New Carbon Modified Nanostructured Double Heterojunction Hybrid TiO2 Electrode for Electrochemical Charge Storage Applications

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The present work reports on the fabrication and potential applications of a new type of highly conductive nanostructured double heterojunction hybrid electrode (DHJHE) consisting of a nanoporous TiO_2 template modified with carbon. Nanotube arrays are made by the anodic oxidation of titanium in fluoride-based electrolytes to provide a high surface area template for Fe-catalyzed carbon growth under suitable Chemical Vapor Deposition (CVD) conditions. Carbon doping/coating of the surface is confirmed using Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD), and Raman spectroscopy. Carbon is found to exist in the form of graphite nanoparticles on top of TiO2 template and doped within the porous structure to yield a highly conductive TiO_2 electrode. Improvements to the specific capacitance of the electrode are made by eliminating the TiO_2 barrier layer between the Ti substrate and solution by periodically decreasing the voltage during anodization. The specific capacitance of the TiO_2-C electrodes at anodizing voltages of 20V, 40V and 60V is 0.32, 11.91 and 9.92 F/g, respectively. Studies of alternate catalyst loading techniques are also carried out. The specific capacitance of the TiO_2-carbon electrodes using catalyst precursors, including $Fe(NO_3)_3$, Fe nanoparticles in octadecene solution, Ferrocene carboxylic acid, and $Fe(NO_3)_3$ under UV irradiation is 5.00, 5.00 and 15.77 and 5.76 F/g, respectively. Ferrocene carboxylic acid binds more strongly to the TiO_2 substrate forming a more even Fe layer which improves mass transfer during CVD for carbon growth and doping. Electrodes fabricated using this procedure have the potential for use in double layer capacitors and could yield high performance supercapacitors after surface modification with relevant redox species.