The Leader in transient techniques

Analysing density variations of extruded Polystyrene samples with the Hot Disk® Thermal Constants Analyser.

Measure thermal transport variations in different volumes of the sample with the TPS – technique.

One of the unique possibilities with the Hot Disk Thermal Constants Analyser is to measure a sample with *different sensor sizes*. Since the probing depth, Δ_p, always is less than the diameter of the sensor, it is possible to estimate the probed volume for the measurement. This makes measuring the "overall" thermal conductivity with a large sensor in comparison to the sample size and compare that result with several measurements carried out with a small sensor (giving a smaller probed volume) and compare these results, straight forward.

It is thus possible *to capture density variations, monitor the variations of impurity concentration, cracks etc. with the TPS- technique* since these variations inevitably will alter the thermal transport properties of the sample.

Sensors are available with radii ranging from 0.5mm to 30mm giving probing depths from as small as *0.5mm up to 60mm*.

Introduction

In this application note an extruded PS sample certified by NIST has been tested with the Hot Disk Thermal Constants Analyser in order to compare the results with the results obtained with the methods used at other laboratories. By marking each side of each sample with "1" for low side and "2" for upper side, it was possible to test four permutations of the sample set-up and thus it could be possible to analyse possible differences between the upper side and the lower side of the samples as they were manufactured. Since the sample is formed by extrusion, it is assumed that the PS will have a higher density on the bottom side of the sample than the upper side and therefore different thermal properties.

Measurements and results

For this measurement a sensor with radius 6.403 mm was chosen. The measurement time was 40s and the power out-put by the sensor was 20 mW giving a rough temperature increase of 1.6 K and a total to characteristic time of 0.33. The probing depth, Δ_p, was 7.5 mm into a sample of thickness 13.4mm, see fig. 1. The standard module was used for these measurements.

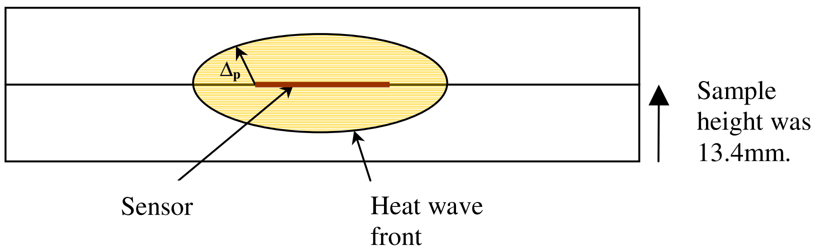

Fig. 1. *The sample set-up. The probing depth was roughly half of the sample thickness, i.e. information on thermal conductivity was collected only from the desired half (upper or lower) of the sample.*

The samples were prepared from a large (100x100cm) board of PS (certificate number 1453). Out of this board two 10x10cm pieces were cut and the density of the samples was measured to be 43.8 kg/m^3 and 40.4 kg/m^3. The thermal resistance [m^{2}W/K] was given by NIST (density wise) and by taking the sample thickness divided by the given thermal resistance values it was found that the certified value of the thermal conductivity, λ, was in the range of 0.0328-0.0338 W/mK for the two samples tested with the Hot Disk Thermal Constants Analyser.

5 measurements were carried out on each permutation 1-1, 1-2, 2-1 and 2-2.

About the Hot Disk instrument
The Hot Disk Thermal Constants Analyser is a system designed to conveniently measure the thermal transport properties of a sample: thermal conductivity, thermal diffusivity and specific heat. The system is based on a patented Transient Plane Source (TPS) technique, which can be used to study materials with thermal conductivities from 0.005 to 500 W/mK and covering a temperature range from 30 to 1000K.

The following modes of operation are available with the Hot Disk instrument

1) Basic method: The sensor is sandwiched between 2 sample. This method also features a single sided option.
2) Thin Film method: A special extremely sensitive sensor is sandwiched between 2 pieces of the film (10-500µm).
3) Slab method: For very conducting materials (> 10W/mK like SiC, Cu etc.).
4) Anisotropic method: This method measures the anisotropic thermal conductivity and diffusivity of a uni-axial sample.
5) Cp-determination: Determines Cp of solid samples.

For more information, please visit **www.hotdisk.se** or contact Hot Disk AB in Sweden.

The results from the measurements were as follows, table 1 and fig. 2.

Table 1. *Thermal conductivity values and standard deviations calculated from 5 individual measurements.*

Number	Combination	λ [W/mK]	Std - λ [W/mK]
1	1-2	0.03394	0.00004
2	2-1	0.03379	0.00001
3	2-2	0.03451	0.00003
4	1-1	0.03346	0.00008

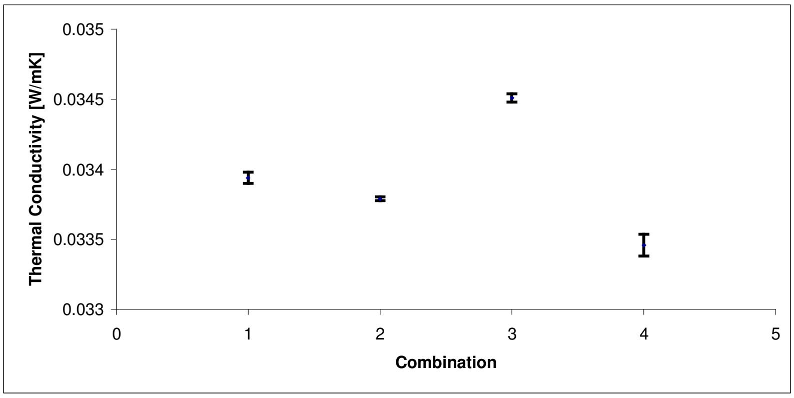

Fig. 2. *The thermal conducivity results plotted together with the standard deviations of the measurements. There is a clear difference between the combinations.*

Conclusion

From fig. 2 it is clearly seen that the combinations 4 (low) and 3 (high) are the extremes. The difference in thermal conductivity is 3.1% between the thermal conductivities and the 1 and 2 combinations lie in between the two extremes. All values are in the vicinity of the certified values given from NIST.

It is thus concluded that by varying the sensor size, consequently also the probing depth, the Hot Disk Thermal Constants Analyser can be used in a unique way to probe selected volumes of a sample. This way it is possible to map up the local influence of density variation, a property that is not possible to measure with GHP , since it measures the average of a full 4x1 m^2 plate.

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