Temperature-Dependent Conductivity of Highly Insulating Polymers

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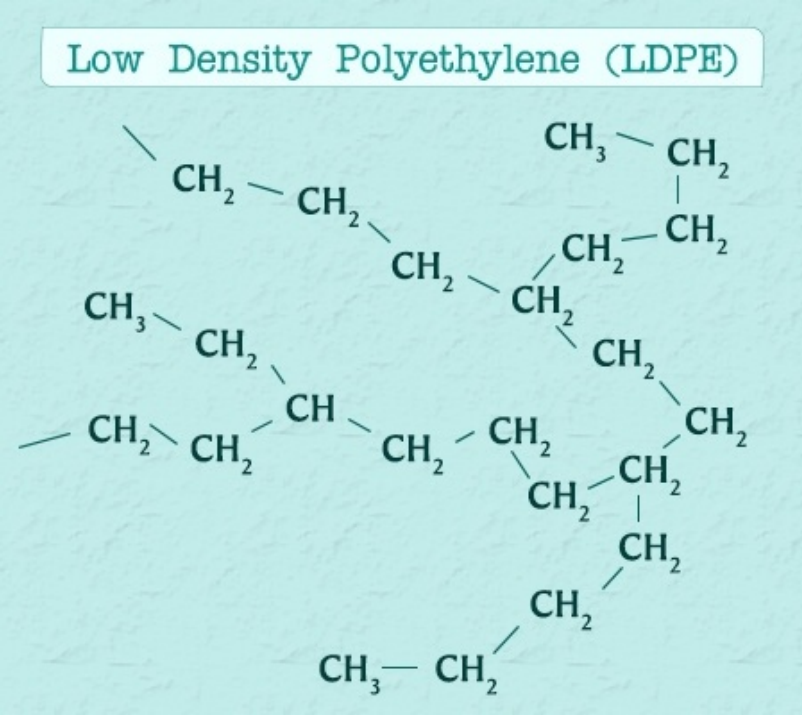
Highly Disordered Insulating Materials (HDIM)



HDIM materials:

- Are very electrically insulating
- Are not organized in a crystal structure (highly disordered polymers)

Thin film highly disordered insulating materials

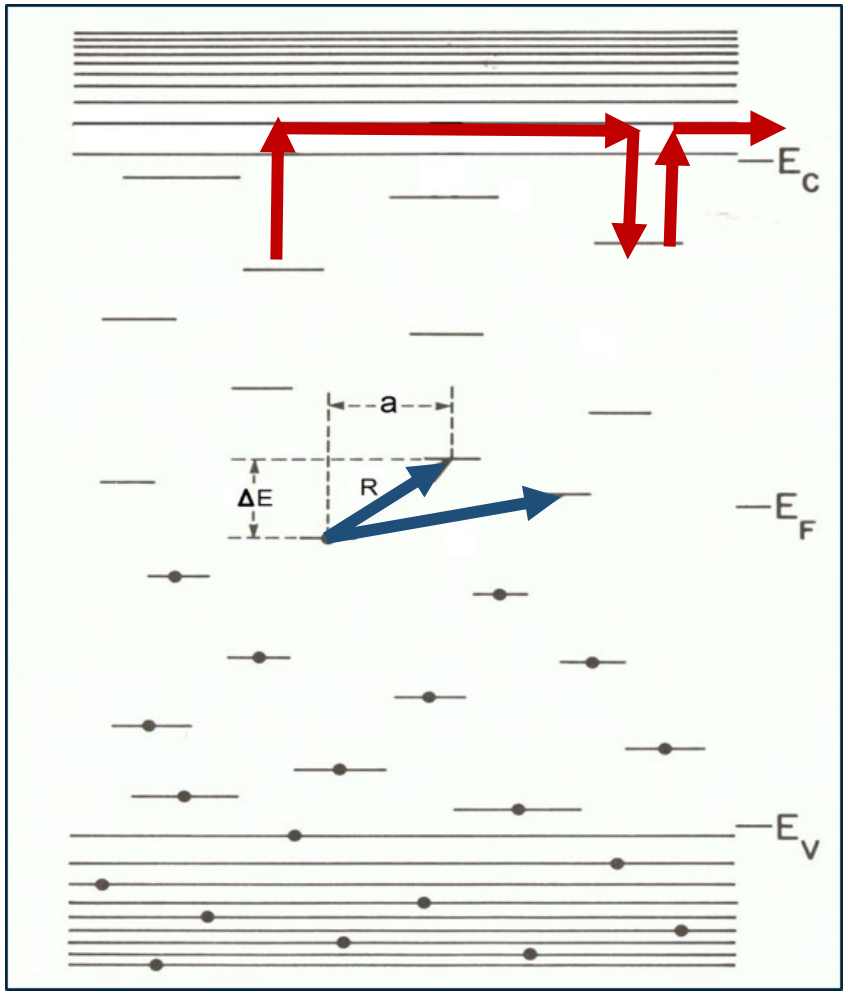
- (LDPE) Low Density Polyethylene
- (PEEK) Polyetheretherketone

