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Three-dimensional graphene patterns on nanoporous alumina: growth and morphology characterization

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The graphene patterns were grown on the nanoporous surface fabricated using alumina membrane by a simple and convenient anodization technique [Fang J., Levchenko I., Ostrikov K. and Prawer S. (2013) Sonochemical Nanoplungers: Crystalline Gold Nanowires by Cavitational Extrusion Through Nanoporous Alumina. Journal of Materials Chemistry C 1, 1727-1731]. The Al foil (thickness of 300 μm, diameter 10 mm) was anodized using direct current voltage of 50 V in the oxalic acid to obtain pore size of 200 nm. The samples were then subjected to various types of post-treatment to obtain different morphology of graphene flakes on the treated surface. Specifically, one sample was processed in ICP plasma (Ar gas, RF power 750 W, 2 min), second one was coated with Au (30 nm), the others were treated with gold and palladium ions by immersing them for 24 hours into KAu(CN)2, CoSO4, and PdCl2 solutions, respectively, and then drying in nitrogen. After that, the mesh-like network of vertically-aligned graphene flakes was grown on all samples in plasma reactor (CH4/Ar/H2 ratio was 2:1:1, pressure of 3.0 Pa, power 850 W, process time 6 min). Samples were characterized using scanning electron microscope (SEM), and the SEM images were used for the statistical analysis. The Minkowski functionals, namely the connectivity (Euler-Poincaré characteristic) and fractal dimension were then used as morphological descriptors for the complex networks of the graphene nanoflakes. The method was validated using the nanoflakes grown on nanoporous alumina and solid (smooth) silica, and high sensitivity demonstrated. Specifically, strongly different connectivity and fractal dimension graphs were obtained for several visually similar morphologies.

Keywords
Graphene
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