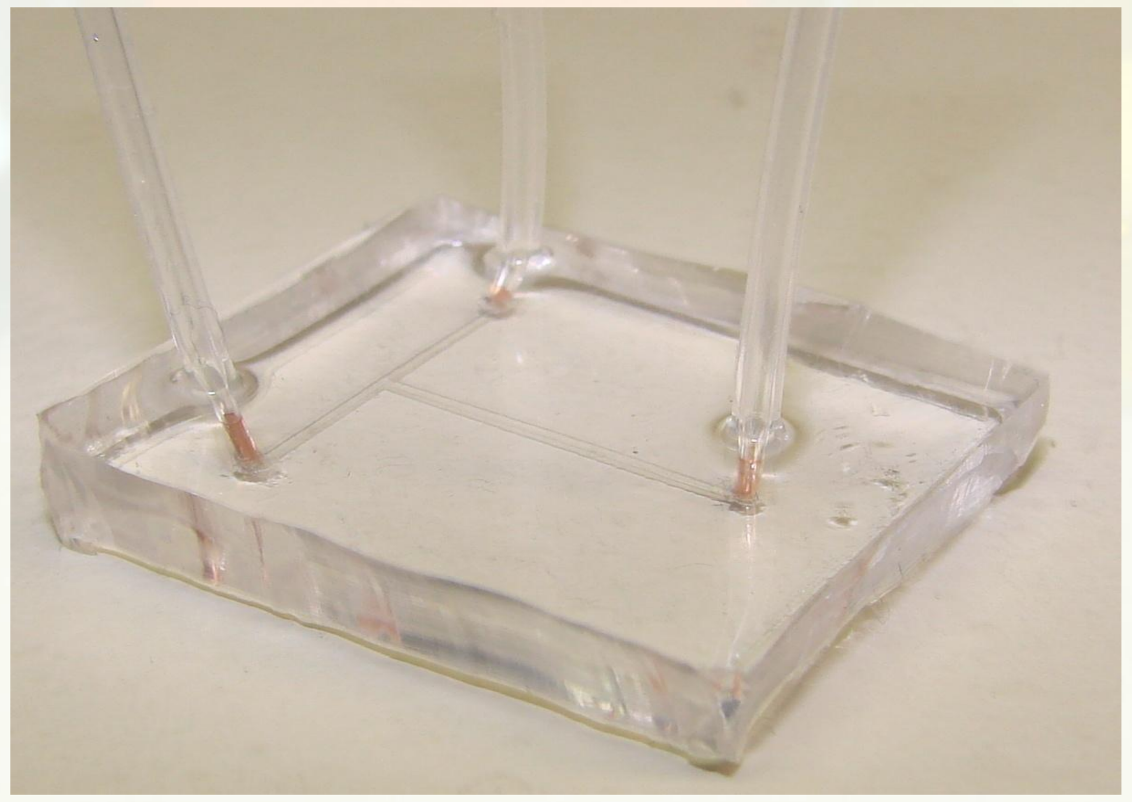


Temp : 4 25 39
(˚ C)

Nanorod Color Change with Temperature (after 7 days)

Temp : 4 25 39
(˚ C)

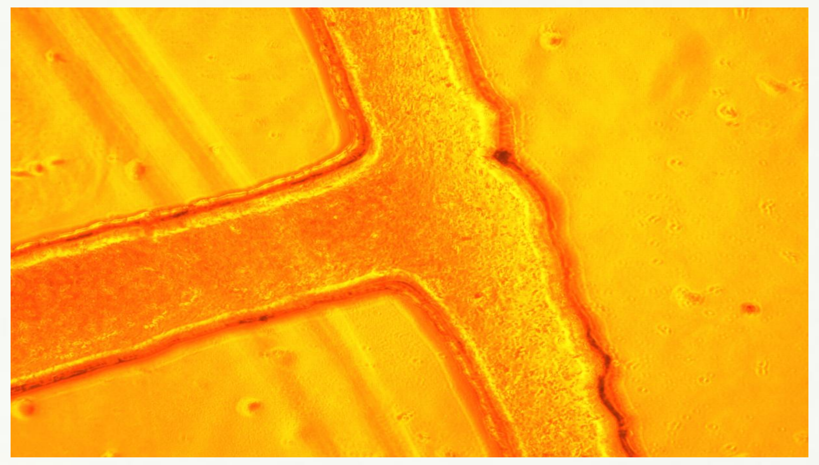
Nanorod Color Change with Temperature (after13 days)



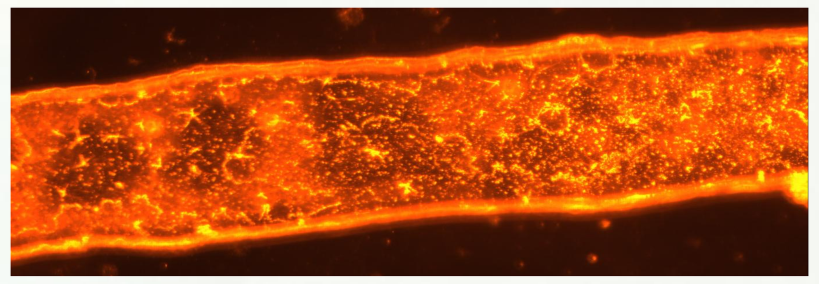
Microfluidic Model

- Microfludic channels were developed as the first step towards a continuous process of producing nanorods.
- It has two inlets on one end for the reactant solutions and an outlet on the other end for the produced nanorods along with solution.

- Microscopic (10X) view of microfluidic channel where two inlets connect (Diameter 200µm)



- Microscopic (20X) view of microfluidic channel where diffusion occurs across concentration gradient (Diameter 200µm)



Conclusion

- Silver nanorods were successfully produced using a batch process.
- The results clearly demonstrate the wide spectrum of color that nanoparticles use to indicate a wider range of temperature relative to its competitors.
- At 0.8 cents/label, the cost of silver nanorods as thermal indicators was determined to be economically viable.
- A continuous flow process using a microfluidic model was designed and testing is in progress to determine where solution mixing occurs through diffusion.

Future Works

- Further develop the microfluidic model to incorporate a steady outlet stream of nanoparticles.
- Explore the viability of introducing reactants like iodine to lower the diffusion time in the reactor.
- Silver nanoparticles' antimicrobial uses could be explored to develop pharmaceutical tools to combat drug-resistant viruses and bacteria in human beings.

Acknowledgments

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