Conductivity of LDPE $\approx 10^{-18}(\text{ohm} \cdot \text{cm})^{-1}$
Conductivity of Al $\approx 10^{7}(\text{ohm} \cdot \text{cm})^{-1}$

Conductivity Mechanisms in HDIM

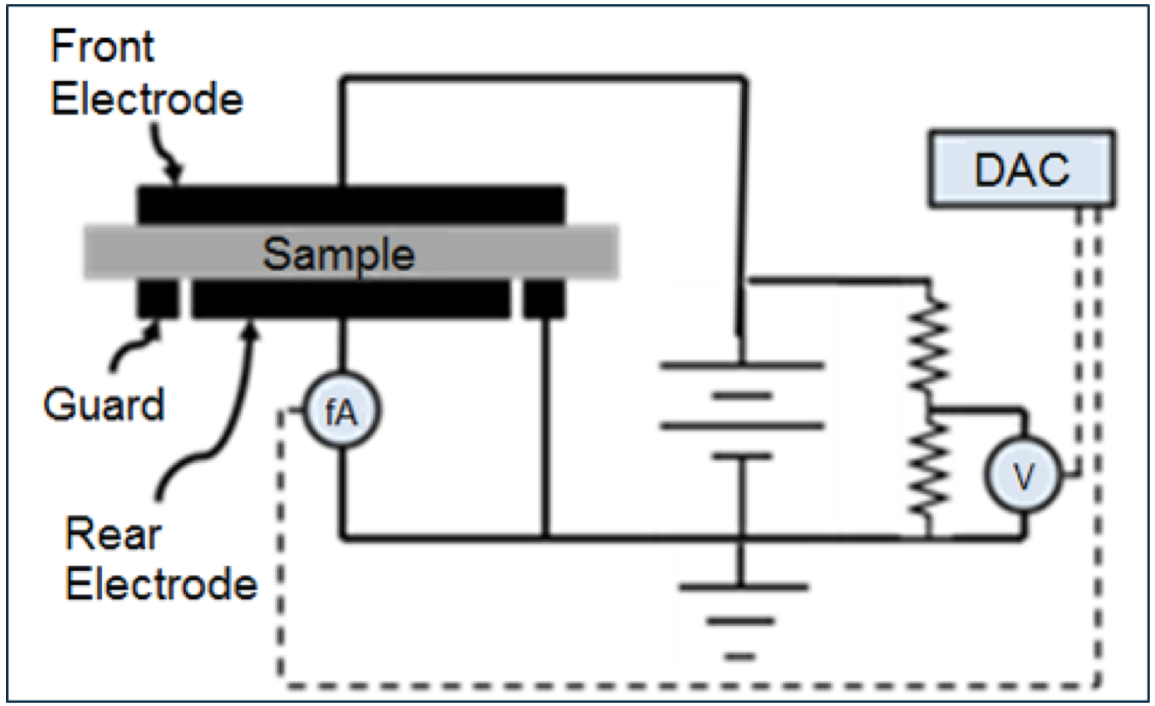
Conductivity Mechanisms

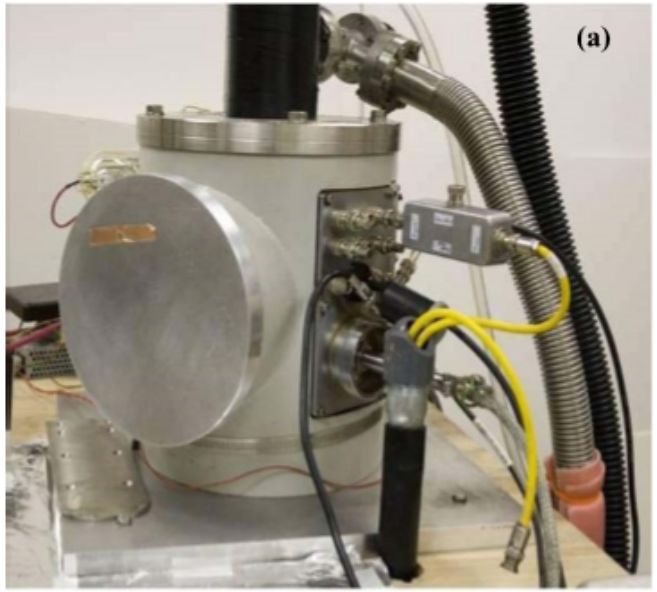
- Thermally Assisted Hopping
- Variable Range Hopping (Tunneling)



- Electrons travel through HDIM by hopping from one defect site to the next.
- By increasing the heat the energy needed to jump from one defect to the next is more likely to be met.
- This leads to an increase in conductivity

