Thermal Insulation

Why is plastic a good insulator?

Plastics are poor heat conductors, because they have virtually no free electrons available for conduction mechanisms like metals.

The **thermal insulating capacity of plastics** is rated by measuring the thermal conductivity. Thermal conduction is the transfer of heat from one part of a body to another with which it is in contact.

- For amorphous plastics at 0-200°C, the thermal conductivity lies between 0.125-0.2 $Wm^{-1}K^{-1}$
- Partially crystalline thermoplastics have ordered crystalline regions and hence better conductivity

Thermal insulation of a polymer (*thermoplastics, foam or thermoset*) is essential to:

1. Understand processing of the material into final product
2. Establish appropriate applications of the material e.g. **polymeric foams for insulation**

For example, PUR and PIR can be molded as a board material and used as insulation foams in roofs, plastered walls, sandwich walls and floors.

View All Commercially Available Polymer Grades with Excellent Thermal Insulation

Check out more on Thermal Insulation:

» Thermal Insulation Values of Several Plastics
» How to Measure Thermal Conductivity of Plastics?
» How do Materials Conduct - Mechanism
» Factors Influencing Thermal Insulation

How to Measure Thermal Conductivity of Polymers

There are several ways to measure thermal conductivity. **Thermal conductivity of plastics** is generally measured by ASTM C177 and ISO 8302, using guarded hot-plate apparatus.

The guarded hot plate apparatus is generally recognized as the primary absolute method for measurement of the thermal transmission properties of homogeneous insulation materials in the form of flat slabs.

Guarded hot plate - A solid sample of material is placed between two plates. One plate is heated and the other is cooled or heated to lesser extent. Temperature of the plates is monitored until they are constant. The steady state temperatures, the thickness of the sample and the heat input to the hot plate are used to calculate thermal conductivity.

Hence thermal conductivity, k, is calculated using the formula:

$$k = \frac{Q \times d}{A\,(T_2 - T_1)}$$

where

- Q is quantity of heat passing through a base area of the sample [W]
- A base area of the sample [m^2]
- d distance between two sides of the sample [m]
- T_2 temperature on warmer side of the sample [K]
- T_1 temperature on the colder side of the sample [K]

Mechanism of Thermal Conduction

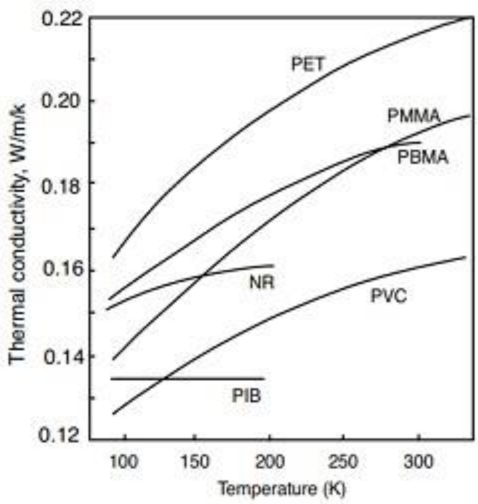
Thermal conduction in polymers is based on the molecule movement across intra- and intermolecular bonds. Structural changes e.g. crosslinking in **thermosets** & **elastomers** increases thermal conductivity because van der waals bonds are progressively replaced by valence bonds with greater thermal conductivity.

Alternatively, decreasing interbond path length or factors causing increased disorder or free volume in polymers results in decrease in thermal conductivity hence increasing thermal insulation.

Also mentioned above, the **presence of crystallinity in polymers** results in improved packing of molecule and hence increased thermal conductivity.

- Amorphous polymers show an increase in thermal conductivity with increasing temperature, up to the **glass transition temperature, Tg**. Above Tg, the thermal conductivity decreases with increasing temperature

- Due to the increase in density upon solidification of **semi-crystalline thermoplastics**, the thermal conductivity is higher in the solid state than in the melt. In the melt state, however, the thermal conductivity of semi-crystalline polymers reduces to that of amorphous polymers



Thermal Conductivity of Various Polymers
(Source: Polymer Processing by Tim A. Osswald, Juan Pablo Hernández-Ortiz)

Factors Influencing Thermal Insulation

1. The organic plastics are very good insulators. *Thermal conductivity of polymers* increases with increasing volumetric filler content (or fiber content up to 20% by volume fraction).

a. The higher thermal conductivity of inorganic fillers increases the thermal conductivity of **filled polymers**.

b. Polymeric foams exhibit marked decrease in heat conduction due to incorporation of gaseous fillers in the structure. Increasing number of closed cells in the foam minimizes the heat conduction by convection further improving the insulating character

2. The thermal conductivity of melts increases with hydrostatic pressure.

3. Compression of plastics further impose opposite effect on thermal insulation as it increases the packing density of molecules

4. The other factors affected the thermal conductivity are the **density of material**, moisture of material and ambient temperature. With increasing density, moisture and temperature the thermal conductivity increases too.

