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## Ruthenium Oxide Electrode Deposited on 3D Nanostructured-nickel Current Collector and Its Application to Supercapacitors

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Supercapacitor is attracting growing attention for a promising energy conversion and storage device because of its desirable electrochemical properties such as rapid charge-discharge rate, high power density and long cycle life. Three-dimensional (3D) metal nanostructure has been widely studied since it can provide efficient charge transport along the 3D network in many device applications. In this work, we fabricated well-ordered 3D nickel (Ni) nanostructures using 3D-arrayed polystyrene nano-opal substrates. We also fabricated half-cell supercapacitors by electrodepositing $RuO_2$ onto these nanostructured Ni current collectors and investigated their morphological and electrochemical properties.

**Keywords:** supercapacitor, 3D nanostructure, Ruthenium oxide

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## Growth of Graphene Films from Solid-state Carbon Sources

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A single-layer graphene has been uniformly grown on a Cu surface at elevated temperatures by thermally processing a poly (methyl methacrylate) (PMMA) film in a rapid thermal annealing (RTA) system under vacuum. The detailed chemistry of the transition from solid-state carbon to graphene on the catalytic Cu surface was investigated by performing in-situ residual gas analysis while PMMA/Cu-foil samples being heated, in conjunction with interrupted growth studies to reconstruct ex-situ the heating process. We found that the gas species of mass/charge (m/e) ratio of 15 ($CH_3^+$) was mainly originated from the thermal decomposition of PMMA, indicating that the formation of graphene occurs with hydrocarbon molecules vaporized from PMMA, such as methane and/or methyl radicals, as precursors rather than by the direct graphitization of solid-state carbon. We also found that the temperature for dominantly vaporizing hydrocarbon molecules from PMMA and the length of time, the gaseous hydrocarbon atmosphere is maintained, are dependent on both the heating temperature profile and the amount of a solid carbon feedstock. From those results, we strongly suggest that the heating rate and the amount of solid carbon are the dominant factors to determine the crystalline quality of the resulting graphene film. Under optimal growth conditions, the PMMA-derived graphene was found to have a carrier (hole) mobility as high as ~2,700 $cm^2V^{-1}s^{-1}$ at room temperature, which is superior to common graphene converted from solid carbon.

**Keywords:** Graphene, solid carbon sources, residual gas analysis, rapid thermal annealing