Constant Voltage Conductivity Chamber





Ohm's Law

$$V = I(\rho \frac{L}{A})$$

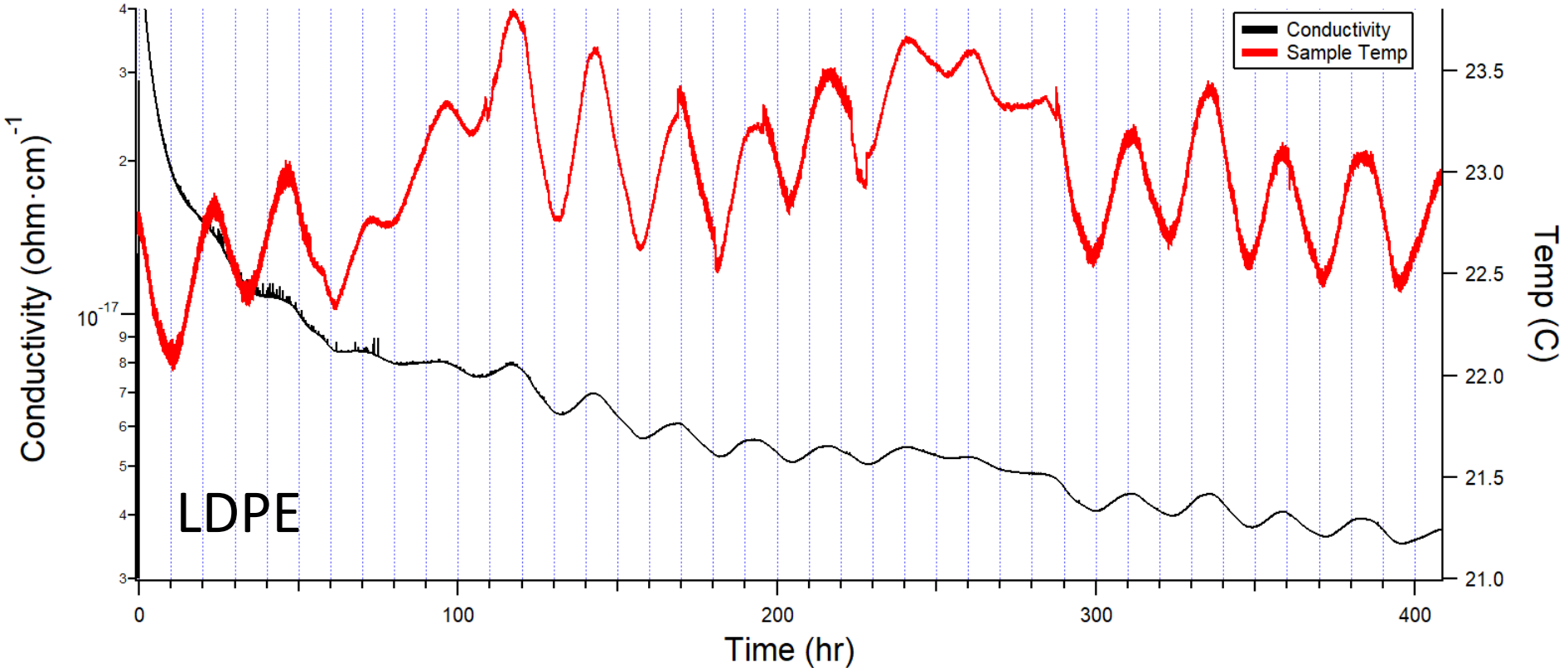
Resistance

$$\rho(t) = \frac{V(t) * A}{I(t) * L}$$

Voltage, Sample Area, Current, Sample Thickness

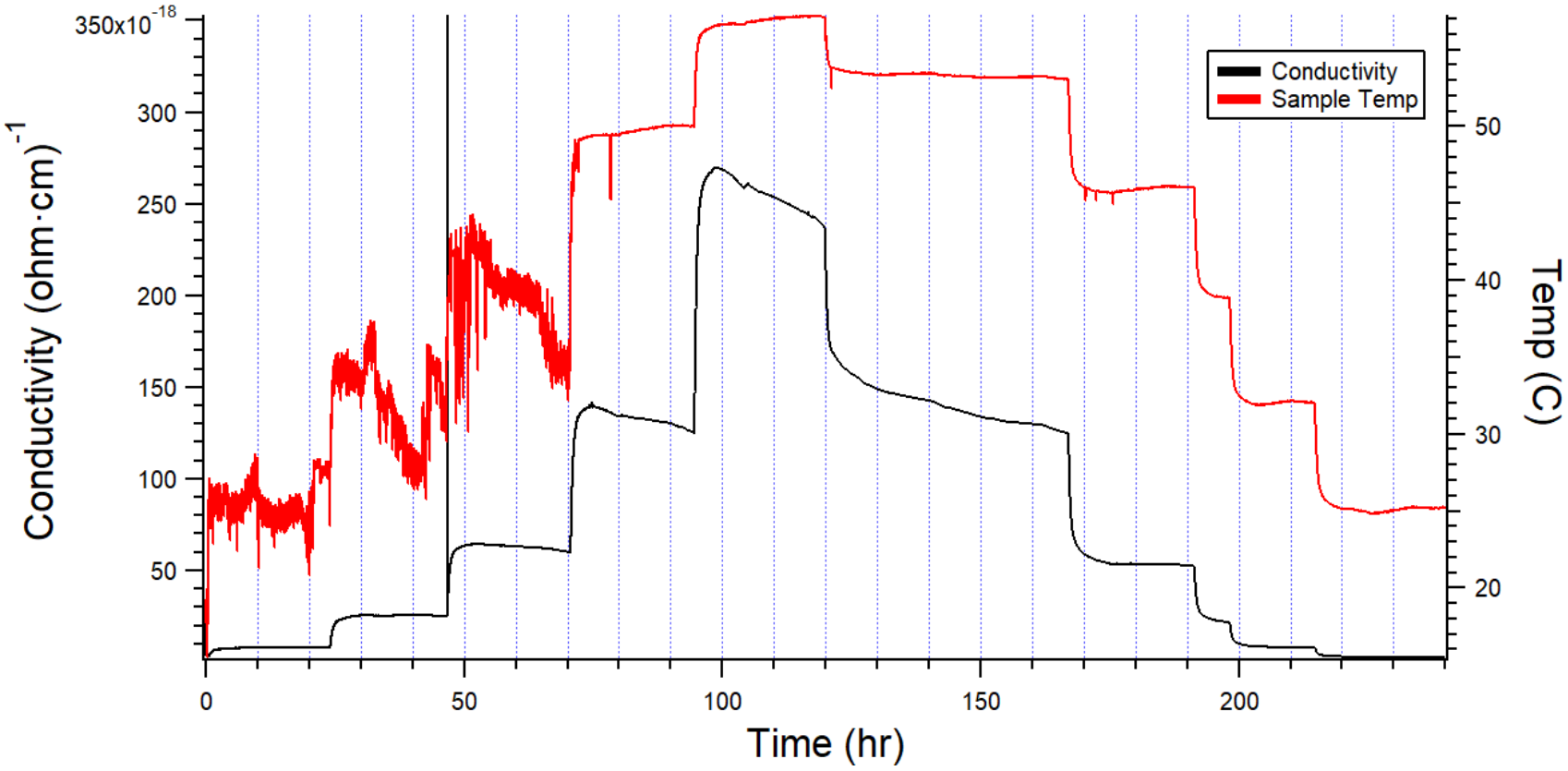
$$\sigma = \frac{1}{\rho}$$

Conductivity Changes due to Variations in Daily Temperature



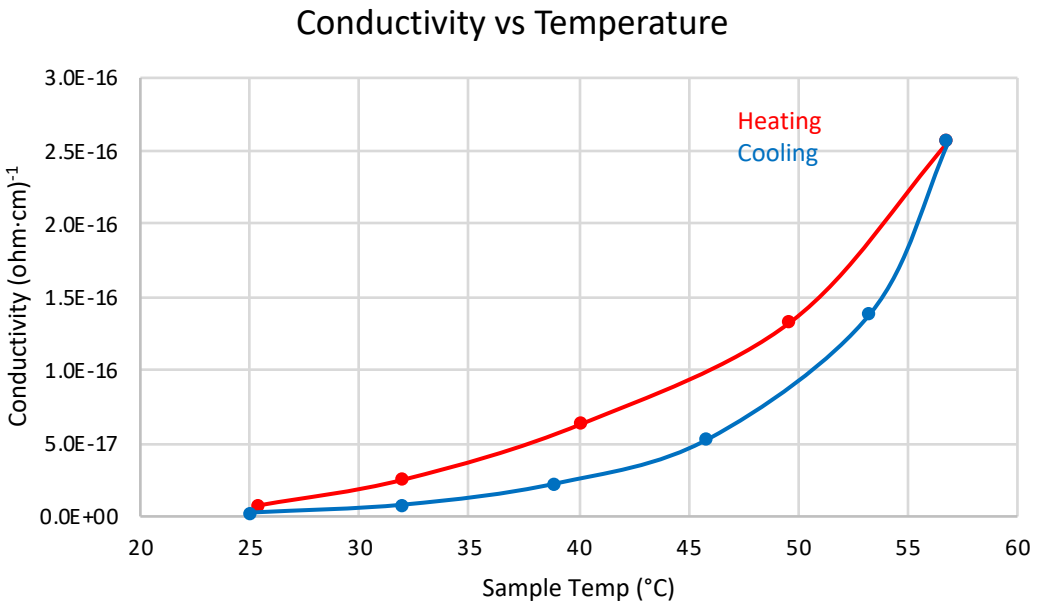
- Initial runtime awaiting for sample to reach its electrical equilibrium
- Conductivity sensitive to small changes in temperature

Results for LDPE



