

Capacitance-enhanced double layer electrochemical cell

Yves Ngu*, Martin Peckerar*, Neil Goldsman*, Michael Khbeis** and George Metzger**

*Department of Computer and Electrical Engineering, University of Maryland, College Park, Maryland 20742

**Laboratory of Physical Sciences, College Park, Maryland 20742

Introduction

We have successfully developed a RuO₂ double-layer capacitor via the use of corrugated structures and a novel electrochemical capacitor cell design. This design yields an electrochemical capacitor of arbitrary geometry to meet energy storage specifications for low-power ad hoc distributed networks and is based on three design approaches. First, the cell utilizes an active surface enhancement through the use of corrugations. Second, the cell is implemented with an ultra-thin "self assembled" dielectric based on RuO₂ in combination with acid to form a double-layer capacitor (1). Finally, corrugation and stacking are combined in a novel way to generate a super-capacitor with battery action (2).

Corrugation

Corrugation (i.e., trench etching) is used to increase the effective surface area. A square corrugation scheme was used (see fig. 1). When the interstitial "struts" are "thin" the area enhancement factor is 4 times the aspect ratio of the trench. In our experiments, there was little correlation between strut thicknesses and aperture area. This was likely due to the microstructures developed during trench etching. However, the measured capacitance may be as high as a factor of 130 greater than the capacitance expected for planar structures.



Fig. 1. Square holes etched in a Si wafer

Double layer capacitor

Double layer capacitance is due to the charge accumulation and charge separation that always occurs at the interface of an electrode immersed into an electrolyte solution (see fig. 2). The excess charge on the electrode surface is compensated by an accumulation of excess ions of the opposite charge in the solution. The amount of charge is a function of the electrode potential (3). We use RuO₂ as the electrode material.

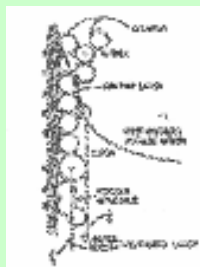


Fig. 2. Model of double layer

There is a redox process that take place at the inert (metal) electrode, the aqueous acid reacts with the electrode.

Packaging approach

Our double-layer capacitor packaging approach is illustrated in fig. 3. It consists of RuO₂ paste compounded and applied to a gold-coated microscope slide and dried. This forms a porous glaze over the gold surface. An acid-resistant epoxy is used to affix a Teflon o-ring to the surface of the slide. A few drops of sulfuric acid are used to wet the filter paper. A metal insert is pressed onto the wet filter paper. The edge of the insert is epoxy sealed.

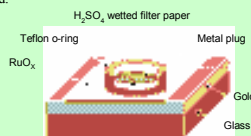


Fig. 3. Single-layer double-layer RuO₂ capacitor

Results of single cell

The capacitance of the device was estimated via a capacitive discharge of an RC circuit (see fig.4). Initial charging voltage is 0.75V. Two regions of discharge are evident followed by a semi stable region. The cell initially engages in a rapid discharge over a time period of about 6 seconds, consistent with a capacitance of 3.5mF/cm². Over the next 30 seconds the cell voltage drops from about 0.3V to 0.1V, where it stabilizes. If we ignore the initial 6 seconds, the discharge from 0.35V to 0.1V would be consistent with a capacitance of 0.23mF/cm². The voltage level after 40 seconds points to some battery action within the device. The battery behavior was examined by charging the device with a 0.75V power source for about 2min and monitoring its voltage potential with no loads during and after charging (see fig. 5). After 24 hours, the device's potential was still close to 100mV.

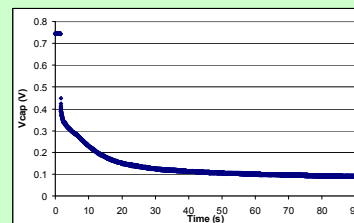


Fig. 4. RC discharge of capacitor of single cell

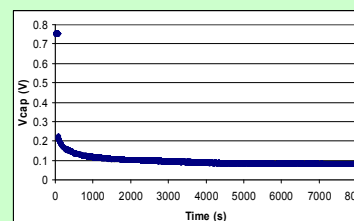


Fig. 5. Charge storage capability of single cell

Stacked structure

The resulting cell is "stackable", as shown in fig.6. Corrugations are accomplished on both side of a thin glass die with RuO₂ applied as shown in fig.3. Each die is separated by acid resistant filter papers. All dies are then connected in parallel to a metal electrode while the other electrode is in direct contact with the acid. The entire structure is contained in an insulated cell. The resulting capacitance of the structure is two times (2 sides) the based capacitance (~0.23mF/cm²) multiplied by the area enhancement factor (~100) and the stacking factor. Hence, stacking 20 dies will yield a total of about 1F in a square centimeter of 1mm thickness.

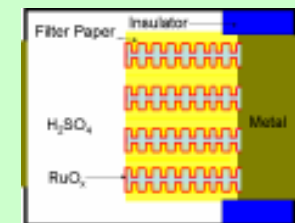


Fig. 6. Stacked electrochemical cell

Conclusions

The next task is to generate stacked structure. A fabrication process need to be establish that enable the assembly of the stacked structure. Furthermore, the battery action needs to be studied in more details.

Literature cited

- 1- C. Hu, W. Chen and K. Chang, *J. Electrochem. Soc.* **151**, A281-A290 (2004).
- 2- B. E. Conway, *Electrochemical Supercapacitors*, Scientific Fundamentals and Technological Applications, Kluwer Academic, New York (1999).
- 3- B. E. Conway, *Electrochemistry Encyclopedia*, Electrochemical Capacitors: Their Nature, Function and Applications Evolution. <<http://electrochem.cwrw.edu/ed/encycl/art-e03-elchem-cap.htm>>. Accessed Jan. 2006.

Acknowledgments

We thank I. Güör for laboratory assistance, Mary Juana for seeds, Herb Isside

For further information

Please contact yngu@umd.edu.