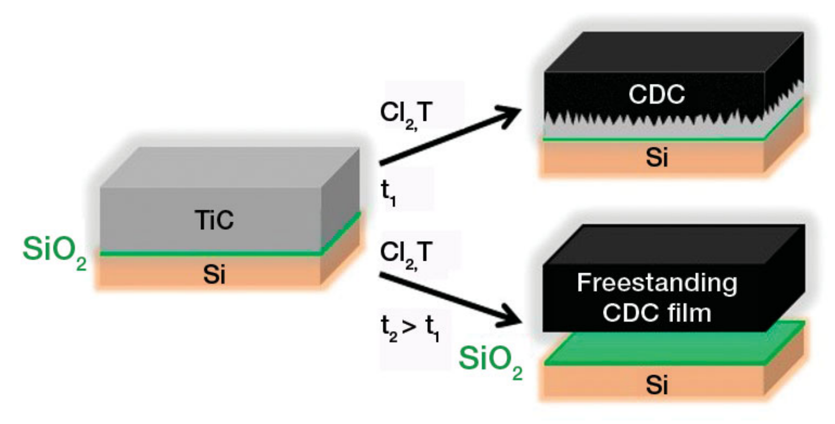
Energy Focus

Elastic carbon films for micro-supercapacitors fabricated by wafer-scale process

What if we could eliminate the need for bulky batteries in wearable electronics? The answer to this question could lie in supercapacitors. A supercapacitor, sometimes referred to as an electrochemical double-layer capacitor, provides both long cycle lifetimes and high power densities for microscale electronic applications. A novel materials processing approach has now enabled wafer-scale, freestanding, and elastic carbide-derived carbon (CDC) thin films to be produced for interdigitated micro-supercapacitors. These CDC thin films exhibit outstanding elasticity, capacitance, and high areal energy density.

A research team led by Patrice Simon in the cross-university Material Research and Engineering Centre at Paul Sabatier University reported the fabrication of CDC-layered structures and characterization of their properties in a recent issue of *Science* (doi:10.1126/science.aad3345). "To [the best of] our knowledge, this is the first example of a freestanding elastic porous carbon film with controlled structure at the nanometer scale," says Peihua Huang, lead author of this work. Since the films are freestanding, this allows for the possibility that they can be integrated with flexible substrates to generate high-performance, monolithic supercapacitors that could be employed in future wearable devices. The subnanometer pores in this high-surface-area carbon film facilitate partial ion desolvation and reversible ion adsorption, leading to high capacitance through charge storage.



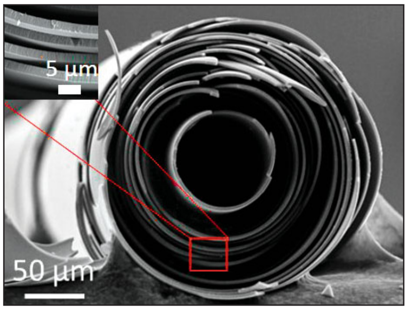


Illustration of a carbide-derived carbon (CDC) thin film, generated by delamination of a sputtered TiC layer on a Si wafer via a chlorination process. Partial chlorination at temperature t_1 leads to a CDC/TiC/SiO_2 structure, followed by full chlorination at a temperature (t_2) higher than that (t_1) produced freestanding CDC film. Cross-sectional scanning electron micrographs show rolled freestanding CDC film delaminated from a Si wafer after full chlorination. Credit: Peihua Huang.

Several techniques have been previously explored in the fabrication of micro-supercapacitors. However, many of these, including wet processing methods, vapor-phase deposition techniques, laser-scribing, and the use of pseudocapacitive materials, are not fully compatible with semiconductor manufacturing processes and thus yield devices with low energy densities or capacitance. The fabrication process described in this work creates a strongly adhering CDC film by sputtering TiC onto a Si wafer. Partial chlorination then promotes the growth of a carbon dendrite microstructure, while subsequent full chlorination with controlled temperature provides control over the carbon pore size in the range of 0.6–0.8 nm to increase electrode surface area.

"The fabrication process of the micro-supercapacitor is fully compatible with mass production at [the] wafer level," says Huang, "and the electrochemical performance of this micro-supercapacitor is collectively advanced in terms of capacitance, energy density, power density, and cycle life."

"The beauty of this study is that the high energy, high power density electrode materials can be naturally delaminated from the rigid substrate during the chlorination process in a controllable manner, without the need for any post solution treatment that may otherwise deteriorate its electrochemical performance," says Sheng Xu, an assistant professor in the Department of Nanoengineering at the University of California–San Diego, with expertise in the field of soft electronics and not connected to this study.

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