- Temperature was increased in increments of ≈10 degrees C from room temperature to ≈60 degrees and then returning to room temperature.
- During each step the temperature was allowed to level out with most steps lasting ≈24 hours.

Results for LDPE



Hysteresis graph of conductivity vs temperature

Temperature Coefficient

$$\sigma_T \equiv \frac{d\sigma}{dT} = \frac{\sigma_2 - \sigma_1}{T_2 - T_1}$$

- Coefficient values increase as temperature increases

Temp Coefficient $\frac{(ohm \cdot cm)^{-1}}{K}$
$2.7 \pm 0.3x10^{-18}$
$4.7 \pm 0.5x10^{-18}$
$7.3 \pm 0.4x10^{-18}$
$1.72 \pm 0.06x10^{-17}$
$3.3 \pm 0.2x10^{-17}$
$1.17 \pm 0.06x10^{-17}$
$4.40 \pm 0.09x10^{-18}$
$2.09 \pm 0.05x10^{-18}$
$7.8 \pm 0.2x10^{-19}$

Conclusions and Future Work

- Conductivity values were found in temperature steps from room temp to 57 °C
- Conductivity had not reached equilibrium, therefor it decreased at higher temperatures
- Temperature coefficient at room temperature was consistent with both methods
- Coefficient increases with the sample temperature as expected for exponential model
- Increased range of temperature will further test model
- There may be a sign of structural change around ≈270 K