Plasma-Enabled Green Approaches for Hybrid Nanocarbon Designs

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Abstract: In this contribution, we discuss the advantages of plasma-enabled techniques for synthesizing and processing hybrid nanocarbon structures. Synthesis of nanocarbons using plasma-enabled chemical vapor deposition (PECVD) methods has been discussed. The potential of plasma for controlled surface engineering to tailor the physico-chemical properties has also been illustrated.

1. Introduction

Plasma-enabled techniques can produce structure-controlled nanocarbons with different morphology and structural organizations and tailor them cleanly and safely. Plasma directly assembles the nanocarbons from gaseous carbon precursor into the solid or solid-to-solid form on any substrate material. It also allows the in-situ or post-processing of material. Such processing could be faster than conventional functionalization techniques. Here, we demonstrate the potential low-pressure plasma for the fast and clean production of high-quality nanocarbons.

2. Methods

The plasma-enabled synthesis and processing of nanocarbons were conducted using low-pressure radiofrequency inductively coupled plasma. During the PECVD process, the plasma power (400-700 W), gas mixture (CH_4, Ar, N_2) and deposition time (1-30 min) are varied to achieve vertical carbon nanotubes, nanoforest and nanowalls. Plasma processing of the nanocarbon structures was conducted to improve the electrical and electrochemical properties in which the nanocarbons were exposed to different plasma environments (e.g., nitrogen). The mechanism of N-doping in carbon lattice was investigated by varying plasma treatment times (10-40 s).

3. Results and Discussion

The surface morphology of different nanocarbons produced by the PECVD process is presented in Figure 1. The SEM micrographs illustrate the homogenously grown and closely packed vertically aligned nanocarbons, including nanotubes, nanoforest and nanowalls [1,2]. All the vertical nanocarbons have an average height of 1-2 µm, directly grown on the substrates (mostly conductive metal foils). The structural quality of the nanocarbons was analyzed by Raman spectroscopy, and all the plasma-grown structures featured graphene-related peaks in the regions of 1350-1360 cm^{-1} (D band), 1580-1590 cm^{-1} (G band), and 2720-2730 cm^{-1} (2D band) [3]. The plasma surface-engineered nanocarbons using nitrogen plasma illustrate the formation of a new peak around 400 eV in XPS spectra, which corresponds to the incorporated nitrogen atom [2]. The plasma-tailored nanocarbons demonstrated superior performances for energy storage systems, such as supercapacitors [3,4].

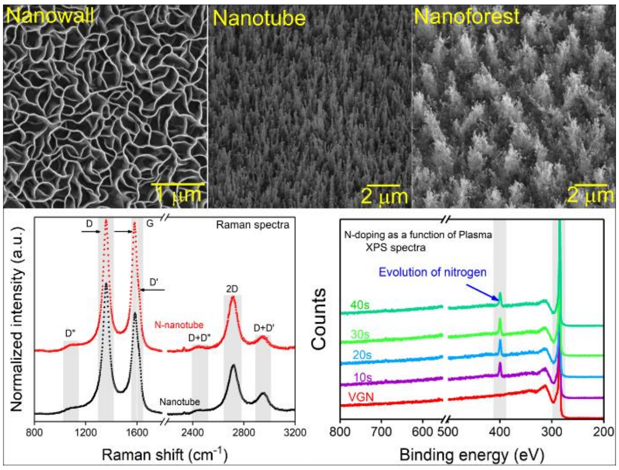

Fig. 1. Surface morphology of plasma deposited nanocarbons [1-4]; Raman spectra of plasma synthesised and engineered nanocarbons [3]; XPS survey spectra of plasma engineered nanocarbons [2].

4. Conclusion

Plasma-enabled techniques were investigated as a fast and facile approach to synthesizing and processing advanced nanocarbons. The morphology and orientation of nanocarbons could be controlled by varying plasma parameters. Also, it is shown that the concentration of heteroatoms in the carbon lattice can be controlled by varying the plasma parameters.

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