LASER INFRARED PHOTOTHERMAL RADIOMETRY OF ISOTROPIC MAGNETITE COMPOSITE

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Abstract

Photothermal techniques are widely used to monitor photoexcited carrier kinetics and transport in materials in a noncontacting and nondestructive manner. The main thermal and electronic transport parameters are derived from the photothermal amplitude and phase (frequency domain) or time evolution (time domain) dependencies. In this work, the laser infrared photothermal radiometry is used to study the thermal properties of natural rubber magnetite composite.

Key words: laser, infrared photothermal radiometry, composite materials

1 Introduction

Commonly used plastics have a low thermal conductivity. However new applications require new materials with an enhanced or high thermal conductivity. By the addition of suitable fillers to plastics, the thermal behavior of polymers can be changed up to significant higher thermal conductivity (diffusivity). The higher thermal conductivity can be achieved by the use of suitable filler. Published values of thermal conductivities of the same filler materials in different polymer matrices vary drastically and a comparison of different materials is impossible.

Photothermal studies are based on the well known fact that the absorption of an intensity modulated or pulsed irradiation by semiconductors results in temperature and plasma density profiles whose temporal behavior is affected by the thermal and electrical transport characteristics of the material, thus allowing the main thermal and electronic transport parameters to be derived from the photothermal amplitude and phase frequency domain dependencies.

2 Experiment

2.1. Experimental method

The experimental method and the mathematical model were described in [1].

The measurement is not bound to the excitation geometry (radius of the source or line width). The laser beam is line focused and then passed through the square-wave filter. The only condition is that the excitation frequency has to be low enough so that the thermal waves from the opposite sides of an unheated zone due to the grating have effective wavelengths of the order of $\lambda/4$ so as to interfere with one another (fig.1).

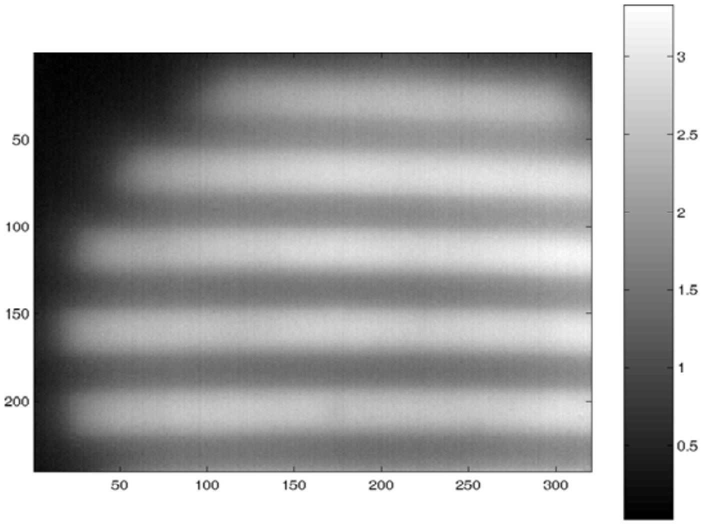

Fig. 1: The interference picture of the sample

Used mathematical model gives the resulting temperature oscillations in space. The modulation depth of the temperature amplitude and phase can be easily determined from the absolute difference of the extremes of the modulation (fig.2 and fig. 3).

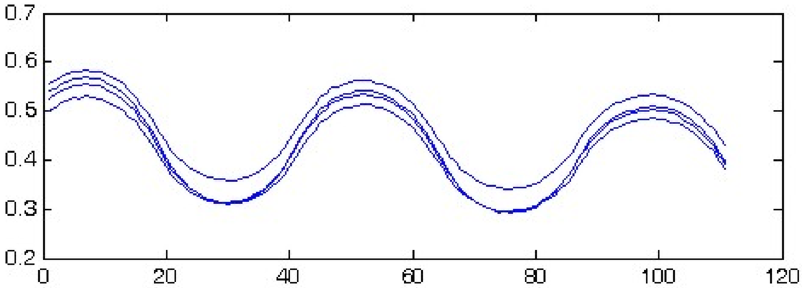

Fig 2: Amplitude modulation of temperature perpendicularly to the grating bands, $\lambda = 4$ mm.

