THERMAL CONDUCTIVITY MEASUREMENTS OF NANOCOMPOSITES

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Goals

- To design and build a set-up to accurately measure thermal conductivity of carbon nanocomposites
- To determine the thermal conductivity of carbon nanotube composite samples
- To compare the values with similar composite samples without carbon nanotubes
- To understand the effects of the carbon nanotubes on the thermal conductivity of these composites
- To recognize any relationship between the carbon nanotubes and thermal conductivity of the composites

Samples

- Nanocomposites made of vinyl ester resin, glass fiber, and carbon nanotubes
  - Dow Derakane 411-c50 resin
  - 2% Trigonox (catalyst)
  - 0.2% CoNap (accelarator)
  - E-glass fibers
  - Multi-walled carbon nanotubes

V_f CNT	V_f E-Glass Fibers	Layers E-Glass Fibers	V_f Vinyl Ester
0.03125	0.00000	0	0.96875
0.03125	0.05400	1	0.91475
0.03125	0.16570	3	0.80305
0.03125	0.27400	5	0.69475

Theory

- Carbon nanotubes
  - Small tubes made of rolled-up graphene sheets
  - Excellent thermal properties, conduct heat well
- Thermal conductivity is an intrinsic property
  - Can not be measured directly
- Will be calculated using Fourier's Law
  - q = k * A * dT/dx
  - q" = k * DT/Dx
  - Supply constant heat flux q"
    - Specify power q
    - Measure area A
  - Measure change in temperature DT
  - Measure thickness of sample Dx
  - Calculate thermal conductivity k

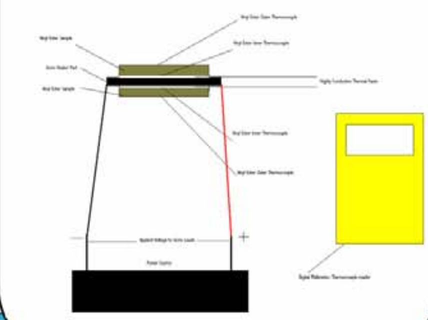
Experimental Set-Up

- Equipment needed:
  - Sample to be tested
  - Reference sample (vinyl ester)
  - Gorix Pad to provide constant heat flux to sample
  - Thermocouples to measure temperatures on all sides of the samples
  - Power source to apply voltage across Gorix
  - Multimeter to read thermocouple temperatures
  - Thermal paste to guarantee good thermal contact between Gorix pad and sample
- Voltage applied across Gorix leads
- Sample will reach steady state in 10-15 minutes
  - Steady state temperature values used to calculate the thermal conductivity of the samples

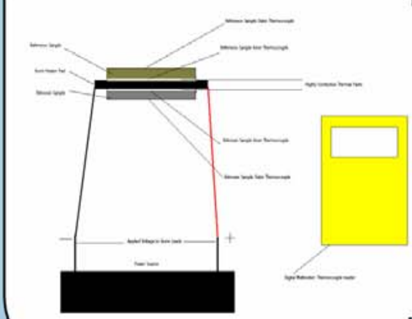
Reference Sample Test Set-Up

- Pure vinyl ester used as reference sample
- Thermal conductivity value of reference sample found by using described set-up with two vinyl ester samples
- Different areas, different thicknesses, same k!
- Can calculate k value because same material used on each side
- Use this value for following experiments

Reference Sample Test Set-Up



General Schematic



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Experimental Composite & Nanocomposite Results

V_f CNT	V_f E-Glass Fibers	Layers E-Glass Fibers	V_f Vinyl Ester	Sample Temperature (K)	k (W/m*K)
0	0.00000	0	1.00000	310.2	0.076
0	0.05400	1	0.94600	312.7	0.114
0	0.16570	3	0.83430	312.8	0.133
0	0.27400	5	0.72600	312.1	0.144

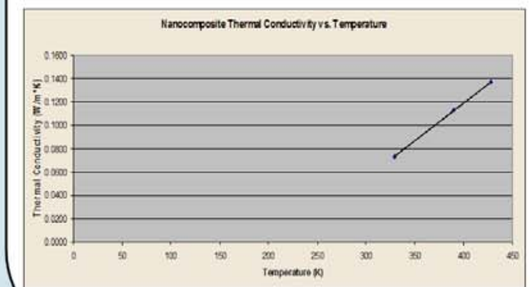
V_f CNT	V_f E-Glass Fibers	Layers E-Glass Fibers	V_f Vinyl Ester	Sample Temperature (K)	k (W/m*K)
0.03125	0.00000	0	0.96875	306.5	0.133
0.03125	0.05400	1	0.91475	307.0	0.167
0.03125	0.16570	3	0.80305	306.8	0.109
0.03125	0.27400	5	0.69475	310.2	0.175

Temperature Dependence Test

- Test for temperature effects on nanocomposites
  - For the same sample, does a different average sample temperature yield a different thermal conductivity?
- Same set-up can be used
- Only change in power source necessary
- Increase voltage supplied to Gorix heater pad, increase in power to sample, increase in sample temperature

Experimental Nanocomposite Results

V_f CNT	V_f E-Glass Fibers	V_f Vinyl Ester	Current (A)	Voltage (V)	Power (W)	k (W/m*K)	Sample Temperature (K)
0.03125	0.16570	0.80305	0.5	2	1	0.0731	329.1
0.03125	0.16570	0.80305	1	4	4	0.1130	389.3
0.03125	0.16570	0.80305	1.5	6	9	0.1369	427.6



Results

- Trends?
- K values increase as volume fraction glass fiber increases
- For equivalent fiber volume fraction
  - Composites with carbon nanotubes have nearly consistently higher thermal conductivities than those without nanotubes
- Increase in temperature yields increase in thermal conductivity
  - Appears to be a linear relationship
  - More data needed
- Statistical outlier?
- Nanocomposite with 3 layers glass fiber has lowest k value of all composites
- Repeated testing gives same result
- Still being investigated

Conclusions & Further Work

- Higher glass fiber volume fraction increases thermal conductivity in composites
- Addition of carbon nanotubes to vinyl ester/glass fiber composites increases thermal conductivity significantly
- As average sample temperature increases, thermal conductivity increases
- More testing of nanocomposites' thermal conductivity dependence on temperature is appropriate
  - Test different samples at varying voltages as before
  - Find relationship between temperature and conductivity

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