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Investigation of Exfoliated Graphene Flakes and Their Self-Assembly Capabilities to Form Thin Coating Films

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Graphene Oxide (GO) has been used with surfactants[1] to create conformal coatings or with polymers to create diffusion barriers[3], and CVD graphene (G) films have shown anti-corrosive properties[2] after a difficult transfer process. The study of exfoliated graphene flakes (EGFs) and water to create a film has not been reported. EGFs have advantages with an intact crystal lattice, However, using EGFs to create a conformal graphene thin film coating, by self-assembling without surfactant has not been studied.

In this report we demonstrate an effort to use EGFs dispersed on the water surface to study their self-assembling capability to create G films. Specifically, the EGFs were collected through thermal expansion of expandable graphite (EG) precursor, exfoliation through sonication in N-methyl-2-pyrollidone (NMP), then centrifugation and resuspension in ethanol to select thinner flakes and remove NMP. The EGFs were dispersed on the water surface and deposited on silicon wafers and conformal surfaces.

The EG is composed of stacked G layers held together by Van Der Waals (VW) forces. Exfoliation separates the sheets into few-layer graphene (FLG) flakes with hydrophobic surfaces. Hydrophobicity allows the EGFs to disperse across the water surface. EGF films are composed of a range of thicknesses and as more EGFs are dispersed flake edges will overlap. Fig. 1a shows an SEM image of a single EGF coating on a silicon wafer with coverage around 85% with an inset showing an area with a large amount of thin EGF's. Many flakes will be flat on the substrate with some at angles due to disordered stacking. Silicon was selected for its atomic flatness for film thickness measurements with a laser profilometer and to show EGF coverage and angled overlap in SEM. The space between flakes and gaps in the film can be covered by second coatings shown in Fig. 1b. Increasing yield of thin flakes will decrease film height in one and two coats with a flatter film overall.

Fig. 2a shows an optical image with a laser height profile taken over a random region of EGF film with coating thickness of 100nm (Fig. 2b) with other scans showing thickness up to 215nm. Fig. 2c shows a laser height image of the same area with the lowest areas being uncoated silicon wafer, low areas with coatings of small G-like EGFs, larger EGFs and high points when flakes are sitting at angles. The presence of small EGFs in gaps in the film was confirmed by Raman spectroscopy shown in Fig. 2d. The use of EGFs as a coating on other substrates is an area of interest. A conformal coating on a stainless-steel nut is shown in Fig. 3 with images detailing high coverage on the top and side. Multiple coats can be used for a better coating, though current methods do not completely coat the inner threads of the nut.

The use of EGFs to create a film without the use of surfactants may offer advantages over current CVD-G and GO films. The thickness of current films may be improved by decreasing EGF thickness and the coverage on flat and conformal surfaces by lateral size and through multiple coatings. Further investigation of EGF films will focus on better control of the self-assembly process and coatings on more substrates [4].

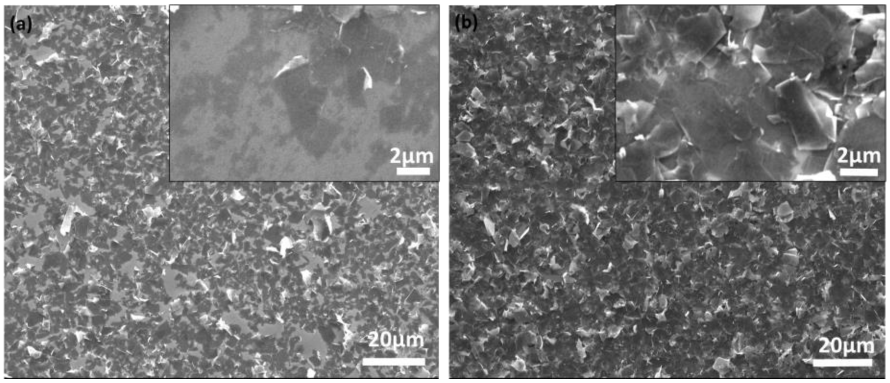

Fig. 1. (a) SEM images of single coat with some uncoated areas and insert showing small EGF’s; (b) Sample with two coatings and insert showing layering of EGF’s to form more coverage

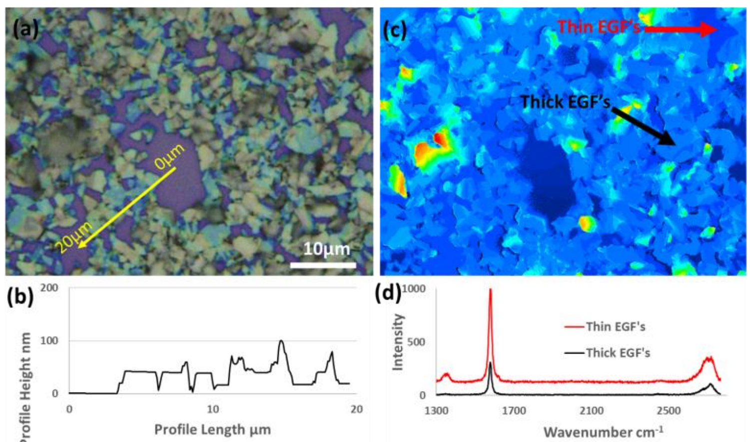

Fig. 2. (a) is the laser scanning image of an area of EGF's, with the line profile location and direction labelled for (b); (b) the height profile showing the coating thickness is around 100 nm; (c) the 3D display (height) image of coating film; (d) the Raman spectra of EGF's labelled in (b).

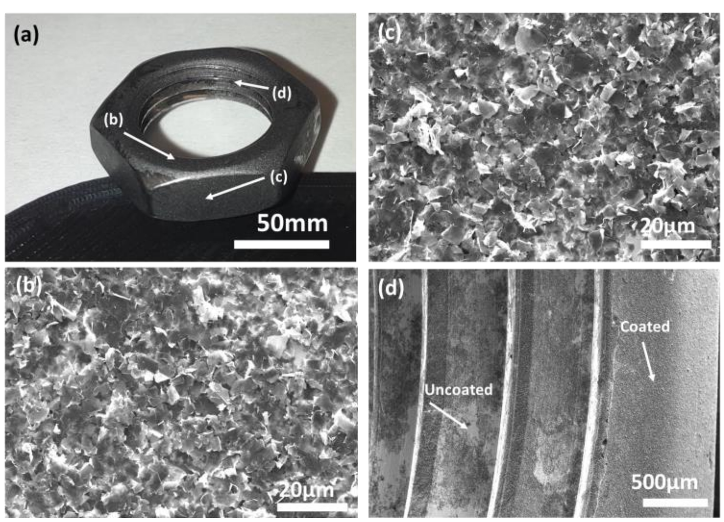

Fig. 3. (a) Optical image of conformal coated nut; (b) SEM image of the coating on the side; (c) SEM image of the coating on the top surface; (d) SEM image of the coating on threads on the inside of the nut.

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