Laser Annealing as an Enhancement Technique for the Optical and Electrical Properties of Graphene Ink based Films

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In this work we propose a fast and on-demand technique to fabricate graphene-based transparent conductive films. Drop casting of high-concentration graphene ink accompanied with an efficient laser annealing process results in a homogenous graphene thin film. Graphene ink was produced by a liquid phase exfoliation (LPE) method through exfoliating graphite powders in dimethylformamide (DMF) and additional stabilizing polymers. Finally, DMF was exchanged by terpineol in order to increase graphene concentration, adjust ink viscosity, and reduce solvent toxicity [1]. The ink was deposited on substrates by drop casting and then annealed at 400°C for 30 min to remove stabilizing polymers. Subsequently, a 532 nm cw laser beam was scanned across the film with a power density of 55 MW/cm^2 and integration times of 1-5 ms. The graphene thin films were characterized by a combination of optical microscopy, laser scanning microscope, scanning electron microscope (SEM), Raman spectroscopy and X-ray powder diffraction (XRD). While the drop casted films are highly resistive, the laser treatment results in sheet resistances on the order of 30 kΩ/sq. Meanwhile, the transmittance of the films increases from 60% to more than 85% (at λ = 550 nm). Raman data indicate that by laser annealing the films, both the FWHM of the Raman G band and the integrated intensity ratio of the D band to the G band decrease significantly. This confirms that the laser treatment reduces structural disorder within the film. XRD data shows the intensity of the peak at 2ϴ = 26.7°, which corresponds to the 002 plane of graphite layers, is higher for laser treated samples. This data indicate after laser treatment there are more graphene flakes overlapped in the (002) crystalline direction. AFM and SEM images show topography changes in the films after laser treatment. Laser annealed films have a significantly more homogenous and smooth surface with roughness of about 10 nm. Electrical and optical properties of fabricated films by this method are comparable to that of the state of the art in printed graphene films. Laser annealing enables the controlled transformation of a high resistive coating into a transparent conductive film with potential applications in electrostatic dissipation or touch displays.

[1] J. Li, *et al*., Adv. Mater., **vol. 25**, (2013**)** 3985–3992

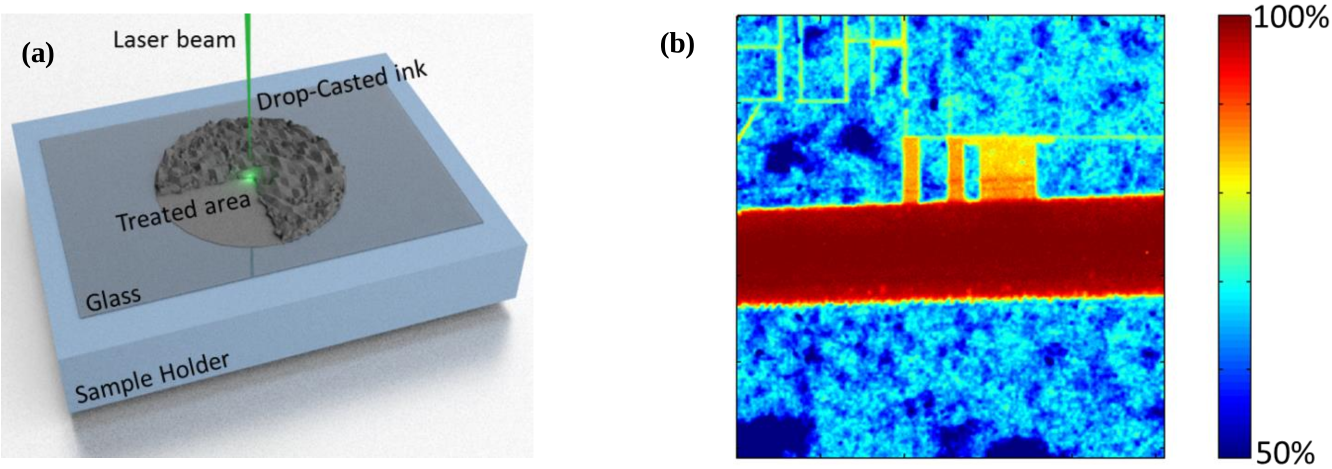

Figure 1: (a) schematic of laser annealing process (b) Transparency at 550 nm, the red area is glass substrate while the yellowish color indicates the laser treated film.