Photothermal Techniques for 3D printing polymer characterization

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Background – Additive Manufacture (AM), also called 3D printing (3DP), includes several technologies that have raised great expectation because it could reduce costs and time to produce prototypes and single pieces. Despite such expectations few organizations have used it and still less have incorporated it into its chain of production [1]. The wide variety in materials, printer models and technologies make standardization a slow process that most investors would desire to be better defined before they could incorporate 3DP to their processes. A concern common to every AM process is to use standardized polymer and assure its quality to minimize the variation due to raw materials in the printing process. Photothermal techniques offer great analytical advantages as high sensibility and accurateness, at a low cost to characterize the polymers used in 3D printing; due to its easy implementation, non-destructive techniques, low cost instruments and easy interpretation they can be incorporated to an economic plan. As an example, in that research, we explored the application of Photoacoustic Spectroscopy (PA) and Thermal Lens Spectroscopy (TL) to thermally characterize nanocompounded acrylic resins.

Methods – Round Silver nanoparticles (AgNPs) with 15.7 nm average diameter synthesized by a green method [2]**,** and Silver nanowires (AgNWs) with 150 x 50 nm average length x transversal diameter synthesized by the Polyol Method [3], were dispersed into a liquid Acrylic resin at 4×10^{-6} to 20×10^{-6} vol % to conform two different nanocomposites series. Essential characterization techniques as TEM, SEM, FTIR, and UV-vis were used to characterize separately AgNPs, AgNWs and resin's morphology, physical and chemical aspects. A TL experimental setup in a mismatched configuration [4] was used to determine the liquid sample's Thermal Diffusivity (D), and, PA in an Open Cell (OPC) configuration [2] was used to determine the nanocomposite's Characteristic Curing Time (τ).

Results – Thermal Diffusivity (D) tested by TL resulted in similar trends between the two nanocomposites series, with AgNPs and with AgNWs as showed in Fig. 1 (A). Slight differences were found in the variation range from0 to 50×10^{-4} (cm/s). In contrast, the Characteristic Curing Time (τ) tested by PA-OPC resulted in two different trends that unambiguously indicates us if the tested sample belongs to AgNWs or AgNPs series; the samples containing AgNPs ranged from 20 to 60 s while the samples containing AgNWs ranged from 480 to 1650 s; such difference is theoretically assigned to the difference in filler´s shape.

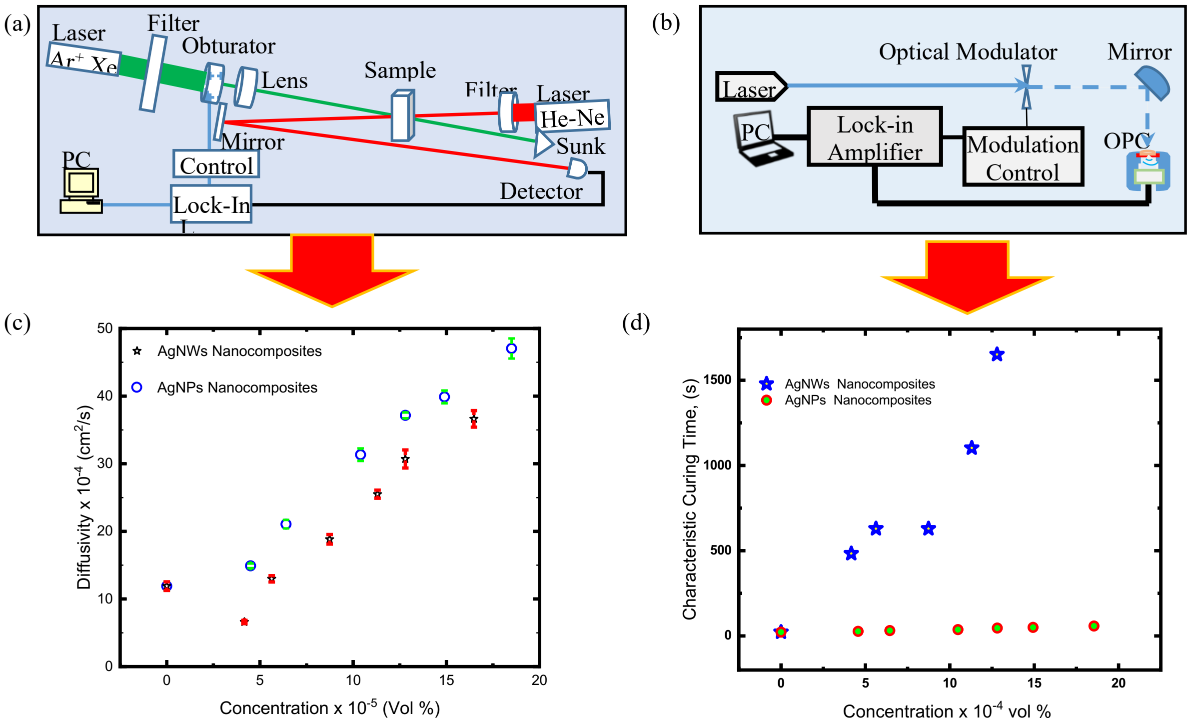

Fig. 1. (a) Thermal Lens experimental set up. (b) Photoacoustic Spectroscopy Open Cell experimental set up. (c) Thermal Diffusivity of nanocomposites by TL technique. (d) Characteristic Curing Time of nanocomposites by PA-OPC technique. Concentration ranged from 4 x 10^{-6} to 25 x 10^{-6} vol % of AgNPs and AgNWs.

Conclusions – PA-OPC and TL are reliable techniques whose accuracy can differentiate among samples having small differences in their components' concentration. The performed tests showed sensitivity to nanometrical differences in the filler's structure. The optical elements used to set up the experimental array can be found as ordinary elements in a physics laboratory and they don't require special environments or supplies. Photothermal techniques can help minimize variation in 3DP process revealing subtle differences in polymers that could be originated by the manufacture process, storage environmental conditions or aging.

References

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