Thermal Insulation Values of Several Plastics

Polymer Name	Min Value (W/m.K)	Max Value (W/m.K)
ABS - Acrylonitrile Butadiene Styrene	0.130	0.190
ABS Flame Retardant	0.173	0.175
ABS High Heat	0.200	0.400
ABS High Impact	0.200	0.400
ABS/PC Blend 20% Glass Fiber	0.140	0.150
ASA - Acrylonitrile Styrene Acrylate	0.170	0.170
ASA/PC Blend - Acrylonitrile Styrene Acrylate/Polycarbonate Blend	0.170	0.170
ASA/PC Flame Retardant	0.170	0.700
CA - Cellulose Acetate	0.250	0.250
CAB - Cellulose Acetate Butyrate	0.250	0.250
CP - Cellulose Proprionate	0.190	0.190
CPVC - Chlorinated Polyvinyl Chloride	0.160	0.160
ECTFE	0.150	0.150
EVOH - Ethylene Vinyl Alcohol	0.340	0.360
FEP - Fluorinated Ethylene Propylene	0.250	0.250
HDPE - High Density Polyethylene	0.450	0.500

HIPS - High Impact Polystyrene	0.110	0.140
HIPS Flame Retardant V0	0.120	0.120
Ionomer (Ethylene-Methyl Acrylate Copolymer)	0.230	0.250
LCP Glass Fiber-reinforced	0.270	0.320
LDPE - Low Density Polyethylene	0.320	0.350
LLDPE - Linear Low Density Polyethylene	0.350	0.450
MABS (Transparent Acrylonitrile Butadiene Styrene)	0.170	0.180
PA 11 - (Polyamide 11) 30% Glass fiber reinforced	0.330	0.330
PA 11, Conductive	0.330	0.330
PA 11, Flexible	0.330	0.330
PA 11, Rigid	0.330	0.330
PA 12, Flexible	0.330	0.330
PA 12, Rigid	0.330	0.330
PA 46	0.300	0.300
PA 6 - Polyamide 6	0.240	0.240
PA 6-10 - Polyamide 6-10	0.210	0.210
PA 66 - Polyamide 6-6	0.250	0.250
PA 66, 30% Glass Fiber	0.280	0.280
PA 66, 30% Mineral filled	0.380	0.380
PA 66, Impact Modified, 15-30% Glass Fiber	0.300	0.300
PA 66, Impact Modified	0.240	0.450
PAI - Polyamide-Imide	0.240	0.540
PAI, 30% Glass Fiber	0.360	0.360

PAI, Low Friction	0.520	0.520
PAR - Polyarylate	0.180	0.210
PARA (Polyarylamide), 30-60% glass fiber	0.300	0.400
PBT - Polybutylene Terephthalate	0.210	0.210
PBT, 30% Glass Fiber	0.240	0.240
PC (Polycarbonate) 20-40% Glass Fiber	0.220	0.220
PC (Polycarbonate) 20-40% Glass Fiber Flame Retardant	0.210	0.390
PC - Polycarbonate, high heat	0.210	0.210
PE - Polyethylene 30% Glass Fiber	0.300	0.390
PEEK - Polyetheretherketone	0.250	0.250
PEEK 30% Carbon Fiber-reinforced	0.900	0.950
PEEK 30% Glass Fiber-reinforced	0.430	0.430
PEI - Polyetherimide	0.220	0.250
PEI, 30% Glass Fiber-reinforced	0.230	0.260
PEKK (Polyetherketoneketone), Low Cristallinity Grade	1.750	1.750
PESU - Polyethersulfone	0.170	0.190
PET - Polyethylene Terephthalate	0.290	0.290
PET, 30% Glass Fiber-reinforced	0.330	0.330
PETG - Polyethylene Terephthalate Glycol	0.190	0.190
PFA - Perfluoroalkoxy	0.190	0.260
PI - Polyimide	0.100	0.350
PLA - Polylactide	0.110	0.195
PMMA - Polymethylmethacrylate/Acrylic	0.150	0.250

PMMA (Acrylic), High Heat	0.120	0.210
PMMA (Acrylic) Impact Modified	0.200	0.220
POM - Polyoxymethylene (Acetal)	0.310	0.370
POM (Acetal) Low Friction	0.310	0.310
PP - Polypropylene 10-20% Glass Fiber	0.200	0.300
PP, 10-40% Mineral Filled	0.300	0.400
PP, 10-40% Talc Filled	0.300	0.400
PP, 30-40% Glass Fiber-reinforced	0.300	0.300
PP (Polypropylene) Copolymer	0.150	0.210
PP (Polypropylene) Homopolymer	0.150	0.210
PP, Impact Modified	0.150	0.210
PPE - Polyphenylene Ether	0.160	0.220
PPE, 30% Glass Fiber-reinforced	0.280	0.280
PPE, Flame Retardant	0.160	0.220
PPS - Polyphenylene Sulfide	0.290	0.320
PPS, 20-30% Glass Fiber-reinforced	0.300	0.300
PPS, 40% Glass Fiber-reinforced	0.300	0.300
PPS, Conductive	0.300	0.400
PPS, Glass fiber & Mineral-filled	0.600	0.600
PS (Polystyrene) 30% glass fiber	0.190	0.190
PS (Polystyrene) Crystal	0.160	0.160
PS, High Heat	0.160	0.160
PSU - Polysulfone	0.120	0.260
PSU, 30% Glass fiber-reinforced	0.300	0.300
PTFE - Polytetrafluoroethylene	0.240	0.240

PTFE, 25% Glass Fiber-reinforced	0.170	0.450
PVC, Plasticized	0.160	0.160
PVC, Plasticized Filled	0.160	0.160
PVC Rigid	0.160	0.160
PVDC - Polyvinylidene Chloride	0.160	0.200
PVDF - Polyvinylidene Fluoride	0.180	0.180
SAN - Styrene Acrylonitrile	0.150	0.150
SAN, 20% Glass Fiber-reinforced	0.200	0.320
SMA - Styrene Maleic Anhydride	0.170	0.170