

Synthesis of new graphene/carbon nanoflower composite

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Abstract

A new carbon nanocomposite is synthesized. It consists of multilayered graphene sheets (typically less than 10 layers) and carbon nanoflowers (CNFs) (Fig. 1) [1]. The synthesis method is a two stage process in which preceramic silicon-carbon nanoparticles are first produced by atmospheric pressure chemical vapor synthesis (APCVS) using liquid hexamethyldisilane ($C_6H_{18}Si_2$) as a precursor [2]. The APCVS setup consists of a bubbler and a vertical flow reactor. Particle formation is based on the thermally induced decomposition and subsequent reaction of the precursor in the reactor. Properties (e.g. crystallinity, amount of excess carbon, particle size) of the produced silicon-carbon nanoparticles can be controlled by changing the temperature (800-1400 °C) of the reactor. In the second stage of the synthesis process, the produced silicon-carbon nanoparticles are annealed at high temperature (1900-2600 °C) in argon (Ar) atmosphere using an inductively heated furnace [1]. The annealing results in dissociation of the silicon-carbon particles and formation of silicon carbide (SiC) crystallites and, after further evaporation of silicon from both the precursor particles and the formed SiC crystallites, graphene-carbon nanoflower composite.

CNFs are new carbon nanostructures in which curved graphite layers grow from the silicon-carbon core that decreases in size with increasing annealing temperature and disappears above the annealing temperature of 2200 °C. The growth mechanism of the CNFs is induced by simple thermal decomposition of the surface of the precursor particles followed by the evaporation of silicon [3]. The curved surface of the precursor particles causes the growth of the flower-like structure. The CNFs are less than 60 nm in diameter and resemble carbon nanohorns [4], with multilayered “flower petals” instead of “horns”. The CNFs are interconnected with the graphene layers, but can also be separated after repeated dispersion-ultrasonication-sentrifugation treatment in organic solvent (e.g., dimethylformamide).

The proportions of the graphene sheets and the CNFs, as well as the number of carbon layers in the CNFs, can be controlled by varying the properties of the precursor particles, i.e. the amount of excess carbon and the crystallinity. Increasing the crystallinity of the precursor particles reduced the number of carbon layers in the CNFs from 7 to 4 when the particles were annealed at a temperature of 2600 °C. Based on transmission electron microscopy (TEM) and Raman analyses the interlayer distance in the CNFs (0.35-0.36 nm) and in the graphene sheets (0.37-0.38 nm) is expanded compared to graphite (0.335 nm), and the graphene layers in the sheets are rotationally disordered. Raman spectra of the as produced graphene/carbon nanoflower composite (Fig. 2) confirm that high quality graphene is synthesized.

The method presented enables atmospheric pressure synthesis of a new carbon nanocomposite with controllable composition. The process provides, after the applicability of the composite is validated, a sufficiently low-cost and industrially scalable material production route for variety of applications, e.g., rechargeable batteries, supercapacitors, or flexible electronics.

