Optical Properties of Oxygen Plasma-Treated Carbon Nanowalls Grown on Glass Substrates

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In this paper, we investigated the effect of oxygen (O₂) plasma treatment on a synthesized carbon nanowall (CNW). A microwave plasma-enhanced chemical vapor deposition (PECVD) system was facilitated to grow CNWs on a glass, using a mixture of CH₄ and H₂ gases. First, the CNWs were post-plasma-treated for different treatment durations, and then their optical properties were analyzed. In addition, the cross-sectional and planar images of the CNWs were examined via field-emission scanning electron microscopy (FE-SEM) depending on the different post-plasma-treatment durations. Then the structural characteristics were analyzed via Raman spectroscopy, and the changes in the light transmittance depending on the O₂ plasma treatment durations were analyzed using UV-Vis spectroscopy. The effects of the post-plasma treatments on the synthesized CNWs were evaluated. The results confirmed that O₂ gas is effective for plasma etching of CNWs.

**Keywords:** Carbon Nanowall, Microwave PECVD, Post-Plasma Treatment, Optical Properties.

1. INTRODUCTION

Active studies are underway on carbon-based materials such as fullerene, carbon nanotubes (CNTs), and graphene due to their excellent physical properties that include chemical stability, high strength, and electric conductivity.¹⁻³ Many studies used a metallic catalyst layer to grow CNTs. However, in some applications, the metal catalyst could adversely influence the device properties. In such cases, additional purification treatments must be applied to the CNT.⁴ Also, graphene is known as difficult to mass-produce because it is a carbon monolayer.

A carbon nanowall (CNW) is a carbon-based material discovered during a CNT growth test, and a two-dimensional structure where nanoflakes have vertically grown on a substrate.⁷ A CNW, being a carbon-based material, has high electrical conductivity and electron affinity, and a much wider reactive surface than one-dimensional CNTs. Therefore, CNWs are expected to become the next-generation carbon-based materials that, if used as electrodes, can enhance the performance of devices. In addition, CNWs are advantageous because their large-scale production is possible without the use of catalysts, via PECVD (Plasma-Enhanced Chemical Vapor Deposition).⁸⁻⁹ To improve the utilization of such CNWs, post-treatment technologies such as low-temperature synthesis, annealing, and plasma treatment are essential.

In this paper, a microwave PECVD system was used to grow CNWs on glass substrates using methane (CH₄) and hydrogen (H₂) as the reaction gases, after which the CNWs were plasma-treated using oxygen (O₂), and then etched. Then the changes in the structural and optical properties of the CNWs were observed.

2. EXPERIMENTAL DETAILS

A 2.45 GHz microwave PECVD system (Woosin Cryovac; M-PECVD) was used to perform the CNW syntheses and the O₂ post-plasma treatments in this study. The CNWs were synthesized using glass substrates, which were cleansed with an ultrasonic cleaner using trichloroethylene (TCE), acetone, methanol, and deionized (D.I.) water, in that order, for 10 minutes each. To remove impurities except the gases needed to synthesize the CNWs, the base pressure in the chamber was set as 1 × 10⁻⁵ Torr using a turbo pump for 30 minutes. Then methane (CH₄) and hydrogen (H₂) were flown into the chamber to keep the working pressure at 2 × 10⁻² Torr, and the CNWs were synthesized for 20 minutes at 1300 W microwave power and at temperatures below 600 °C. The synthesized CNWs were formed with plasmas using O₂ at 300 W microwave power, and then post-plasma-treated for different treatment...