Thermal Conductivity of Polymers

Matt Jutkofsky, Jayce Wheelhouse, Omar Taleb, Daniel Hallinan, PhD
FAMU-FSU College of Engineering

FAMU-FSU Engineering

Introduction

• A block copolymer is a group of polymer blocks combined together to create a new material. These group of polymers are composed of different species of monomers that have been synthesized together.
• Through the use of block copolymers society has been able to create and use materials that have properties unparalleled by natural elements. The applications of these polymers range from battery components to road manufacturing.
• One of the most important elements in the battery lifespan is heating. To protect the efficiency of your battery you should prevent your battery from overheating.
• Recently our team has studied thermal conductivity of different species of polymers used as polyelectrolytes in lithium-ion batteries.
• Our goal is to study the effect of combining two different types of polymers with a high and low thermal conductivity.
• The material studied could be used as a way to increase the efficiency of batteries.

Above: Laminar Phase Block copolymer composed of two separate polymers.

Methodology

• A sample of 2mm thickness and 2.5 cm diameter was prepared as required by the manual of the C-Thermal trident console.
• The polymer polystyrene PS or poly(ethylene oxide) PEO are loaded into the custom mold, (2mm thickness and 2.5 cm diameter).
• The polymer was pressed on a hot plate into the mold to create the sample.
• After the sample is cooled, we check to see if the sample has the correct dimensions.
• The reference material chosen is set on the sensor of the C-Therm Trident and tested to calibrate the sensor before the polymer sample measurement. (Make sure this test passes.)
• The sample is put on the sensor (use a contact agent if necessary) with a 500-gram weight on top, the sample is then tested by taking 10 measurements using the software connected to the c-therm.
•Data is collected, and the process is repeated with other samples.

Results

Sample	Contact agent	Thermal conductivity (W/m K)	Effusivity Ws^(1/2) / Km^2
PEO S1	Water	1.1284	1425.5
		1.0840	1387.5
		1.0458	1354.4
		1.0192	1331.1
		0.9792	1295.9
		0.9550	1274.3
		0.9357	1257.1
		0.9156	1239.0
		0.8905	1216.3
		0.8688	1196.5

Table 1: The Thermal Conductivity of Poly(ethylene oxide) is measured using water as a contact agent. The Thermal Conductivity seemed to drop from 1.1284 to 0.8688 as the tests went on due to the water absorbing into the polymer and affecting its conductivity.

Sample	Contact Agent	Thermal conductivity (W/m K)	Effusivity Ws^(1/2) / Km^2
PEO S1	Thermal paste	0.4904	831.78
		0.4878	829.07
		0.4879	829.23
		0.4901	831.50
		0.4882	829.57
		0.4914	832.76
		0.4902	831.54
		0.4893	830.69
		0.4887	830.05
		0.4907	832.08

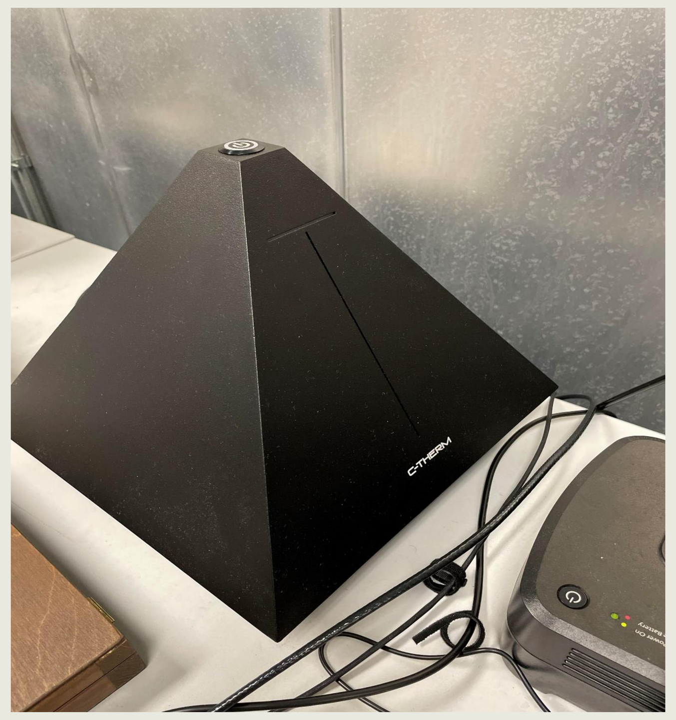
Table 2: Water is replaced with a thermal paste (as contact agent) that came with the C-Therm Trident. The using of the paste kept the thermal conductivity readings consistent

