Vertically-oriented Graphene: Plasma Synthesis and Applications

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***Abstract*— Vertically-oriented graphene (VG) nanosheets or carbon nanowalls (CNWs) are two-dimensional 'graphitic' platelets that are standing on a substrate at their edges. An individual CNW can be a few layers of graphene up to several micrometers wide. Due to the high electron mobility of graphene, exposed sharp edges, and vertical orientation of CNWs, CNW materials have been demonstrated as a good field emission material. Moreover, CNWs have open edges; the theoretical surface area of CNWs is twice that of closed boundary structures, such as carbon nanotubes (CNTs) or C60. The high surface area of CNWs makes them attractive for a wide range of applications, such as catalyst supports, sensing, and energy storage. Growth of CNWs was typically carried out at a low pressure. Here we report on the synthesis of CNWs at atmosphere pressure using direct current plasma-enhanced chemical vapor deposition by taking advantage of the high electric field generated in a pin-plate dc glow discharge. CNWs can be grown on silicon, stainless steel, and copper substrates without deliberate introduction of catalysts. The as-grown CNW material is mainly mono- and few-layer graphene having patches of O-containing functional groups. We further demonstrate synthesis of patterned VG nanosheets through artificially designing the surface electric field distribution. Finally we demonstrate the growth of a brand-new, three-dimensional (3D) carbon nanostructure comprising few-layer graphene (FLG) sheets inherently connected with CNTs through sp2 carbons, resembling plant leaves (FLGs) growing on stems (CNTs). Example applications of these VG-based materials include gas sensing, corona discharge, lithium-ion batteries, and supercapacitors.**