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Vertical Graphene Network: Synthesis and its Emerging Applications

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Carbon nanowalls (CNWs) are few-layer graphenes with open boundaries, standing vertically on a substrate. The sheets form a self-supported network of wall structures with thicknesses ranging from a few nanometers to a few tens of nanometers, and with a high aspect ratio [1]. The maze-like architecture of CNWs with large-surface-area graphene planes would be useful as templates for the fabrication of other types of nanostructured materials, electrodes for energy storage devices, electrochemical and bio-sensors, and scaffold for cell-culturing. Figure 1 shows schematic illustration of CNW structures that should be controlled in the nucleation and growth stages, and modified by the post processes including etching and surface functionalization. The morphology and structure of CNW film grown using plasma-enhanced chemical vapor deposition (CVD) are dependent on the types of carbon source gases, pressure, input power, and temperature of substrate [1,2]. From a practical point of view, structures of CNWs including spacing between adjacent nanowalls, crystallinity and alignment should be controlled according to the usage of CNWs. Moreover, post processes such as integration techniques including etching and coating of CNWs and surface functionalization should also be established. We report the current status of the control of the CNW structures during the growth processes as well as post treatment, together with examples of electrochemical applications using CNWs.

Most important factor affecting morphology, crystallinity and growth rate of CNWs is the balance between carbon precursors and etching radicals. Composition of gas mixture, pressure and power determine the balance between carbon precursors and etching radicals such as H atoms. For example, as the H atoms in the plasma increased, interspaces between adjacent walls increased and crystallinity of CNWs was improved, while the growth rate decreased. Alternatively, the increase of ion flux incident on the growing surface would enhance the nucleation of vertical nanographene, resulting in the formation of dense (small interspaces) CNW films. Moreover, metal nanoparticles such as Ti on Si and SiO_2 enhance the nucleation of nanographene.

As an example of application, CNWs were used as platform for hydrogen peroxide (H_2O_2) sensing. This kind of application is based on the large surface area of conducting carbon and surface modifications including decoration with metal NPs. It is known that H_2O_2 is a major messenger molecule in various redox-dependent cellular signaling transductions. Therefore, sensitive detection of H_2O_2 is greatly important in health inspection and environmental protections. For the H_2O_2 sensing, CNWs were grown on carbon fiber paper (CFP) using plasma-enhanced chemical vapor deposition with CH_4/Ar mixture to increase the surface area. Then, CNW surface was decorated with Pt-NPs by the reduction of H_2PtCl_6 in solution. Cyclic voltammetry results showed that the Pt-decorated CNW/CFP electrode exhibited excellent electrocatalytic activity to the reduction of H_2O_2. Amperometric responses indicate that high-sensitivity detection of H_2O_2 can be attained using Pt-decorated CNW/CFP electrode.

Electrochemical experiments demonstrate that nanoplatform based on vertical nanographene offers great promise for providing a new class of nanostructured electrodes for electrochemical sensing, biosensing and energy conversion applications.

References

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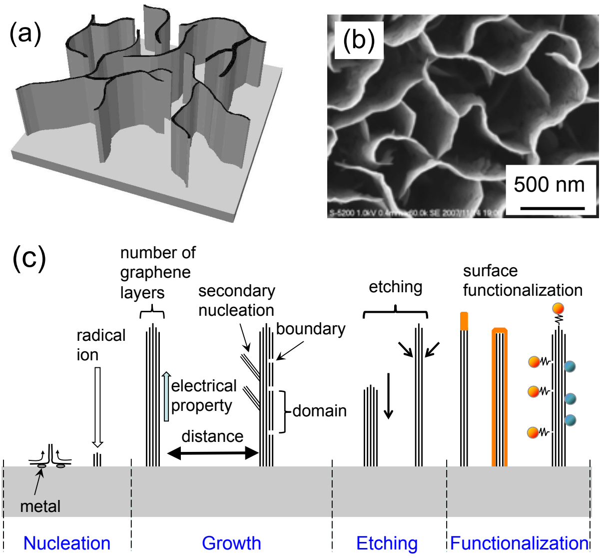

Figure 1 (a) Schematic illustration and (b) SEM image of CNWs, together with (c) schematic illustration of structures of CNWs to be controlled in the nucleation and growth stages, and modified by the post processes including etching and surface functionalization.