Dynamic Mechanical Properties of MWCNT/$CoFe_2O_4$ Reinforced PEEK Composites

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Undergraduate Researcher: Amy DiRienzo

Faculty Advisor: Dr. Carl Frick

Department of Mechanical Engineering

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Introduction

- Polyetheretherketone (PEEK) is a widely used polymer
- Well suited for a variety of applications
- Excellent properties and performance
- Desirable shape memory polymer (SMP) candidate

Introduction

- Semi-crystalline and amorphous polymers undergo a glass transition
- The temperature at which the polymer experiences transition is termed the glass transition temperature (T_g)
- SMPs can be deformed into a temporary shape and recover their original shape
- Recovery takes place with respect to T_g

Introduction

- The shape memory effect can be triggered electrically or magnetically provided the polymer contains a suitable filler
- Multi Walled Carbon Nanotubes (MWCNTs) allow the shape memory effect to be induced electrically
- Cobalt Ferrite ($CoFe_2O_4$) allows the shape memory effect to be induced magnetically

Research Procedures

- Study focuses on
  - Dynamic mechanical properties of MWCNT and $CoFe_2O_4$ reinforced PEEK composites
  - Possibility of thermally inducing crystallinity in amorphous PEEK
  - Possibility of activating the shape memory effect of MWCNT reinforced PEEK using resistive heating

Materials

- PEEK Matrix: KetaSpire KT-820FP supplied by Solvay Advanced Polymers

- MWCNT and $CoFe_2O_4$ nanopowder supplied by material science department at the University of Kentucky

Preparation of Composites

- 0.1, 0.5, 1.0, 5.0 vol % of each nanopowder was blended with PEEK powder
- Pressed between aluminum plates at 343°C (650°F) for 25 minutes then quenched in room temperature water
- Resulted in semi-crystalline sample

Preparation of Composites

- Amorphous specimen manufactured by increasing temperature to 399°C (750°F)
- Specimens appeared heterogeneous

Semi-Crystalline Specimen

Amorphous Specimen

Preparation of Composites

- Heterogeneous specimens led to the desire to reheat semi-crystalline specimens
- Numerous reheating processes investigated

Dynamic Mechanical Analysis

- Dynamic Mechanical Performance studied using TA Instruments Q Series 800 DMA
- Rectangular samples tested
  - Tensile mode
  - Frequency of 1 Hz
  - Temperature range of 50-250°C
  - Heating rate of 5°C/min
  - Preload of 0.1 N
  - Strain of 0.07%
  - Force Track of 150%