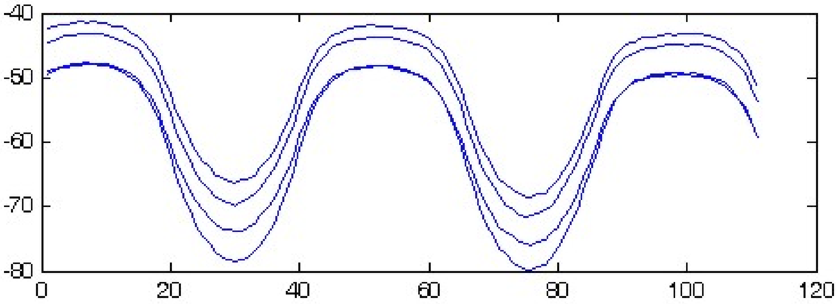

Fig 3: Phase modulation of temperature perpendicularly to the grating bands $\lambda = 4$ mm.

2.2. Materials

We used composite material consists of natural rubber matrice and the strontium ferrite filler ($SrFe_{12}O_{19}$).

The filler content of the measured samples is in the table 1.

Sample (No.)	Filler volume fraction (%)	Weight fraction (%)
5	11.9	29.7
3	12.9	31.7
1	13.8	33.5
8	16.9	38.9
9	17.7	40.3
7	18.6	41.7
4	20.9	45.3
6	23.8	49.6

Table 1: Identification of samples

3 Results

To illustrate the influence of the filler fraction on thermal properties one can compare too extreme filler volume contents: 11.9% (sample 5) and 20.9% (sample 4).

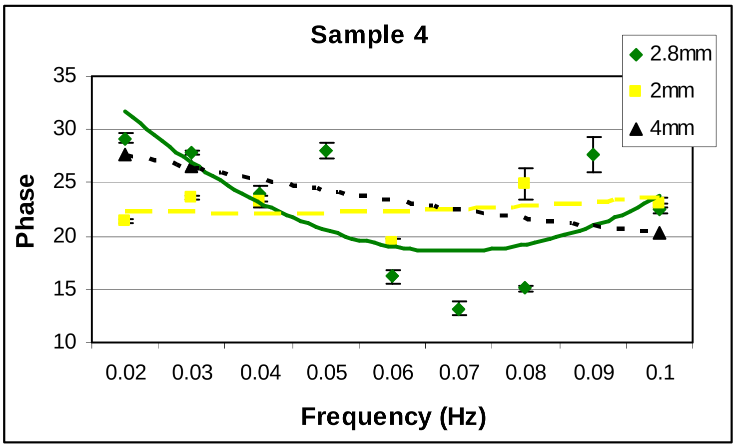

Fig. 4: Modulation phase of temperature for the sample 4 as a function of frequency for different gratings.

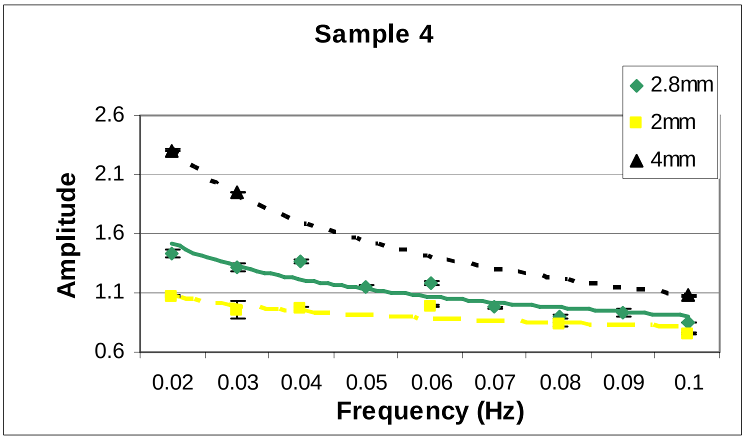

Fig. 5: Modulation amplitude of temperature for the sample 4 as a function of frequency for different gratings.

