Carbon Nanosheets and CNT by RF PECVD

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Abstract

A planar antenna RF plasma enhanced chemical vapor deposition apparatus was built for carbon nanostructure syntheses. When operated in inductive and capacitive plasma discharging modes, two carbon nanostructures, carbon nanotube (CNT) and carbon nanosheet (CNS), were synthesized, respectively. A nanosphere lithography method was developed and used to prepare catalyst patterns for CNT growth. Using capacitively coupled C_2H_2/NH_3 plasma, randomly oriented CNT were synthesized on Ni dot patterned Si substrates. Aligned CNT arrays were grown on SiO_2 coated Si substrates, using both C_2H_2/NH_3 and CH_4/H_2 capacitive plasmas.

When operated in inductive coupling mode, CNS were successfully deposited on a variety of substrates without any catalyst. Carbon nanosheets are a novel two-dimensional structure, have smooth surface morphologies and atomically thin edges, and are free-standing roughly vertical to substrate surfaces. CNS have a defective graphitic crystalline structure, and contain only C and H elements. Typical CNS growth parameters are 680 °C substrate temperature, 40% CH_4 in H_2, 900 W RF power, and 100 mTorr total gas pressure. Morphology, growth rate, and structure of CNS change with the variations in the growth parameters. Increasing substrate temperature yields a less smooth morphology, a faster growth rate, and more defects in CNS; increasing CH_4 concentration causes a faster growth rate and more defects in CNS, but only slightly changes the morphology; increasing RF power results in a more smooth morphology, a faster growth rate, and less defects in CNS; and decreasing total gas pressure induces a less smooth morphology, a faster growth rate, and more defects in CNS. In CNS growth mechanism, a base layer forms underneath the vertical sheets; the growth of CNS is through growth species surface diffusion; the electric field near substrate surfaces promotes and keeps the vertical orientation of the CNS, and the atomic hydrogen etching keeps the CNS atomically thin.

Carbon nanosheets have large surface areas, and can stabilize metal thin films into particles 3-5 nm in diameters. For field emission testing, typical CNS have turn-on fields of 5-10 V/_m, a maximum emission current of 28 mA, an emission current density of 2 mA/mm^2, and a life-time of 200 hours.