Dynamic Mechanical Analysis

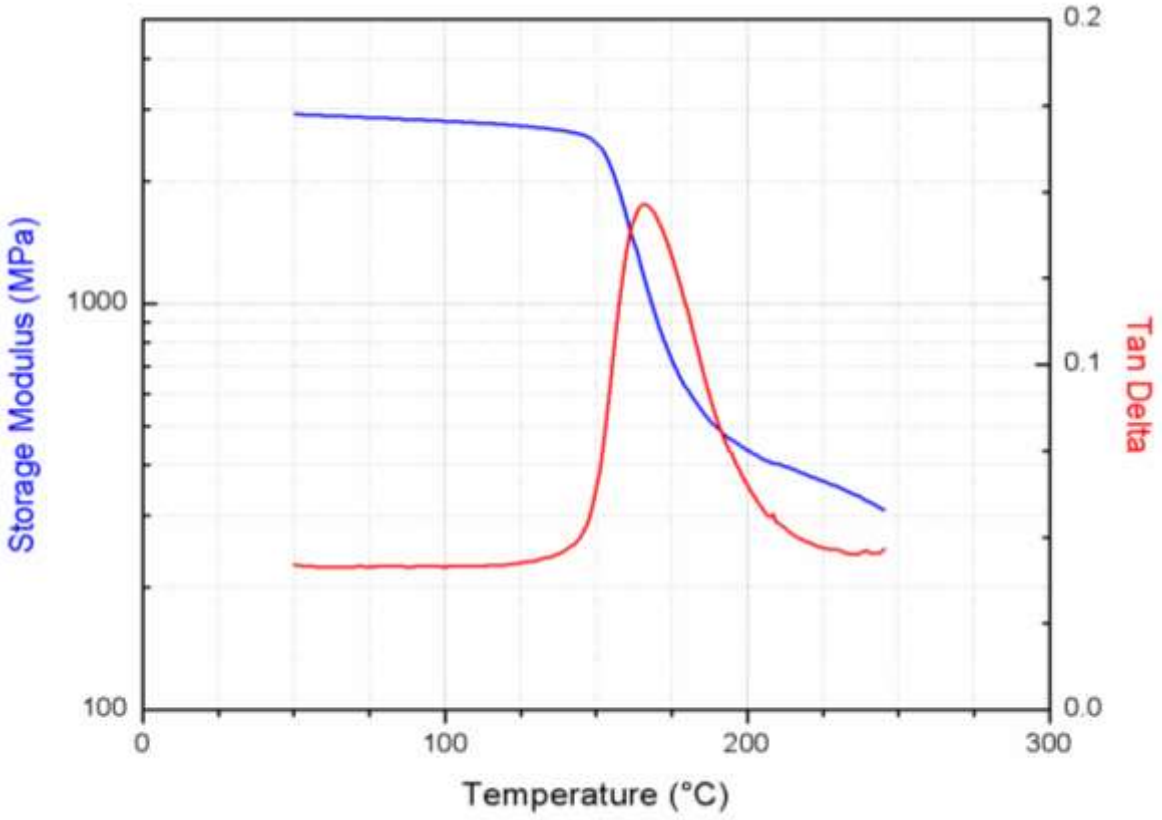
- Storage Modulus: Elastic response of the material
- Loss Modulus: Strain energy dissipated
- Tan Delta: Ratio of Storage modulus to loss modulus
- Spike in Tan Delta marks T_g

Resistive Heating

- 0.1, 0.5, 1.0, 5.0 vol% MWCNT samples tested
- Samples subjected to 5V, 10V, 20V
- Any rise in temperature was recorded

