Development of a high-dielectric-constant material

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Test Fixture Team
Ginny Brock (MMAE)
Jason Brudniki (EE)
Hristiyan Kourtev (EE & CPE)
Ahmed Tolba (MMAE)
Sameer Verma (CPE & CS)

Materials Team
Minh Evans (CPE)
Beth Grzenia (BCPS)
Julien Julius (MMAE)
Joe Stainbrook (MMAE)

Student team leader: Joe Stainbrook (MMAE)
Faculty Advisors: Judith Todd (MMAE) and Thomas Wong (ECE)
Sponsor Advisors: Brett Rickett and Gus Panella
Introduction

• Molex – the second largest manufacturer of electronic, electrical and fiber optic interconnects

• Capacitor properties:
  - stores energy
  - can be used as a filter for DC current

• Basic capacitor structure:
  - parallel conducting plates
  - dielectric material
  - qualitative analysis and the dielectric constant
Goals

• Dielectric Constant: > 100
• Operating Frequency: 100 MHz to 9 GHz
• Compressible: 50% thickness reduction at < 9 psi
• Flexible: > 0.25” deflection over 3” length under its own weight
• Operating Temperature: 0ºC to 120ºC
• Thermal Shock Durability: -50ºC to 105ºC
• Thickness of 0.008” with minimum lateral dimensions of 3” x 3”
• Cost: < $7.00 / ft²
Strategy

• Identify research areas:
  - materials and their properties
  - material design
  - dielectric testing techniques

• Divide the group in two teams for greater efficiency:
  - materials team
  - test fixture team

• Research, Research, Research

• Build a test fixture

• Test materials and compare results to goals
Research Goals

• Relate the properties of dielectric materials to molecular structure

• Investigate feasibility of various material classes
  - ceramics
  - liquids
  - polymers
  - composites
Findings

• Molecular structure of dielectrics and their properties
  - dielectric constant directly related to polarizability
  - types of polarizability
    a) dipole – polar molecules
    b) ionic – shifting of bonds
    c) electronic – relative displacement of electron cloud

• Ceramics
  - high dielectric constants
  - unlikely to meet flexibility and compression

• Liquids
  - highly polar (i.e. high dielectric constants)
  - suitable oscillations over a wide range of frequencies
  - packaging concerns
Findings

• Polymers
  - Closer to desired mechanical properties
  - Unlikely to meet the desired dielectric constant

• Composites
  - Focus on epoxy matrix / ceramic particulate composites
  - New materials could facilitate proper electrical behavior
  - Epoxy matrices unlikely to result in proper mechanical properties
  - Other matrix materials may be better suited
Research Goals

- Research the feasibility of various dielectric constant measurement techniques
  - transmission method
  - reflection method
  - cavity resonance method

- Select the best method for our purposes

- Build a test fixture to be used with materials suggested by the materials group
Findings

• Transmission method
  - easy to implement
  - allows measurement over wide range of frequencies

• Reflection method (most appropriate)
  - same benefits as with the transmission method
  - less error prone than transmission method due to the symmetry of the transmission line
  - equations simpler than with the transmission method

• Cavity resonance method
  - provides very accurate measurements
  - very difficult to construct
  - measurements limited to resonance frequencies only
The Old Fixture

- Produced by Molex
- Employs the transmission measurement method
- Accurate for measuring dielectric constants at kHz and MHz frequencies only
- Transmitted signal measured using a network analyzer
The New Fixture

• Uses Molex’s existing fixture as a base
• Employs the reflection measurement method
• Should be capable of measuring dielectric constants at kHz, MHz and GHz frequencies (not yet tested)
• Reflected signal measured using a network analyzer
Issues

• Materials Team
  - Key information difficult to locate
    a) dielectric response vs. frequency
    b) mechanical properties
  - Inability to test materials on-site

• Test Fixture Team
  - Concepts of high-frequency dielectric measurements were complicated and difficult to grasp
  - Test fixture development delayed by:
    a) uncertainty in the design
    b) impedance matching the transmission line was harder than expected by the team
Conclusions

• Intellectual challenge higher than expected
• Lectures by Molex advisors and IIT faculty were extremely helpful
• Website could have been better utilized
• On-site analysis of experimental materials may become necessary, in the future
Suggestions

• Liquid research is still an option which should be pursued
• Composites with matrices other than epoxies should be considered
• Group meetings should be encouraged
• The new test fixture has to be run through a thorough test program to determine its capabilities and limitations
Thank You!