Towards deposition of single layer graphene by an electrospray ion-assisted method

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The technological potential of graphene fosters studies on its deposition to form thin films on a variety of substrates (Blake *et al*, 2008). Spraying is a physical process extensively used to fabricate films and coatings because of its flexibility in the chemical composition of materials that can be deposited. Electrospray, a liquid atomization method that leads to highly charged, nearly monosized micro- and nano-droplets, has been applied to create thin films and coatings (Jaworek, 2007; Modesto-Lopez & Biswas, 2010). Because of its electrostatic control, electrospray deposition (ESD) results in a nearly 100 % deposition efficiency on conductive substrates.

Previously we have reported the deposition of multilayer graphene nanosheets onto silicon and quartz substrates using an electrospray ion-assisted (EIA) method (Modesto-Lopez *et al*, 2012; Uecker et al, 2010). The films comprised multilayered graphene and large agglomerates. In our EIA approach the ions facilitate the deposition of graphene onto dielectric substrates, which is otherwise difficult to achieve with conventional ESD. Films of varying thicknesses can be obtained by adjusting the deposition time and the concentration of graphene in the precursor suspension.

The objective of this study is to deposit single layer graphene films using the EIA method. We also investigate the relationships between coating morphology and EIA process parameters. Suspensions of commercial graphene flakes (Grupo Antolin, Spain) were diluted to 0.005 wt% in dymethylformamide, and were electrosprayed onto Si and quartz substrates. Electrospray was performed in the cone-jet mode. The films were characterized with atomic force microscopy (AFM) and micro-Raman spectroscopy. Figure 1a shows an AFM image of a film collected for 10 min onto Si from an electrospray operated at a liquid flow rate of ~1 μL/min. The film is comprised of relatively large graphene flakes of uniform thickness (clear areas) over the Si substrate (darker areas). Such thickness is approximately 1.1 nm as shown in the profile of Figure 1b, which corresponds to the green line in Figure 1a.

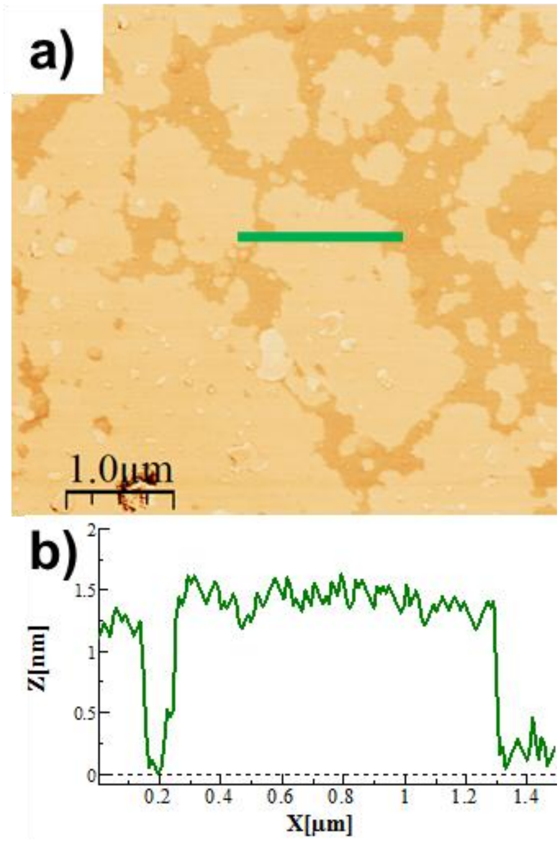

Figure 1. a) AFM phase image of a graphene thin film deposited for 10 min onto a Si substrate, b) cross-section profile from topographic image (green line shown in a)).

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