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Application Sheet TA-003E

Measurement example of a single-layer graphite sheet with Thermowave Analyzer

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1. Introduction

Since heat generation shortens product life and increases power consumption, electronic components need to release heat efficiently. CPUs and communication ICs are driven at high clock speeds, so heat tends to concentrate in a small area. In such areas, it is effective to use a material with high thermal conductivity in the plane direction, such as graphite sheet, to diffuse the heat.

Graphite sheets are also effective as heat-conductive materials due to their extremely high thermal conductivity in the in-plane direction. On the other hand, there are few devices that can accurately measure thermal diffusivity/thermal conductivity in the in-plane direction in a non-contact manner. The thermowave analyzer is one of the few devices that can perform such measurements.

Please refer to "Application Sheet TA-001E Multifunctional Thermal Diffusivity Thermal Conductivity Measuring Equipment: Thermowave Analyzer Measuring Principle and Equipment"

2.Measurement sample

There are artificially synthesized and natural graphite sheets, but this time we will measure the artificially synthesized one. In general, an artificially synthesized graphite sheet has a higher thermal diffusivity, and some have a thermal diffusivity five times or more that of silver. Natural graphite is made from [1] acid-treated natural graphite, carefully selected, subjected to high-temperature expansion treatment, and then compressed. In addition, artificial ones are manufactured by heating and baking polymer films such as polyimide at elevated temperature in a high-temperature inert gas [2, 3]. Graphite sheets include single-layered ones and laminated ones to conduct more heat, but this time we measured single-layered ones.

The thicknesses of the samples were measured at 25 μm and 40 μm. The external dimensions of the samples were 50 mm x 50 mm squares. This system can measure any shape and dimension if it is 10 mm or larger in diameter.

*For highly accurate evaluation of the measured values, it is desirable to use the same sample size.

3. Measurement results

3.1 Relationship between distance and phase

When the position of the detection point is moved around the heating point, the difference from the phase of the heating point increases. Near the heating point, the linear relationship between distance and phase is not satisfied because of the effects of thermal diffusivity and thickness of the sample in the out of plane direction. Away from the heating point, the linear relationship is obtained and the influence of thermal diffusivity and thickness in the out of plane direction can be ignored. On the other hand, if the heating point and detection point are further apart, the signal attenuates, and the measurement error increases. In this measurement, the distance between the heating point and the detection point was analyzed in the range of 2 mm to 4 mm.

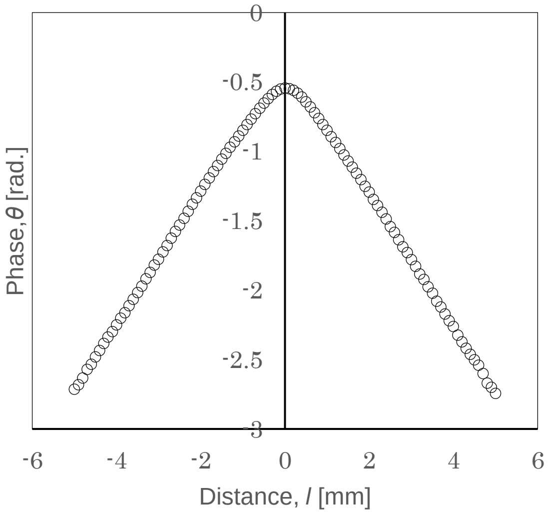

Figure 1: Measurements of the relationship between distance and phase of an artificial graphite sheet with a thickness of 40 μm.

Figure 1 shows the actual distance vs. phase relationship measured. A graphite sheet with a thickness of 40 μm was measured. The distance between the heating point and the detection point is close to the center of the sheet, so the thermal diffusivity in the out of plane direction and the thickness of the sample have an effect, and a linear relationship is not obtained. In the range of 2 to 4 mm, a linear relationship is obtained; after 4 mm, the distance between the heating point and the detection point is so far apart that the signal begins to attenuate and the variation between the distance and the phase begins to increase. The analysis was performed in the range of 2 to 4 mm distance. Comparable results can be obtained by analyzing in the -2 to -4 mm region. When the range where the linear region is obtained is experimentally known, only the analysis range needs to be measured.

3.2 Consideration of sample temperature rise and thermal diffusivity measurement results

Thermal diffusivity measures the physical properties of a material by applying energy to the sample by light heating or Joule heating and measuring the temperature change. Therefore, temperature rise of the sample is inevitable. On the other hand, thermal diffusivity is a physical property value that changes with the temperature of the sample. Metals have slight change in physical properties due to temperature changes, but carbon-based materials have substantial changes in thermophysical properties around room temperature. In inspection applications, if the measurement conditions are fixed, relative thermal diffusivities can be compared, which is sufficient. When obtaining the absolute value of the thermal diffusivity, it is necessary to consider the temperature rise due to the heating of the sample.

The thermal diffusivity in the case of "zero heating light intensity" is obtained as follows. The thermal diffusivity is obtained by measuring the thermal diffusivity while varying the heating light intensity and extrapolating the thermal diffusivity when the heating light intensity is zero. The thermal diffusivity of a 25-μm-thick graphite sheet and a 40-μm-thick graphite sheet were measured by varying the amount of heated light. The thermal diffusivity is plotted on the vertical axis and the heating light intensity on the horizontal axis, and the intercept of the vertical axis at zero heating light intensity is the thermal diffusivity of the function that approximates the relationship with a straight line.

Table 1 shows the thermal diffusivities of graphite sheets of 25 μm and 40 μm thickness. The respective thermal diffusivities are 965±48x10^{-6}m^{2}s^{-1} for the 25-μm-thick graphite sheet and 1062±10^{-6}m^{2}s^{-1} for the 40-μm-thick graphite sheet with a thickness of 40 μm resulted in a thermal diffusivity of 1062 ± 53 x10^{-6}m^{2}s^{-1}.

Table 1 Thermal diffusivity of graphite sheet

Material name	Sample thickness, *d* /μm	Thermal diffusivity κ /×10^{-6}m^{2}s^{-1}
Artificial graphite sheet	25	965±48
Artificial graphite sheet	40	1062±53

4.Summary

The thermal diffusivity of graphite sheets in the in-plane direction was measured, showing that it is possible to measure samples with large anisotropy.

These results indicate that this measurement method can evaluate the detailed thermal diffusivity of non-isotropic materials and can be applied to the measurement of a wide variety of heat-conducting materials. In addition, since the sample preparation and installation are quite simple and non-contact measurement is possible, it is possible to reduce man-hours and measurement result variation among users compared to conventional thermal diffusivity measurement devices.

*Optional software is required for analysis of graphite sheets with a thickness of 100 μm or more.

5.References

[1] Toyo Tanso Graphite Sheet Product Web Page, https://www.toyotanso.co.jp/Products/perma-foil/
[2] Panasonic Graphite Sheet Product Web Page, https://www.panasonic.com/jp/corporate/technology-design/technology/pgs.html
[3] Kaneka Graphite sheet product web page, http://www.elecdiv.kaneka.co.jp/graphite/index.html

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