Effects of Plasma Treatment on Carbon Nanowalls Grown by Microwave Plasma Enhanced Chemical Vapor Deposition

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In this study, the effects of post-plasma treatment on synthesized carbon nanowalls (CNWs) grown with a microwave were investigated. CNWs were synthesized by microwave plasma enhanced chemical vapor deposition (PECVD), employing a mixture of CH₄ and H₂ gases. The plasma treatment was done in different plasma environments (O₂ and H₂) but under the same condition of synthesized CNWs. Raman spectroscopy, field emission scanning electron microscopy (FE-SEM), energy dispersive X-ray spectroscopy (EDS), and fourier transform infrared spectroscopy (FT-IR) were used to analyze the effects of the post-plasma treatment on the synthesized CNWs. After the H₂ post-plasma treatment, no significant changes in the appearance and characteristics of the CNWs were observed. After the O₂ post-plasma treatment, on the other hand, the CNWs were etched at a rate of 18.05 nm/sec. The Raman analysis confirmed, however, that the structural changes in the CNWs caused by the O₂ post-plasma treatment were insignificant.

Keywords: Carbon Nanowall, Microwave PECVD, Nanostructure, Post-Plasma Treatment.

1. INTRODUCTION
Carbon has various structures and unique and excellent states, such as diamond, fullerene, and nanotube.¹-³ A carbon nanowall (CNW) is a petal-shaped carbon structure that was discovered during a carbon nanotube (CNT) growth experiment.⁴,⁵ It is considered to have a two-dimensional structure wherein nanoflakes stand vertically on a substrate.⁶ A nanostructured material consisting of multilayers of graphene, CNW has high electrical conductivity and electron affinity. It can enhance cell performance when utilized as an electrode, thanks to its very wide reaction surface.⁷ In addition, since CNW does not need metal catalysts in its synthesis, it has the advantage of not requiring post-treatments for removing catalysts such as acid, or plasma treatments for improving CNT purity. To make better use of CNW, CNW performance improvement through post-treatment is needed along with process improvement and optimization. In this paper, CNW was synthesized using methane (CH₄) and hydrogen (H₂) gases as reaction gases by microwave plasma enhanced chemical vapor deposition (PECVD). To determine the effects of the plasma treatment of CNWs, plasma treatments were applied to the synthesized CNWs by microwave PECVD in different plasma environments with oxygen (O₂) and H₂ gases.

2. EXPERIMENTAL DETAILS
I PECVD equipment (WoosinCryoVac, M-PECVD) using a 2.45 GHz microwave source was employed for synthesizing CNWs and for post-plasma treatments. CNWs were synthesized on a Si(100) substrate each cleansed for 10 minutes using an ultrasonic cleaner, in a solution containing trichloroethylene (TCE), acetone, methanol, and deionized (DI) water, and were treated for 45 seconds in a solution diluted with DI water and hydrofluoric acid (HF) to 10:1, to remove the native oxide. The base pressure inside the chamber maintained a vacuum state less than 10⁻³ Torr, and 30 sccm CH₄ gas and 15 sccm H₂ gas were flowed into the chamber. After fixing the working pressure at 1.9 × 10⁻² Torr, the CNWs were synthesized for...