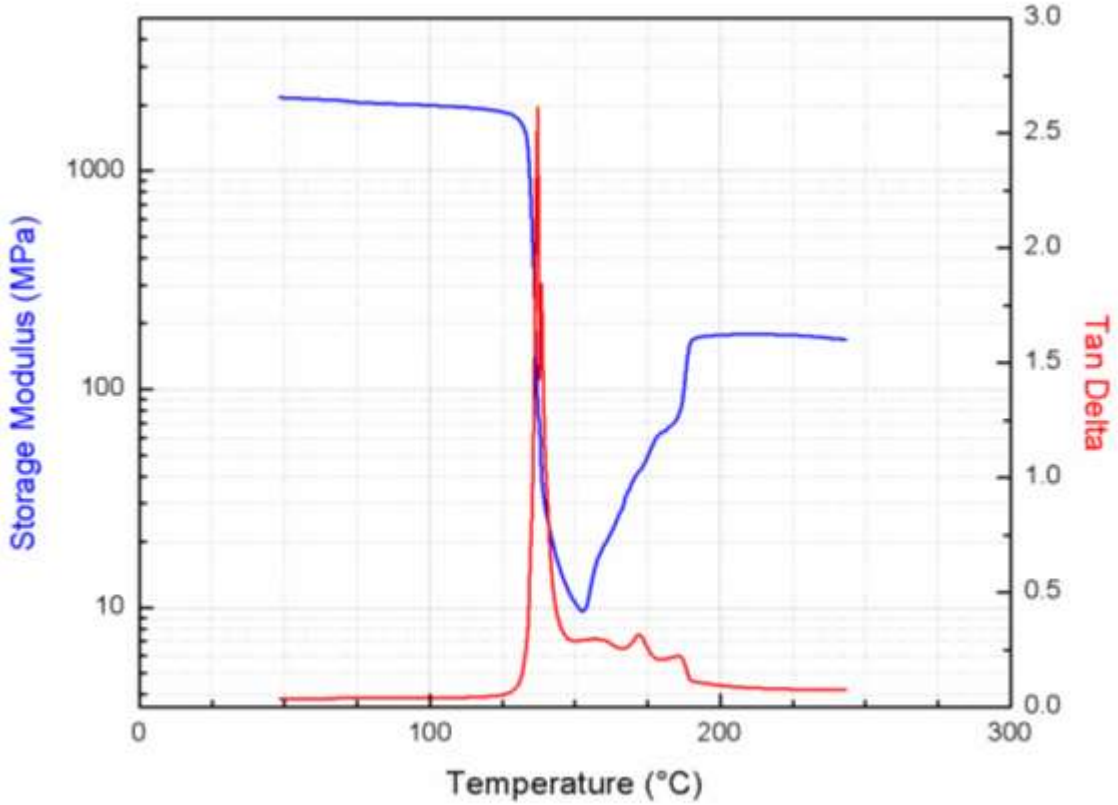
Results and Discussion

DMA Results: Semi-Crystalline PEEK

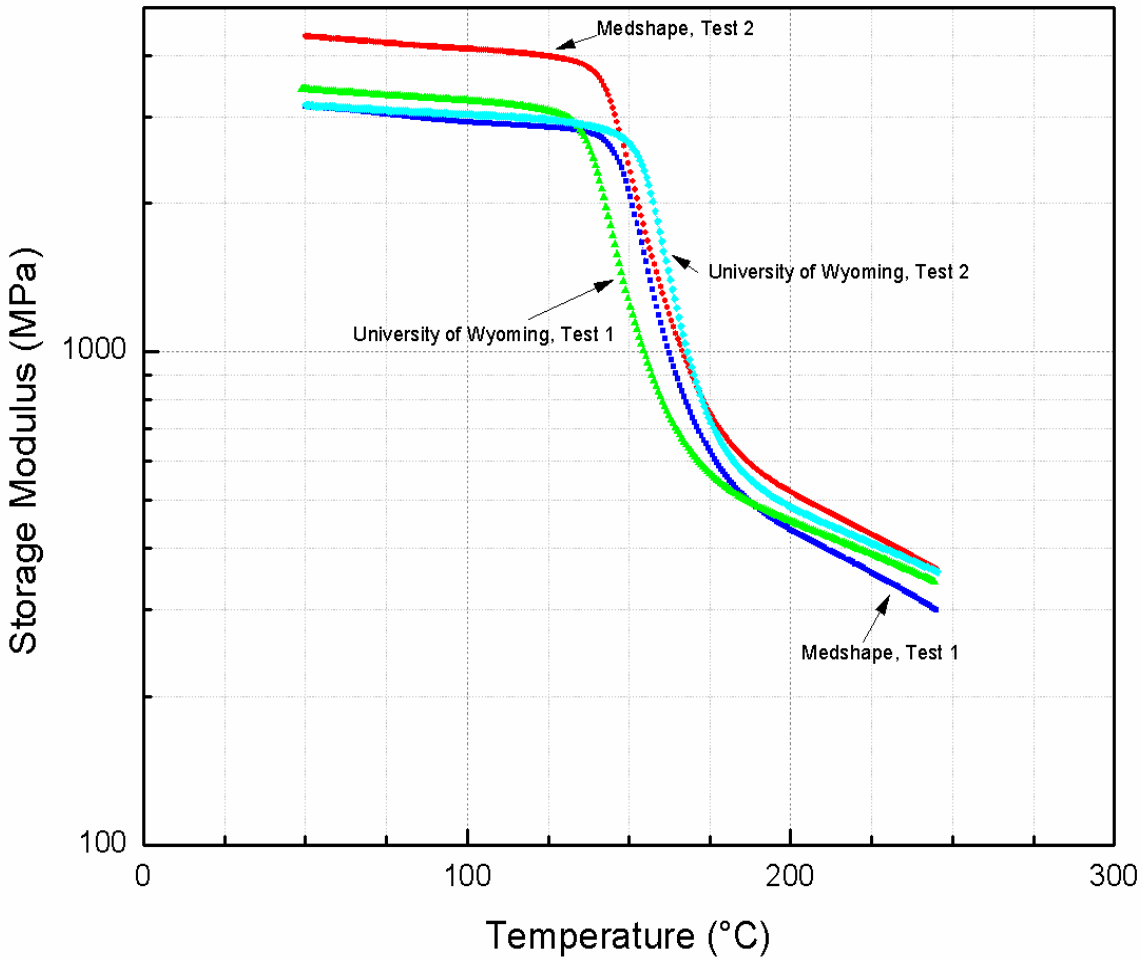


Results and Discussion

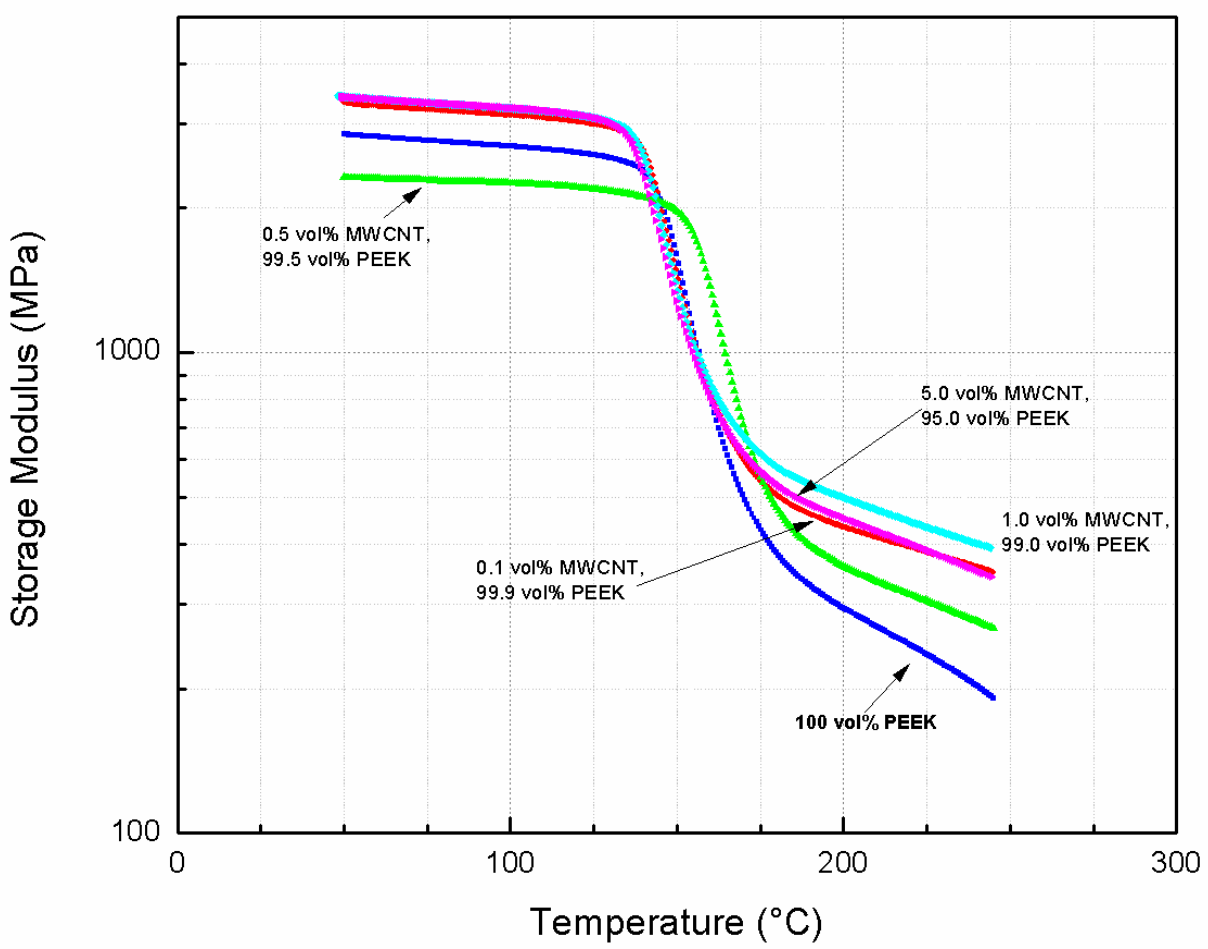
