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A Versatile Electrode Technology for Energy Storage and Conversion

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Abstract – Electrodes are a key component of many energy storage devices. In ultracapacitors, the electrode determines energy density and cell voltage. In current ultracapacitors only a fraction of the carbon surface actually contributes to the stored charge. This limitation is due to the need to attach the carbon to the substrate using a binder, which reduces the accessibility of the carbon surface. An optimum electrode requires not only the right choice of material but also the appropriately engineered microstructure. In this presentation, we will describe a versatile electrode technology that has application in a broad range of portable energy storage devices.

The current generation of ultracapacitors uses a thin coating of activated carbon applied to an aluminum foil as the electrode. The widespread use of ultracapacitors has in large part been limited by the less than theoretical specific capacitance and associated low energy densities achieved with activated carbon electrodes and their relatively high cost. In batteries, the nature of the electrode is even more complex than it is in ultracapacitors because it undergoes a structural change during operation. Batteries also have an added complexity in that the anode and cathode are different. For radical improvements in energy and power densities of chemical energy storage systems, new materials and chemistries are required. Nanostructured materials with high accessible surface areas and engineered surfaces could revolutionize battery and ultracapacitor technology and provide the critical breakthroughs necessary for a broad range of applications including electric transportation.

The performance of a number of energy conversion devices such as fuel cells and solar cells also depends on the nature of the electrode material. As an example, in dye-sensitized nanocrystalline solar cells titanium dioxide (TiO_2) nanoparticles in contact with a transparent conductor form one electrode of the cell. The accessible surface area is a critical factor in determining cell efficiency. In addition the TiO_2 nanoparticles must be in the correct phase. Being able to engineer electrodes with the desired chemical and physical attributes is critical for realizing many of these novel solar cell and energy conversion technologies.

We have developed a low cost process to produce large area mats of silica Nanosprings™ that provide a thermally and chemically stable support [1]. Nanosprings™ can be grown at temperatures as low as 300°C and can be formed on a range of substrates including flexible materials such as Kapton and aluminum foil and rigid substrates such as silicon, sapphire, and ITO films. The surface of the Nanosprings™ can be further functionalized by the application of nanocrystalline oxides (e.g., ZnO, TiO_2, CuO) and/or metal nanoparticles (e.g., Au, Pt, Pd) [e.g., 2]. The surface can also be conformally coated with a range of activated carbons, nanocrystalline carbons, and highly oriented pyrolytic graphite. This process creates a suite of hierarchical 3D nanostructures that can be engineered for specific electrode applications.

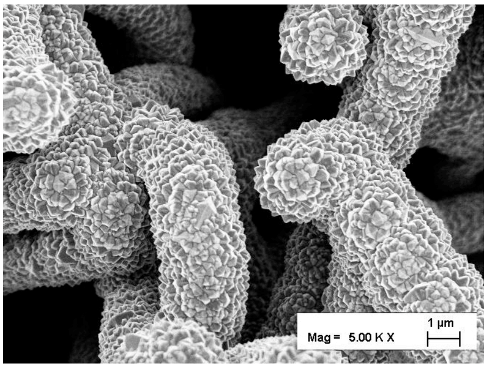

Figure 1: Silica Nanospring mat coated with nanocrystalline titanium dioxide (anatase) suitable for use in a dye-sensitized solar cell.

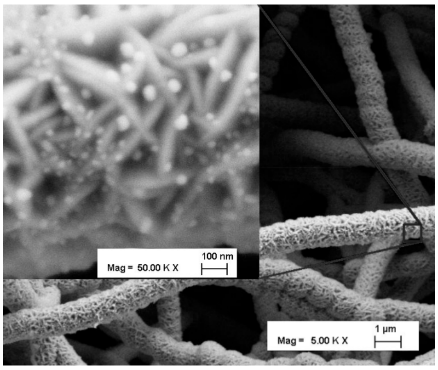

Figure 2: Crystalline ZnO-coated silica Nanosprings decorated with Cu nanoparticles.

References

[1] L. Wang, D. Major, P. Paga, D. Zhang, M. G. Norton, and D.N. McIlroy, Nanotechnology 17, S298 (2006).
[2] A.D. LaLonde, M.G. Norton, D. Zhang, D. Gangadean, A. Alkhateeb, and D.N. McIlroy, J. Nanoparticle Res. 8, 99 (2006).