Directly grown vertically aligned single-walled CNTs on conducting substrate as electrode material for electrochemical capacitor

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There has been a growing interest in densely packed or vertically aligned single-walled CNTs (VA-SWCNTs) because of their suitability in high potential applications such as supercapacitors, electrodes for lithium-ion batteries, and nanotube-polymer composites [1, 2]. In particular, the SWCNTs were experimentally proved to have a very high specific area value after a simple treatment (controlled slow oxidization), and to be well suit for the requirement of electrochemical devices [3]. Furthermore, well aligned CNT arrays on the substrates offer advantages for a wide variety of high demanded applications compared to those with random and entangled forms [4].

Various methods including the chemical vapor deposition (CVD) have been developed to grow or synthesize aligned CNTs, especially those using the insulating Si wafers and quartz as a substrate. Among them, the alcohol catalytic CVD (ACCVD) method [5, 6] is a promising one which is well-known for its economical merit, wide selectivity of substrates and highly yielding catalytic reaction to grow the CNTs. One of the catalysts commonly used for SWCNTs growth in ACCVD is the ultra-thin Co film (~ 1nm thick) supported on an oxide support film with thickness in the range of 10 ~ 50 nm. Using this supported catalyst and hydrocarbon feedstock, highly dense SWCNTs of even up to millimetre-scale heights can be achieved via the CVD growth technique [7]. However, in the application of electrochemical devices, especially the electrical double layer capacitor (EDLC), it is desired to directly grow the CNTs onto conducting substrates to prepare the electrodes. This procedure can simplify the steps (processes) in fabricating the device, and also might avoid the incorporation with binder material, which in principle could increase the capacitance performance.

Here, we report our research work on growing VA-SWCNTs using ACCVD technique on metal alloy substrates to act as electrode material for the SWCNT based EDLC. Al_2O_3-supported Co catalyst and high purity ethanol (carbon feedstock) were used for the CVD growth process. Optimization of the CNT growth was carried out using a SiO_2/Si substrate, and the same growth parameter was applied to the conducting substrates, such as Inconel 601, and SUS 310S. The as-grown CNTs were characterized using Raman spectroscopy and scanning electron microscope (SEM) for the growth confirmation, and for investigating quality level. Due to the different grain size and structures of the catalyst and Al_2O_3 support layer, analytical studies were carried out separately using atomic force microscope (AFM), X-ray photoelectron spectroscopy (XPS), and SEM. The 2-electrodes EDLC was fabricated using directly grown VA-SWCNTs on the conducting substrates (as current collector).

From our preliminary experimental results, the growth of VA-SWCNTs on conducting substrates was possible and confirmed to have almost similar structural properties with those grown on SiO_2/Si substrate. From the cyclic voltammetric (CV) measurement using aqueous and organic electrolytes, the fabricated EDLCs were successfully worked as electrochemical capacitor, with a relatively good capacitance performance (~ 92 F/g). Further optimization towards higher electrochemical performance such as selection of electrolytes, additional treatments, and alignment control will be continuously carried out. This research would be significance and helpful for the development of high performance nanomaterials based energy storage device.

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