Study of the thermal properties of resin/graphene nanocomposite for 3D print applications

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Background – In recent decades, the use of multiple polymers for 3D part printing applications has been intensively exploited. Therefore, the use of new resin-based composite resins, mixed with graphene oxide (GO), is necessary. This composite is of great interest, because this material is produced from the exfoliation of graphite, which has interesting properties of resistance, rigidity and thermal conductivity. Lately, graphene nanotechnology has become a main topic in current research, since this material has a high surface area, which is greater in its exfoliated form. Therefore, it increases overall performance when is used in compounds. Similarly, some authors suggest that GO can be used to increase matrix properties in nanostructures. Hence, it is important to know their thermal properties such as thermal diffusivity when is added to nanocomposites, for small amounts of sample. In this work, the thermal wave resonant cavity (TWRC) technique was used, by means of a pyroelectric detector with a length sweep in the resonant cavity. The accuracy and precision of this technique was established by comparing the thermal diffusivity of distilled water. From the results obtained, an increase in the thermal diffusivity of the nanocomposite with concentration was observed. To obtain a strong resin-nanostructure interface remains a challenge for many researchers.

Methods – For the synthesis of the selected nanocomposites, a set of samples of polymer resins (PMMA) of the same weight were determined, then samples of graphene oxide enriched with COOH were obtained. For the mixture of both compounds, a mechanical mixture was first carried out for approximately 1 hour and then the sample was subjected to a sonification process for approximately 3 hours, once the graphene was fully integrated into the resin. The weight concentrations of 0.02 to 0.12 wt%.

For resin/graphene thermal characterization, the TWRC arrange was used. In this technique, a small amount of the liquid resin was placed in a chamber composed of a metal foil and a PZT temperature sensor. Then, the light of a laser beam modulated by an oscillator is absorbed by the resin acting as thermal wave generator. Then, the temperature variation is measured by a pyroelectric sensor as function of sample thickness. The signal was detected by a lock-in amplifier. Thermal diffusivity was measured using the back-photopyroelectric technique [1].

Results – The results for thermal diffusivity are shown in Table 1. Representative graphs of thermal diffusivity (*D*) for graphene NPs/resin are shown in figure 1 and Theoretical equation 1 [1]. Thermal diffusivity (*D*) in amplitude, phase, enhancement and literature values are also shown in Table 1.

$$Ln(V(L,\alpha,\omega)) = ln(Const(\omega)) + ln(e^{-qL}) , \; q = \sqrt{\frac{\pi f}{\alpha_l}} \qquad \text{Eqn.1}$$

Table 1. Thermal properties values for the graphene NPs /resin

Wt%	$\alpha_{Amplitude}$ $\times10^{-7}(cm^2/s)$	α_{Phase} $\times10^{-7}(cm^2/s)$	***Enhancement*** %	***Literature* value**
0.12	1.27	1.03×10^{-7}	33.68	
Resin	0.915	0.885×10^{-7}		0.95×10^{-7} [2]
Distilled water	1.47	1.45×10^{-7}		15.9069×10^{-3} [3]

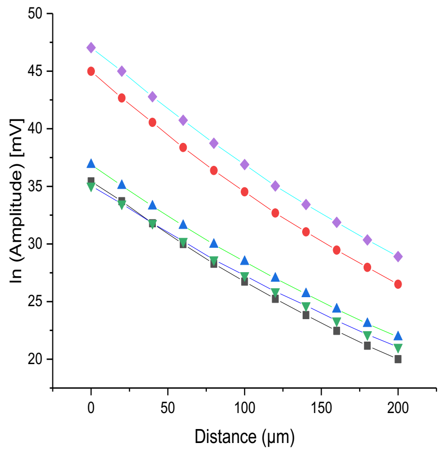

Fig. 1. Thermal diffusivity graphs of amplitude for graphene NPs /resin. The continued line is the best fit for the experimental values.

From the results, thermal diffusivity of graphene NPs/resin was higher than for pure resin. From calculation, the highest thermal diffusivity value was of 1.27×10^{-7} m^2/s for a 0.12 wt% concentration of graphene NPs /resin. The results found in this work are of special interest because the process is associated with the improvement of the interfaces between the NPs and the matrix as well as the morphology of the GO NPs (nanoplatelets), the thermal diffusivity increases by several times [4].

Conclusions – For the pure liquid resin studied, a higher diffusivity was obtained with a concentration of 0.12 wt% graphene NPs, followed by an enrichment of 33.7% and finally the increase in thermal diffusivity is related to the surface area, phononic network, morphology and interfaces between the NPs and the matrix [18]. In addition, the thermal diffusivity was calculated with the TWRC technique. Further research studies are needed to explore the mechanisms of thermal transport through graphene/polymer interfaces.

References

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