DMA Results: Amorphous PEEK



Results and Discussion



Results and Discussion



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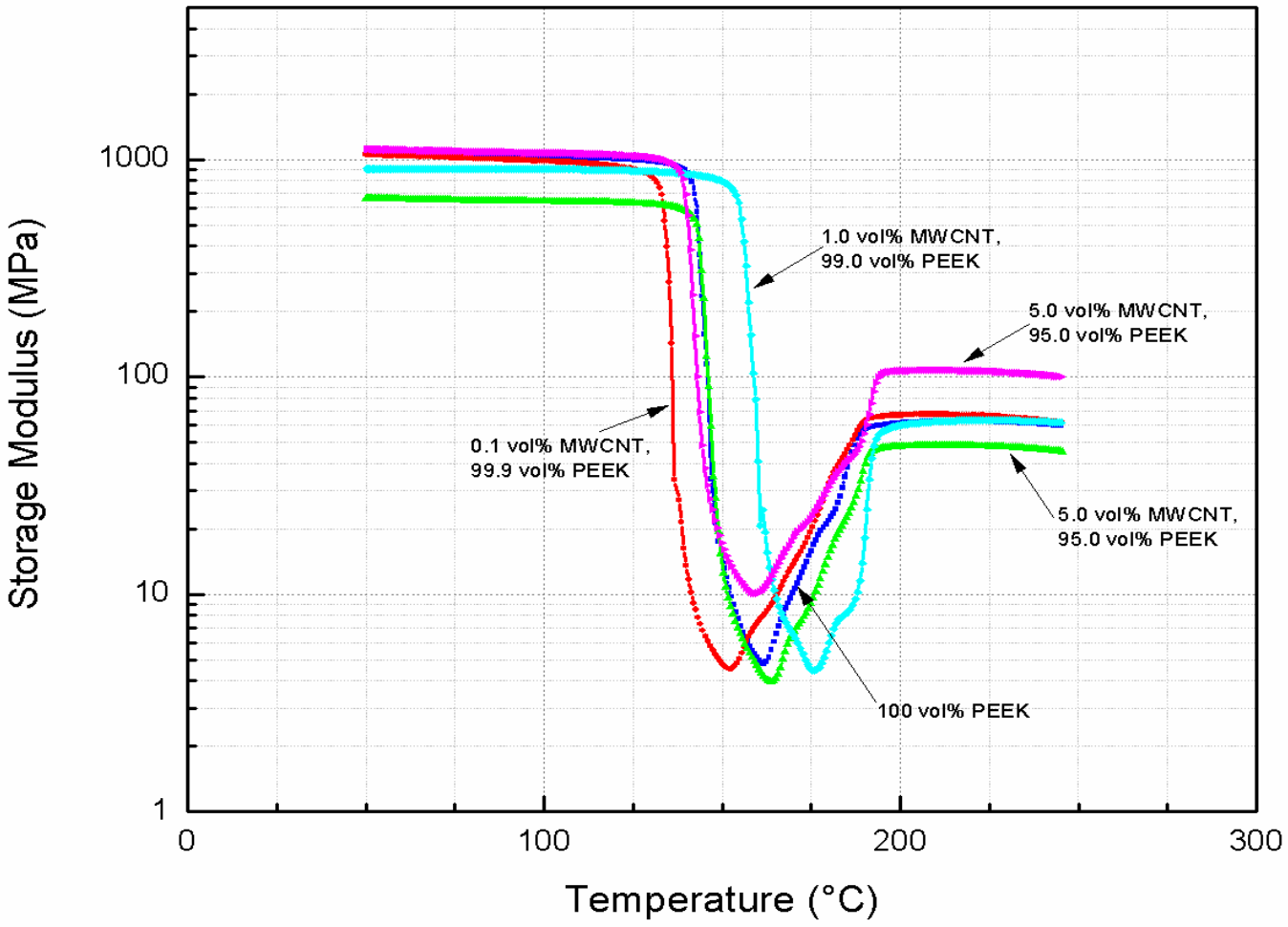