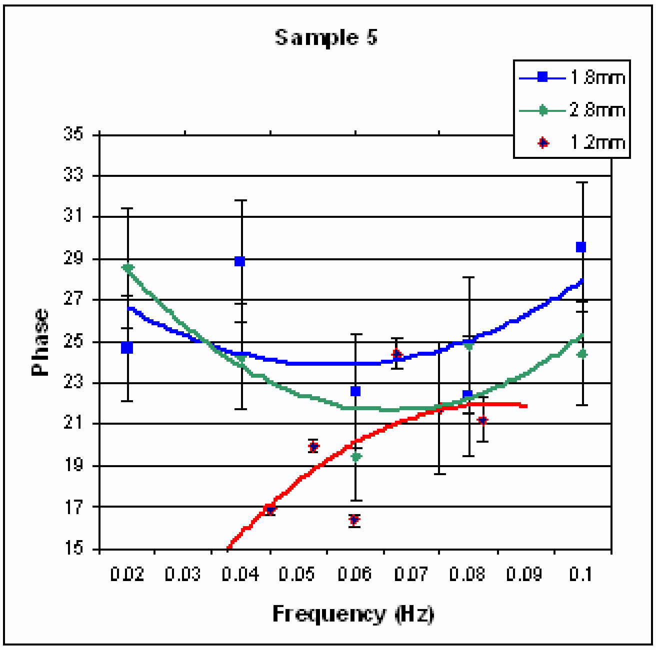

Fig. 6: Modulation phaseof temperature for the sample 5 as a function of frequency for different gratings.

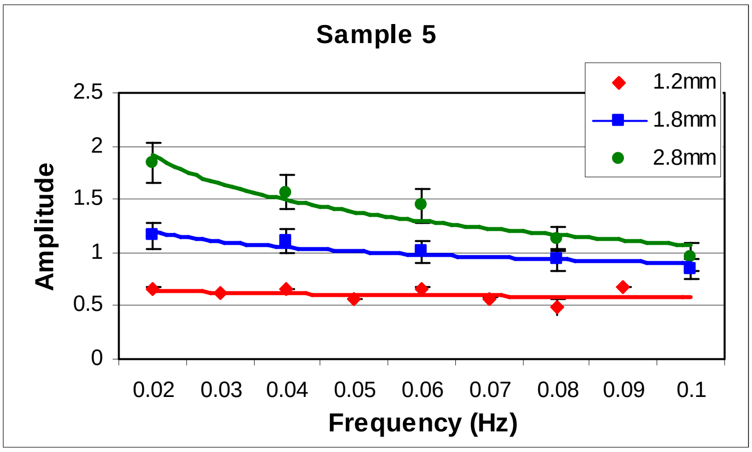

Fig. 7: Modulation amplitude of temperature for the sample 5 as a function of frequency for different gratings.

There are fitting two values, the amplitude of the field's normalized amplitude and phase modulation. There is conducted a parametric study in order to analyze the influence of each property to the temperature field. The specific heat $C = 800 J / kg.K$ and the density was calculated for each sample. The final thermal conductivities are: $(2.74 \pm 0.34) W / mK$ for the sample 4 and $(1.19 \pm 0.29) W / mK$ for the sample .5

The thermal properties were found by fitting the thermal wave field for all excitation frequencies.

Conclusions and discussion

The theory is neglecting the possible presence of internal optical reflections, optical diffusion and assumes constant thermal properties. These conditions are not perfectly fulfilled and not even well known. As can be seen in figures 1 and 6 the phase was also clearly much more affected with the offset at the center of excitation.

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References

[1] G. Kalogiannakis, D. Van Hemelrijck: Thermal characterization of anisotropic media in photothermal point, line, and grating configuration. JOURNAL OF APPLIED PHYSICS 100, 063521 (2006)