FABRICATION OF FLEXIBLE ULTRACAPACITOR/GALVANIC CELL HYBRIDS USING ADVANCED NANOPARTICLE COATING TECHNOLOGY

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"Ultra-capacitors" are an essential storage element for a variety of hybrid energy sources ranging from automobile power systems to low-power motes in a distributed sensor network. Ruthenium oxide has demonstrated superior performance in terms of energy storage density (over a Watt-hour per kilogram) when compared to other material systems. But the cost of the oxide has been a major impediment to the widespread use of this technology. In this paper, we report on a the fabrication of ruthenium oxide based ultra-capacitor made with a coating system capable of providing continuous, densely packed layers of the nano-particles a single nano-particle thick. The system is shown in figure 1. Continuous films are shown in figure 2. This technology allows us to control the weight of the expensive oxide to a minimum and to reduce material cost by as much as an order of magnitude without compromising system performance.

In addition, we show how the same process using ruthenium oxide and an oxidizing counter-electrode as an anode can create a mechanically flexible ultra-capacitor, galvanic cell hybrid (a capacitor/battery hybrid.) As such, it can be made to conform to a wide variety of package topologies. As a thin-film battery, we demonstrate a stored energy density of over 2 mW-hr/cm^2 and a burst current delivery capability of over 5ma/cm^2 for 200 seconds. This is the highest area storage density we have seen reported for a flexible cell. The resulting system is shown in figure 3 lighting an LED.

As an added advantage, the voltage developed across a single galvanic electrode pair is relatively low (0.9V to 1.3V, depending on the anode material used), allowing for low-voltage recharging. This is a necessity for RF recharging systems, as it is difficult to create high voltages when the RF source is more than a meter from the power reception point. Electronics integrated into the power source can digitally "restack" the cells to move from charge mode to power delivery at higher voltages. We describe the complete control electronics for the hybrid source, including voltage multipliers, regulators, RF detectors, matching networks and digitally controlled switches capable of shunting between capacitive and galvanic power delivery and required output voltage.

Figure 1: The monolayer nanoparticle coater

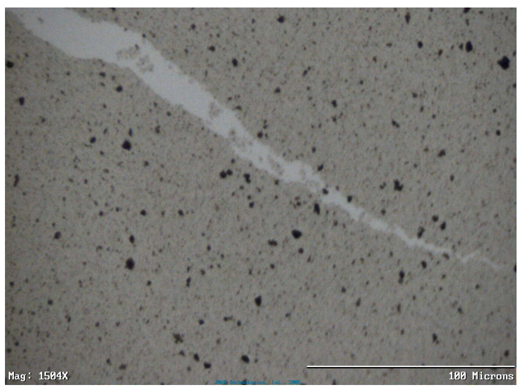

Figure 2: A (scratched) monoparticle thick layer of ruthenium oxide

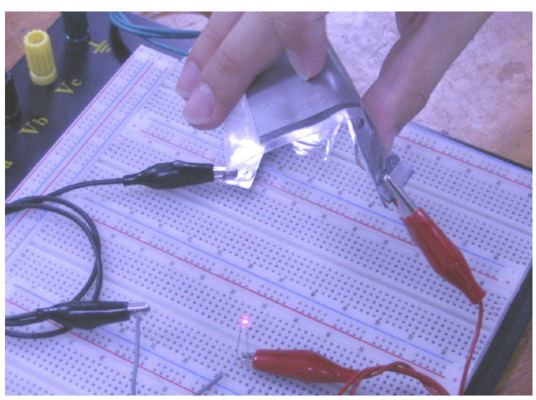

Figure 3: The flexible ruthenium oxide galvanic cell lighting an LED drawing 1.5mA of current.