Nanowire-MeshTemplated Growth of Out-of-Plane Three-Dimensional Fuzzy Graphene

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Graphene,a honeycomb sp^2 hybridized carbon lattice, is a promising buildingblock for hybrid-nanomaterials due to its electrical, mechanical, and opticalproperties. Graphene can be readily obtained through mechanical exfoliation,solution-based deposition of reduced graphene oxide (rGO), and chemical vapordeposition (CVD). The resulting graphene films' topology is two-dimensional (2D)surface. Recently, synthesis of three-dimensional (3D) graphitic networkssupported or templated by nanoparticles, foams, and hydrogels was reported. However,the resulting graphene films lay flat on the surface, exposing 2D surfacetopology. Out-of-plane grown carbon nanostructures, such as vertically alignedgraphene sheets (VAGS) and vertical carbon nanowalls (CNWs), are still tetheredto 2D surface. 3D morphology of out-of-plane growth of graphenehybrid-nanomaterials which leverages graphene\'s outstanding surface-to-volumeratio has not been achieved to date.

Herewe demonstrate highly controlled synthesis of 3D out-of-plane single- to few-layerfuzzy graphene (3DFG) on a Si nanowire (SiNW) mesh template. By varyinggraphene growth conditions (CH_4 partial pressure and process time),we control the size, density, and electrical properties of the NW templated3DFG (NT-3DFG). 3DFG growth can be described by a diffusion-limited-aggregation(DLA) model. The porous NT-3DFG meshes exhibited high electrical conductivityof ca. 2350 S m^{-1}. NT-3DFG demonstrated exceptional electrochemical functionality,with calculated specific electrochemical surface area as high as ca. 1017 m^2g^{-1} for a ca. 7 μm thick mesh. This flexible synthesis will inspire formationof complex hybrid-nanomaterials with tailored optical and electrical propertiesto be used in future applications such as sensing, and energy conversion andstorage.

T.C.K. would like tothank the National Science Foundation (CBET1552833) and the Office of NavalResearch (N000141712368).