Energy and Power of Titanium Electrolytic Capacitors

Donald McGervey and Gerhard Welsch

Department of Material Science and Engineering
Case Western Reserve University
Cleveland, Ohio

The energy and power of titanium electrolytic capacitors made from thin sheets of sponge will be compared to that of other energy storage devices. Capacitors have a lot more power than batteries, but store less energy. For many applications it is desirable to have a device that has both power and energy. Figure 1 shows a comparison of batteries, electrochemical capacitors, electrolytic capacitors, and ceramic capacitors.

The energy density of a capacitors dielectric depends on the dielectric constant and the dielectric strength. TiO_2 has a dielectric constant of 150 and a dielectric strength of 7.5MV/cm when grown on a titanium surface by anodizing. This yields an energy density of 375J/cm^3. By doping the titanium substrate with earth alkali elements before anodizing we have been able to achieve a dielectric constant of 900 with no decrease in dielectric strength. With the doped titanium a dielectric energy density of over 2000J/cm^3 was achieved. The energy density of a fully packaged capacitor depends on the dielectric energy density and on the fraction of the capacitor volume occupied by the dielectric (packaging efficiency).

Dielectric films can be grown as thin films only. A 30V capacitor has a dielectric thickness of 40nm. Sheet metal is typically over 1000 times as thick. A piece of titanium sheet metal anodized to 30V would have a very low packaging efficiency and a low energy density. To increase the energy density we must increase the surface area. We do this by growing a sponge on the surface of the sheet metal (figure 2 shows a 5000x image of titanium sponge on foil). A shallow sponge can increase the surface area by more than 100 and have the entire surface accessible. Accessibility of the surface gives the capacitor a high power density.

Acknowledgement: Research support by NRO

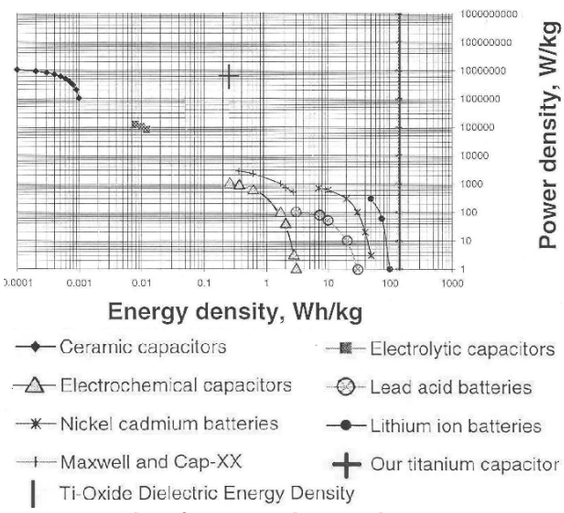

Figure 1 Plot of energy and power densities
Data is from Lipton and from Miller and from measurements by the authors.

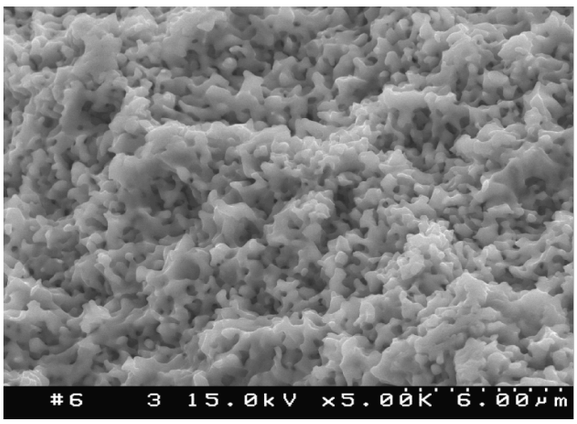

Figure 2 SEM image of titanium sponge on foil. Magnification 5000x