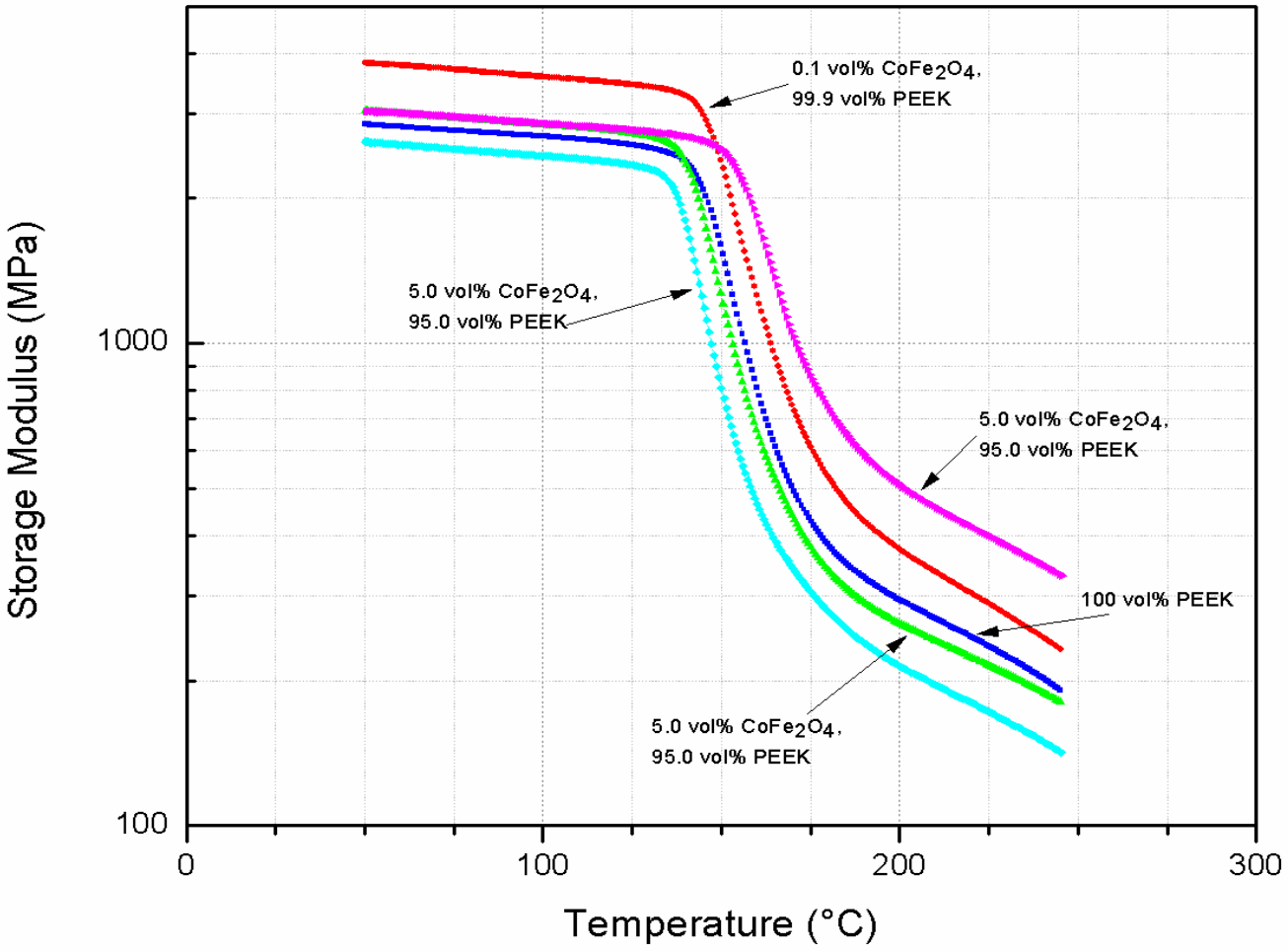
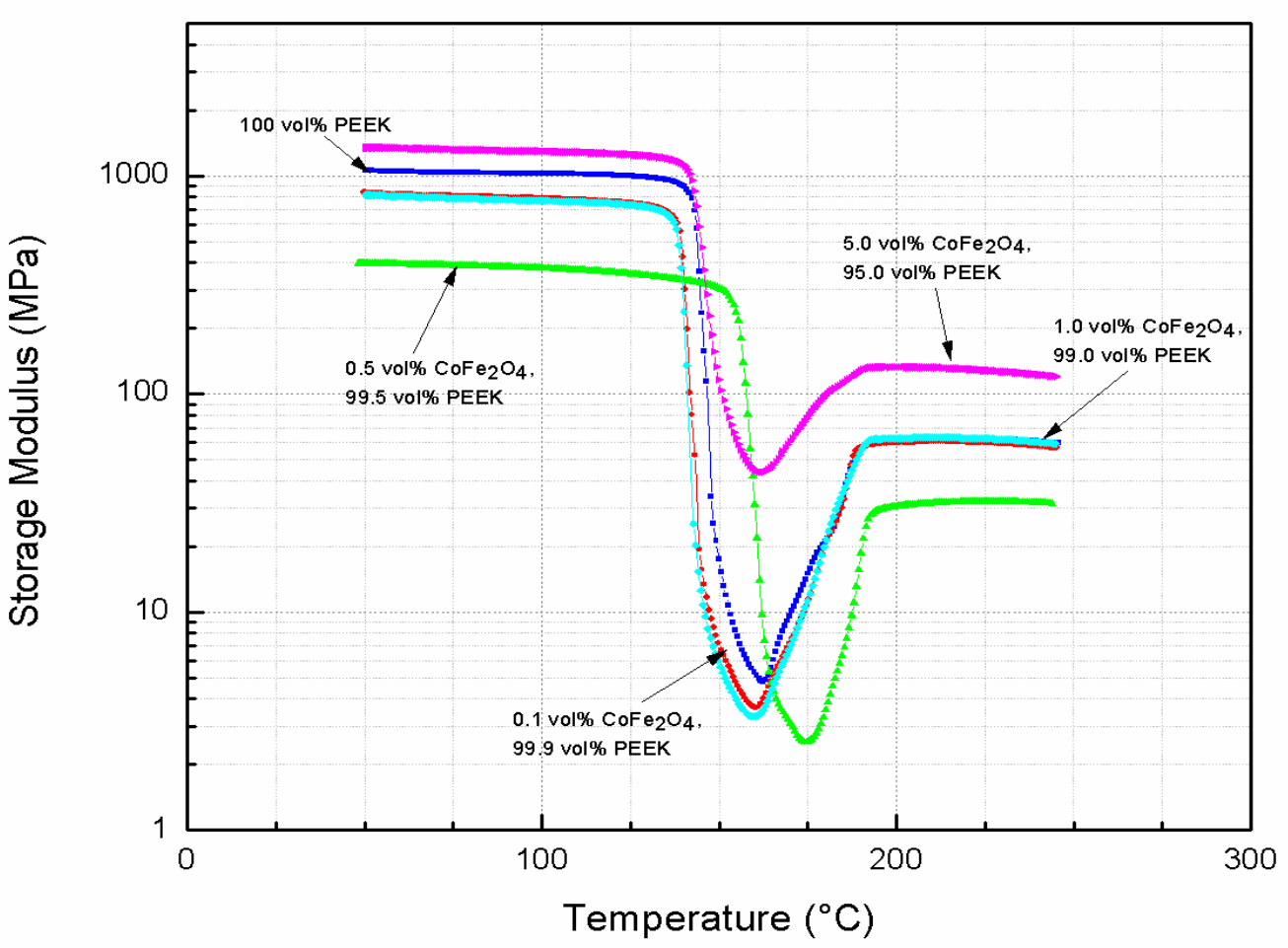


Results and Discussion



Results and Discussion



Results and Discussion

5.0 vol% MWCNT Resistive Heating Results

Applied Voltage (V)	Beginning Temperature (°C)	Maximum Temperature (°C)
5	21.7	24.2
10	21.8	25.2
20	21.8	44.0

Conclusions

- Able to duplicated Medshape Solutions' manufacturing procedure
- Able to create amorphous specimens
- Vol % of nanopowder did not affect storage modulus of T_g in semi-crystalline samples
- Resistive heating possible with 5.0 vol% MWCNT or greater