Research Article

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# Fabrication and Characterization of the PMMA/G/Ag Nanocomposite by Pulsed Laser Ablation (PLAL)

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## Abstract

In this work, By using the laser ablation technique (PLAL) to fabricate novel PMMA/G/Ag nanocomposites with less laser energy and short time ablation and study the structural, morphological and optical properties. The X-ray diffraction (XRD) confirmed that the GNPs and AgNPs in the PMMA matrix have a crystallite size increased with increasing the pulse number. Also, the SEM images confirm the homogeneous distribution of the GNPs and AgNPs in the PMMA matrix and the sizes of particles in the nanoscale. Additionally, the link between GNPs and AgNPs in the polymer matrix has been confirmed by the FTIR. Moreover, UV-VIS spectroscopy was studied and confirm the nanocomposite has optical properties with the presence of the polymer as a host and calculating the optical energy gap. For that, this novel nanocomposite with these properties promising for many applications. Finally, the study proved that the PLAL is very suitable for decorated graphene and metal on the polymer matrix with lower pulse laser energy and short ablation time.

**Keywords:** PLAL, Graphene, Silver, Polymer, Nanocomposite, Characterization, Properties

## Introduction

Graphene is a 2D dimensional Hexagonal lattice made up of a single sheet of carbon atoms tightly packed together [1]. Due to its unique electrical, optical, and mechanical properties, graphene is attracting increasing interest from a variety of research fields. It is a zero-band gap semiconductor that is not expected to be photoactive or photo luminescent. Other important features include a high optical transmittance (97.3%) [2-7]. As a result of the discovery of graphene, Geim A. K. and et. al. were awarded the Nobel Prize in Physics in 2010 [8].

Mechanical exfoliation [9], graphite intercalation [10], epitaxial growth of silicon carbide pyrolysis [11], an electrochemical technique [12], reduction of oxidized graphite [13], and chemical vapor deposition CVD [14] are some of the methods used to make graphene. These techniques, which include multiple steps and the use of strong reducing agents, are not environmentally friendly. On the other hand, pulsed laser ablation in liquid (PLAL) is another method for producing graphene due to its cleanliness, simplicity, ease of particle synthesis at the nanoscale, and strong tools for controlling the final production of the laser ablation process [15-18]. Besides, an important way to purify the particle size produced in this way is to use the newest method as in the [19]. A few polymers can be extended essentially by homogeneously joining graphene due to their low Young's modulus, making polymer/graphene nanocomposites appealing for a variety of applications. Polymer-graphene nanocomposites, such as poly(methyl methacrylate (PMMA) prepared by a simple casting method [20] and graphene/polyvinyl alcohol (PVA) nanocomposite films, have been fabricated using various techniques such as a facial aqueous solution [21], simple solution method [22], and solution cast method [23]. While many achievements have been made, such as graphene and various metallic nanoparticle like silver (Ag) [24, 25], copper (Cu) [26], and gold (Au) [27]. In this article, we propose a new method for the production of nanocomposites PMMA/G/Ag by PLAL technique with lower pulse laser energy and short ablation time.

# Experimental

## Preparation of graphite (G) and Silver (Ag) plate

Graphite powder (5 g) and silver powder (5 g) weight (99.99%; Interchemiques SA, Germany) (99.99 percent quality; Sigma Aldrich, St. Louis, MO). After cleaning the cylinder with ethanol, the graphite and silver powders were compressed with a hydraulic piston under pressures of 20 MPa for the graphite powder and 22 MPa for the silver powder, with widths of 2 cm and thicknesses of 2 mm, and then annealed for 4 hours at 450 °C for strengthening. Graphite and silver plate have been cleaned by using cleaned paper and washed with ethanol and refined water to avoid degradation.

## Preparation of solvent of poly (methyl methacrylate) (PMMA)

0.5 g Poly(methyl methacrylate) (molecular weight 120000 g/mol, glass temperature 106 °C, density 1.2 /cm$^3$) was dissolved in 30 mL chloroform for 10 minutes with a magnetic stirrer at 40 °C.

## Synthesis of PMMA/G/Ag nanocomposite by laser ablation in liquid

The prepared graphite plate was placed on a bracket 2 mm below the liquid surface in a glass vessel filled with 5 mL of the PMMA solution and then exposed with (100, 200, 300, and 400) pulses using a pulsed Q-Switched Nd: YAG laser. As shown in Fig. 1, the pulse has a duration of 10 ns and a repetition rate of 6 Hz at a wavelength of 1064 nm with an energy of 80 mJ per pulse. This colloid solution PMMA/G nanocomposite will be decorated with AgNPs by immersing an Ag plate in this nanocomposite solution and exposing it to

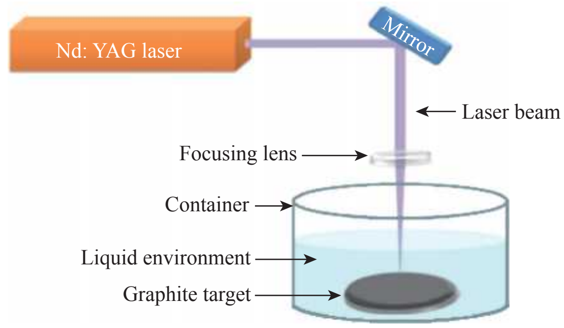


**Fig. 1** Laser ablation setup.

(400, 500, 600, and 700) pulses with an energy of 160 mJ from the same Q-Switched Nd: YAG laser, and then preparing the colloid PMMA/G/Ag. By using casting methods on the petri dish to prepare films from this nanocomposite.

By using the dynamic light scattering and interferometric method to find concentration for the GNPs and AgNPs in part per million gram (ppm) in 10ml of the PMMA solvent and thickness for all the films prepared. The concentration of the GNPs and AgNPs and the thickness films increased with increasing the number of pulses as shown in Table 1.

**Table 1** The concentration of the GNPs, Ag NPs and thickness for all the prepared films

| Symbol | Nanocomposites | Concentrations | Film thickness (μm) |
|---|---|---|---|
| -- | PMMA | | 1.06 |
| S1 | PMMA/(G100 p) | G = 20 ppm/10 mL | 1.46 |
| S2 | PMMA/G(100 p)/ Ag(400 p) | G = 24 ppm/10 mL Ag = 32 ppm/10 mL | 1.48 |
| S3 | PMMA/G(200 p)/ Ag (500 p) | G = 34 ppm/10 mL Ag = 57 ppm/10 mL | 1.66 |
| S4 | PMMA/G(300 p)/ Ag(600 p) | G = 77 ppm/10 mL Ag = 83 ppm/10 mL | 1.78 |
| S5 | PMMA/G(400 p)/ Ag(700 p) | G = 87 ppm/10 mL Ag = 97 ppm/10 mL | 1.83 |

## Characterization

To obtain information about the atomic structure of the materials, Philips PW X-ray diffraction technique (XRD-6000-SHIMADZU) with Cu-Ka radiation source at 2θ = (0–80) degree. To investigate the morphology of prepared samples, Hitachi S4160 was used in scanning electron microscopy (SEM). To obtain the structural characterizations of the prepared nanocomposite, FTIR spectroscopy (Shimadzu, IRAffinity-1, Japan) in the 500-4000 cm$^{-1}$). To investigate the UV-Visible used (Shimadzu UV-1650 PC) made by Phillips, (Japanese company) for the wavelength range from 200 to 900 nm. To record the spectra, samples were in 10 mm