References

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Figures

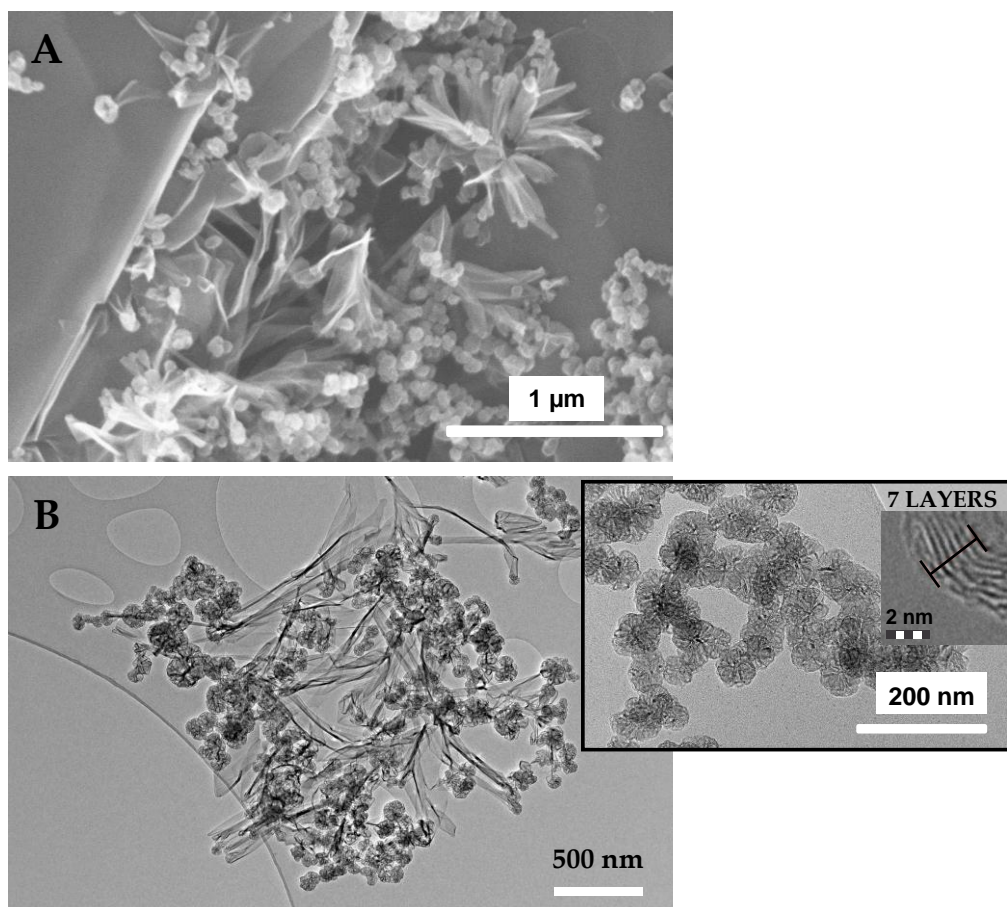


Fig. 1 a) SEM and b) TEM images of synthesized graphene/carbon nanoflower composite. A higher magnification TEM image of the carbon nanoflowers is shown in subfigure b.

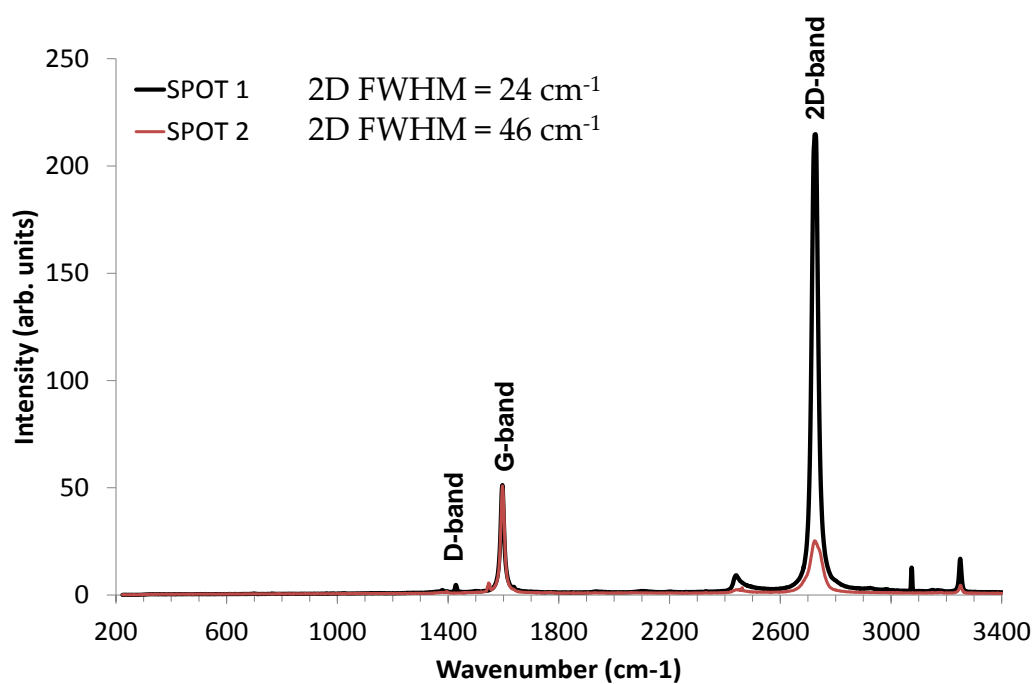


Fig. 2 Raman spectra of as produced graphene/carbon nanoflower composite.