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Rapid growth of carbon nanowalls by surface wave microwave plasma-enhanced chemical vapor deposition

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Carbon nanostructures such as graphene and carbon nanotubes are attracting much attention as a building block for nanotechnology. Since the carbon nanostructures have excellent physical and chemical properties. Carbon nanowalls (CNWs), one of the carbon nanostructures, may have advantages for the possible application of them such as field emitter, electrode, storage, coating, since they have unique structure. CNWs are usually obtained on a flat substrate, and have a petal-like structure which stands perpendicular to the substrate surface. A CNW is a sheet with a length of several μm, a height of several μm, and a thickness of several tens of nm. Such sheet is composed of nanographite domains. CNWs have been synthesized by various chemical vapor deposition (CVD) techniques, such as a microwave plasma-enhanced CVD (MPECVD), a radio frequency PECVD, a dc PECVD, electron beam excited PECVD, helicon PECVD, and a hot-filament CVD. In these techniques, CNWs are synthesized on various substrates including Si, SiO_2, Al_2O_3, Ni, Cu, and so on. However, the yield of CNWs are not enough for practical applications. We here report the rapid growth of the high-quality CNWs by a surface-wave MPECVD, which we have developed. We investigate the effects of substrate temperature, carbon feedstock concentration, chamber pressure, and growth duration.

A Si wafer was used as a substrate for the deposition. Deposition chamber pressure was ranged from 15 to 50 Pa. Process gases were methane and hydrogen. Methane gas concentration was ranged from 10 to 50 %. Total flow rate of the process gases was 45 sccm. Substrate temperature was ranged from 540 to 725 ^{o}C. Deposition duration was examined up to 15 min. Frequency and power of microwave were 2.45GHz and 350 W, respectively. Synthesized materials were characterized by scanning electron microscopy (SEM), transmission electron microscopy (TEM), micro-Raman spectroscopy, and nitrogen gas adsorption.

The thickness of the synthesized CNWs film on the Si wafer, which is analyzed by SEM images, increase linearly with the deposition duration regardless the substrate temperature. The growth rate of CNWs film in height was 1 μm/min. From the analysis of TEM images and Raman spectra of the synthesized CNWs film, the structure of the synthesized CNWs are comparable to the previous reports. The Brunauer-Emmett-Teller (BET) surface area was 100 m^2/g. Experimental results indicated that the surface-wave MPECVD technique has an advantage in terms of the growth rate or the yield of CNWs and that the CNWs are promising materials as electrode materials.