Sample	PS S1 front	PS S1 back	PS S1 Front	PS S1 Back	PS S2 Front	PS S2 Front	PS S2 Back	PS S3 front	PS S3 back	PS S4 Front	PS S4 Back	PS S5 Front	PS S5 Back
Date	28-Oct	4-Nov	9-Nov	9-Nov	4-Nov	9-Nov	9-Nov	4-Nov	30-Nov	30-Nov	30-Nov	30-Nov	30-Nov
Average Conductivity	0.2024	0.1776	0.2195	0.1692	0.1509	0.1432	0.3125	0.2424	0.3086	0.2220	0.3301	0.3009	0.2050
Conductivity RSD	1.03%	0.74%	0.55%	0.46%	1.04%	0.65%	0.38%	0.50%	0.69%	0.52%	0.27%	0.56%	0.44%
Average Effusivity	525.99	498.35	544.83	488.93	468.42	459.75	645.93	570.03	641.80	547.62	664.81	633.53	528.78
Effusivity RSD	0.44%	0.30%	0.24%	0.18%	0.38%	0.23%	0.20%	0.23%	0.36%	0.23%	0.14%	0.29%	0.19%
Test RH	50%	54.10%	30.80%	30.80%	54.10%	30.80%	30.80%	54.10%	13.10%	13.10%	13.10%	13.10%	13.10%
Test Temp	69	68	66	66	68	66	66	68	67.3	67.3	67.3	67.3	67.3

Table 3: Above are the results of the polystyrene samples that were tested.
The front and backs on the polymer samples had significant differences in their thermal conductivities. This is due to the change of the surface flatness and smoothness, as well as cooling rate.
When testing the same sample on two different occasions, as in samples 1 and 2, we notice that the conductivity changes as the humidity and temperature of the room changes. For this reason, we installed a climate control chamber to regulate these variables.

Above: Hot press used to make samples

Above: C-Therm trident sensor used to measure samples thermal conductivity



Above: C-Therm Trident

Conclusion

• Many different factors contribute to the thermal conductivities of poly(ethylene oxide) and polystyrene.
• Using water as a contact agent led to a significantly changes the thermal conductivity of the Poly(ethylene oxide) sample, where a gradual decrease in thermal conductivity was seen over multiple readings. This is due to the polymer being hydrophilic and absorbing the water. The thermal conductivity we recorded is between .48-.5 W/mK. This is close to literature that repots amorphous PEO thermal conductivity as .37 W/mK.
• The data we have collected from the polystyrene samples shows us that the Humidity and temperature of the environment can affect the thermal conductivity. In order to overcome this problem in future tests we have installed an environmental chamber that regulates the humidity and temperature.
• Another major factor that affects our sample conductivity has been the cooling rate of the polymer. This is due to the thermal memory of poly(ethylene oxide) and the way it crystalizes while cooling. To address this problem, the samples need to be cooled at the same rate.
• Thermal conductivity of the PS is between 0.2-0.35. W/m K

Future Work

- As a future study we can combine these two polymers to see how it affects the thermal conductivity
- Using the PEO and PS samples we can prepare a new type of sample where we cut 25 micrometer thick sheet of each polymer and combined them.
- We combined the samples by stacking the sheets of polymers into mold alternatively and pressing them to create a lamellar structure.

Acknowledgements

Special Thanks to
- FAMU-FSU Polymers for Advanced Energy Sustainability
- FAMU FSU Machine shop

References

- 50th Anniversary Perspective: Block Polymers—Pure Potential, Christopher M. Bates and Frank S. Bates, Macromolecules 2017 50 (1), 3-22, DOI: 10.1021/acs.macromol.6b02355