Chemical Signature of Cured Epoxy Fracture Surfaces

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The aim of this research is to properly discover the effect of curing temperature and stoichiometry on the mechanical behavior of a commonly studied thermoset polymer by investigating the fractured surface of the epoxy resin to identify the vital chemical bond structures that are responsible in a well controlled environment in order to reduce ambiguity.

Material science and engineering is at the center of a wide range of disciplines and industries, including aerospace. Performing material science and engineering research requires a broad range of learning experience.
RESEARCH OBJECTIVES

- Expose and identify the vital chemical bond chains that lead to mechanical failure in a “widely available” and frequently studied epoxy resin.

- Observe the differences of chemical bond chains that appear in epoxy fracture with changes in stoichiometry and curing temperatures.

- Use observations of broken chemical bond chains and known mechanical property values to infer structure-property relationships.

- Create a well-controlled curing environment to reduce variability and ambiguity regarding the cross-linked structure of epoxy resins.

- Reduce the effects of blending variability by curing multiple epoxy samples at one time.

- Generate an experiment methodology that is repeatable and can be recreated by other researchers.
Research Methodology

1. Produce multiple cured epoxy samples in a controlled environment to reduce experiment error during curing
2. Vacuum oven
3. 0.364 curing agent to resin blend ratio
4. Aluminum molds
5. Temperature Controllers - curing schedule
6. Insulation
7. Post cure and ejection
8. Vacuum chamber pulverization – N2 atmosphere
9. Diffused Reflectance FTIR Spectroscopy – vital bond peaks
10. make proper inferences from observed data given known mechanical property data

- Reduce ambiguity
- Increase accuracy
- Preserve integrity of study
- Maintain control over curing chemistry given involvement of mechanochemical reactions
Synchronization and Tuning of Temperature Controllers

- PID Controller Theory
- Programming the Curing Schedule
- Synchronizing Controllers with Software
Sample Molds

- Material
- Insulation
- Sample's cross-link coherence

CX-25 M3 Ejector Pin
MECHANICAL EXPERIMENT DESIGN

Engineering Challenge: Creating a controlled atmosphere for epoxy resin pulverization.
Solution: Coffee grinder inside of custom vacuum chamber pipe.
Result: Reduced variation and ambiguity of polymer chemical cross-link composition
DETECTING CHEMICAL BOND STRUCTURES WITH FOURIER TRANSFORM INFRARED SPECTROSCOPY

Thermo Nicolet NEXUS 670 FTIR
Manufacturer: Thermo Scientific
SKU#: 8356-30-0012


FTIR Reflectance Results

- DGEBA System (44’-DDS, DER-332, MDA, etc.)

- Mid-IR Comparison with Mijovic and Wijaya. “Etherification Reaction in Epoxy-Amine Systems at High Temperature.”
FTIR Reflectance Results

• Near and Mid-IR Comparison with González “Applications of FTIR on Epoxy Resins”
Future Work

- pulverization apparatus (pipe-gas system assembly)
- cure new epoxy test samples for FTIR analyzation
- Investigate any unknown spectra data
- Fine tune the FTIR machine/settings to reduce all noise
- Investigate the peaks from properly cured and fractured samples
- characterize the vital peaks of proper samples to molecular bond-chains in order to associate them with fracture behavior and known mechanical properties of the epoxy
Thank You!
Presentation Resources and References


