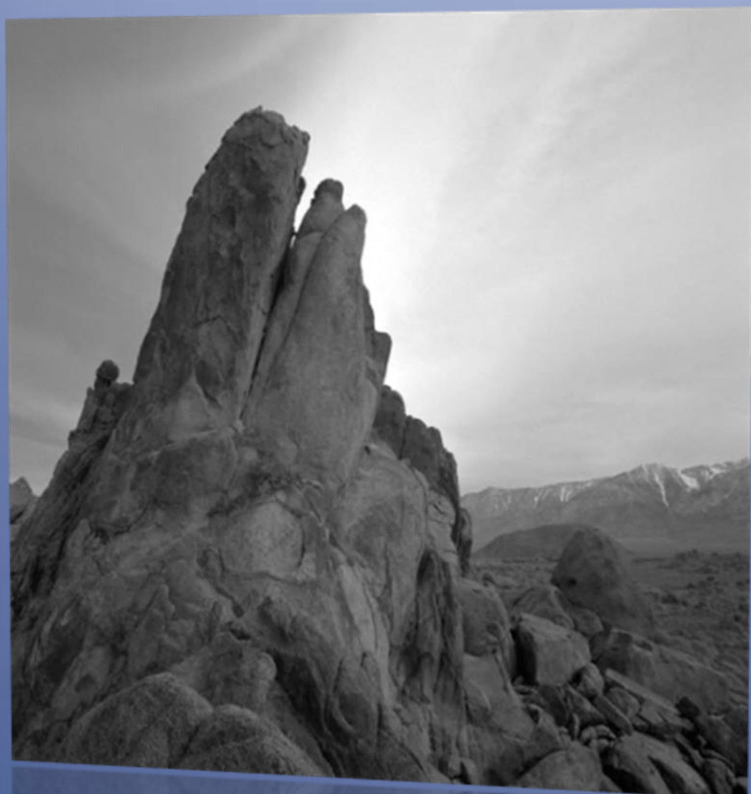


Thermal Conductivity Measurement by Hot Disk Analyzer

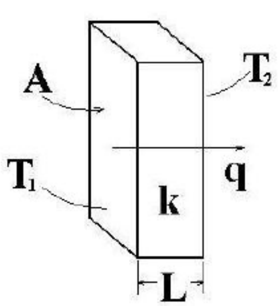
Abdullah Al Ashraf

Measurement of Thermal Conductivity and Diffusivity of Different Materials by the Transient Plane Source Method Using Hot Disk Thermal Constants Analyzer.

1. Introduction:

The transient plane source (TPS) thermal characterization technique is becoming an important tool for the determination of the thermal properties of a variety of materials due to its robust design, rapid characterization time and for its ability to simultaneously measure the thermal conductivity and thermal diffusivity of complex materials, such as Nano composites [1].

The TPS method is based on the procedure of a transiently heated plane sensor, and is in its most common adaptation referred to as the Hot Disk Thermal Constants Analyzer. The Hot Disk sensor comprises of an electrically conducting pattern in the shape of a double spiral, which has been etched out of a thin metal (Nickel) foil. This spiral is sandwiched between two thin sheets of an insulating material (Kapton, Mica, etc.). When performing a measurement, a plane Hot Disk sensor is fitted between two pieces of the sample – each one with a plane surface facing the sensor. By running an electrical current, strong enough to increase the temperature of the sensor between a fraction of a degree up to several degrees, and at the same time recording the resistance (temperature) increase as a function of time, the Hot Disk sensor is used both as a heat source and as a dynamic temperature sensor [2-4]. By using TPS method we measure the thermal conductivity which is defines as the property of a material to conduct heat. More precisely, it is the amount of heat per unit time and unit area that can be conducted through a plate of unit thickness.[2]



$$q = k A \frac{T_1 - T_2}{L}$$

Where,

q = the rate of conduction heat transfer

k = thermal conductivity of the material

A = area perpendicular to heat flow

ΔT = the temperature and

L = the distance through which conduction heat transfer is taking place

2. Experimental:

Hot Disk TPS 2500 S model was used for the experiment. Specifications of the device is as follows[5]:

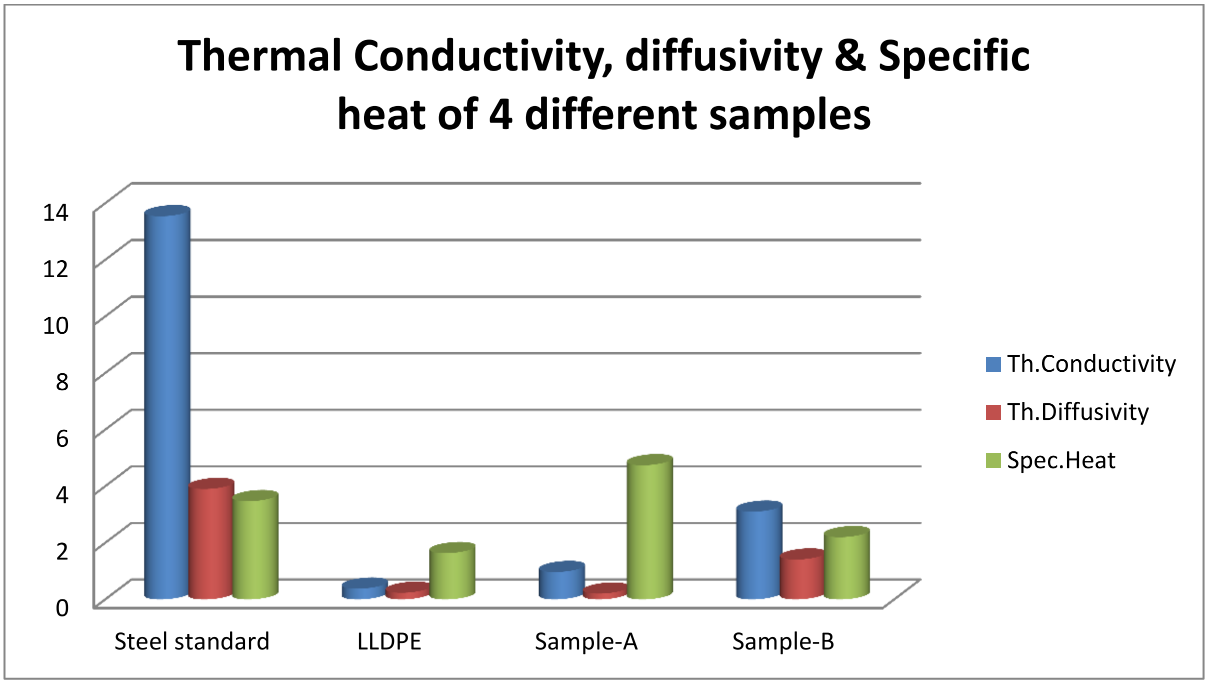
Thermal Conductivity	0.005 to 1800 W/m/K.
Thermal Diffusivity	0.1 to 1200 mm^2/s.
Specific Heat Capacity	Up to 5 MJ/m^3K.
Measurement Time	1 to 1280 seconds.
Reproducibility	Typically better than 1 %.
Accuracy	Better than 5 %.
Temperature Range	-253 °C to 1000 °C.
With Furnace	Ambient to 750 °C [1000 °C oxygen free].
With Circulator	-35 °C to 200 °C.
Smallest Sample Dimensions	0.5 mm × 2 mm diameter or square for bulk testing. 0.1 mm × 10 mm diameter or square for slab testing. 10 mm × 5 mm diameter or square for one-dimensional testing.
Sensor Types Available	All Kapton sensors. All Mica sensors. All Teflon sensors.

It is important to mention that, input criteria like measurement time, output power etc. differs from sample to sample. For conducting samples, high output power and short measurement time is applied whereas for insulating samples, low output power and long measurement time is applied. For unknown materials we need to start from low output power and short measurement time in order to get a precise result. Accordingly, to measure 4 different samples we changed the values of output power and measurement time as follows.

Sample ID	Temperature (ºC)	Output power.	Meas.time(Sec.)	Radius	TCR	Disk Type
Steel standard	22.6	1	10	6.403	0.004682	Kapton
LLDPE	22.6	0.05	40	2.001	0.004682	Kapton
Sample-A	22.9	0.10	20	2.001	0.004680	Kapton
Sample -B	22.6	0.30	5	2.001	0.004682	Kapton

3. Results & Discussion:

Sample ID	Th.Conductivity (W/(m. K)).	Th.Diffusivity (m^2/s)	Spec.Heat (J/(kg·K))
Steel standard	13.53988355	3.90131075	3.470598579
LLDPE	0.379188712	0.231995114	1.634468523
Sample-A	0.965682173	0.203704327	4.74060708
Sample-B	3.099836426	1.40954279	2.199178661



Graph 1: Thermal Conductivity, diffusivity & Specific heat of 4 different samples

Thermal conductivity is the amount of heat per unit time and unit area that can be conducted through a plate of unit thickness.

Thermal diffusivity is the thermal conductivity divided by the volumetric heat capacity.

Specific heat is the heat required to raise the temperature of the unit mass of a given substance by a given amount (usually one degree).

From the definitions, it is very clear that the sample of steel(metal) which has very high thermal conductivity because of its free electrons which transfer the heat very quickly. Whereas, the thermal conductivity of LLDPE is very low because of having strong C-H bond and no free electrons but the heat transfer happens by vibrations of the bond. Sample -A and sample-B which are the LLDPE with 5 and 15 wt% of graphite composite shows higher conductivity than LLDPE because of the addition of graphite which is very conductive hence made the samples conductive. Volumetric heat capacity of steel sample is very high which result its lower thermal diffusivity of the sample because thermal diffusivity is defined as the thermal conductivity divided by the volumetric heat capacity. For LLDPE and sample-A there is not much difference in thermal diffusivity but for sample-B it is more than 6 times higher. The specific heat of LLDPE and sample-B is differs by only 0.56; whereas the specific heat of Sample-A is even higher than the steel standard sample which is unexpected. The reason of that could be the sample adjustment or the higher measurement time than steel standard and Sample-B. As the thermal conductivity and diffusivity of Sample-B is much higher than sample-A, so we can conclude that the Sample-A is LLDPE + 5% graphite and sample-B is LLDPE + 15% graphite.[3]

4. Conclusion:

The advantages of using a TPS instruments involves non-destructive method, contact resistance between sensor and sample does not influence measurement results, porous and transparent samples are easy to test, without modification; surface roughness or surface color does not influence measurement results. To get very good result the fixation of the sample during test and choosing suitable sensor, output power, measurement time is very important.

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