College of Engineering

TENNESSEE TECH

The Department of

Chemical Engineering

Announces the Thesis Defense

of

Bo Bonning

In Partial Fulfillment of the Requirements

For the degree of

Doctor of Philosophy in Engineering

May 21, 2020

2:00 p.m.

Held in

Prescott Hall 203

Tennessee Tech University

Zoom Link: https://tntech.zoom.us/j/94035820813

FIELD OF STUDY

Polymer chemistry, dynamic mechanical analysis, cryogenic electronics, mathematical modeling, time-temperature superposition

DISSERTATION TOPIC

Mechanical Analysis and Predictions of Properties for Polymer Materials at Cryogenic Temperatures

EXAMINING COMMITTEE

Dr. Holly A. Stretz (Chairperson)

Dr. Wayne Johnson

Dr. Venkat Padmanabhan

Dr. Cynthia Rice

Dr. Chris Wilson

ABSTRACT

Obtaining accurate measurements of mechanical properties at cryogenic temperatures, especially near liquid helium temperatures, can be difficult to obtain experimentally. A range of polymer materials are used in devices that would require those materials to be exposed to these extreme cryogenic temperatures. Therefore, it is important to predict how these materials will behave at these temperatures. The research presented here suggests parameterized mathematical fits to predict different mechanical properties (creep compliance and modulus) for three core polymers of dielectric laminate films and an epoxy underfill to temperatures approaching 4 Kelvin. The thermoplastic polymers used were etched from Ultralam 3850HT (a liquid crystal polymer or LCP), Pyralux AP 8525R (a laminate of a polyimide and Teflon), and Pyralux TK185018R (a polyimide). Vespel SP-1 was used for validation of the polyimide fit. MasterBond EP29LPSP is a thermoset epoxy often used for underfill in computer chip packaging. Three fitting methods were featured including time-temperature superposition (an Arrhenius method), a cubic fit and a sigmoidal fit. All of these materials were experimentally tested using dynamic mechanical analysis from room temperature to about 130K, and the fits projected that behavior to 4K. Anisotropy was supported for the LCP, presumably because the crystallites exhibited some degree of orientation, by data for the modulus, but not the creep compliance data. This would indicate that modulus is more sensitive to crystallite orientation. The epoxy modulus did not plateau as expected, and this was attributed to low temperature movement of the methyl groups in a bisphenol A component, which if the transition was broad might not appear as an abrupt change in modulus but rather a continuous drift upwards. In summary, the fitting equations reported here can be used to predict properties at 4K for such polymers and aide in device design for devices operated in a liquid helium or similar extreme cold environment.

BIOGRAPHICAL SKETCH

Bo Bonning was born in Coral Springs, FL. He and his family later moved to Tennessee where he attended high school at Livingston Academy. He started at Tennessee Technological University in 2010 and graduated with Bachelor of Science in Chemical Engineering, Chemistry, and Biology in May 2015. Bo joined Tennessee Tech as a graduate student in 2015 and joined Dr. Holly Stretz's research group in 2016. His interests in polymer research led him to work with the Cryogenic Electronics research group on the polymers used in their materials. Bo was awarded best paper at the AIChE 2018 National Conference and was acknowledged by Oak Ridge National Lab's Distinguished Scholar Program.

EDUCATION

Ph.D. Engineering
Tennessee Technological University, 2015-2020 (Expected)

B.S. Chemical Engineering w/ Bio-molecular Concentration
Tennessee Technological University, 2010-2015

B.S. Biochemistry
Tennessee Technological University, 2010-2015

B.S. Biology w/ Cellular & Molecular Concentration
Tennessee Technological University, 2010-2015

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