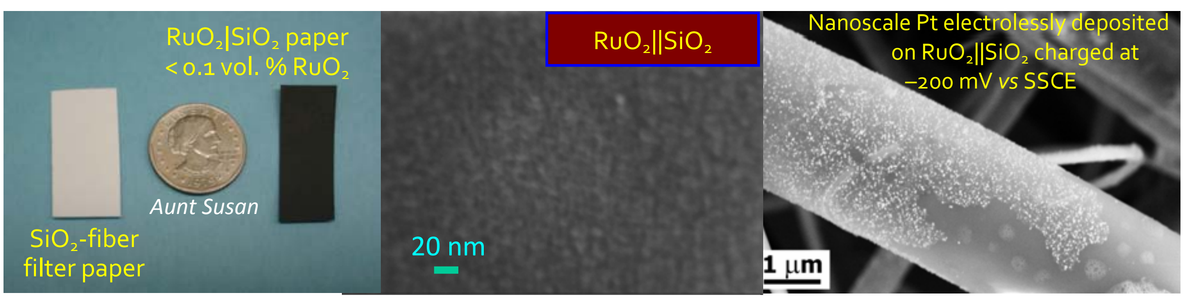
Scientific Accomplishments: Fundamental Nanoscale Phenomena and Processes (PCA 1)

Using low-cost nanofabrication to make the most of a scarce, but technologically precious metal

In the pursuit of a robust, flexible, scalable, and inexpensive electronic and catalytic substrate as well as a carbon- and ionomer-free fuel-cell electrode, we developed a simple method to deposit an electronically conductive, ~3-nm-thick skin of RuO_2 onto the curved fiber surfaces in silica filter paper. Sub-ambient thermal decomposition of ruthenium tetroxide in nonaqueous solution leads to the formation of nanowebs and ultimately nanoscale films of RuO_2 on the silica surfaces thereby converting the rugged and inexpensive substrate into a multifunctional, flexible, and highly conductive macroscopic object with ~0.5 S/cm of electron conductivity at a miniscule volume fraction (<0.1 vol.%) of RuO_2, thereby maximizing the utilization of this expensive, but technologically important platinum-group metal. Expressing the ruthenia as a nanoskin wrapped contiguously around a curved dielectric imparts a four-fold enhancement in the electron conductivity compared to polycrystalline RuO_2. The $RuO_2||SiO_2$ fiber membranes are electrochemically addressable, can be modified with metal nanoparticle or molecular catalysts, and have the technologically important attributes of:

(1) low weight loadings of RuO_2, ~0.3 mg/cm^2 of silica paper (at the current Ru market value of $300/troy ounce that equates to 0.3 cents/cm^2);
(2) high electrifiable surface area, 90 m^2/g(RuO_2);
(3) high specific capacitance and therefore effective energy storage, 650 F/g(RuO_2);
(4) fast electron-transfer kinetics.

The thickness of the RuO_2 coating and the value of the specific capacitance demonstrates that the ruthenia acts as though >90% of the atoms are expressed at the surface; in essence, the NRL protocol creates the equivalent of an exfoliated layer of rutile RuO_2 units as supported and stabilized by the silica fibers of the paper. We can now attain the vaunted electronic and electrochemical properties of ruthenium oxide—high electronic conductivity, high specific capacitive charge storage, and fast electron transfer—by distributing the material at modest amounts on dirt cheap, insulating substrates.



Patents or other steps toward commercialization: A patent application has been filed based on these NRL-developed materials: "Nanoscale coatings of RuO_2 on flexible, porous glass substrates with high conductivity." D. R. Rolison, C. N. Chervin, J. C. Lytle, J. W. Long, K. A. Pettigrew, [Navy Case #98,962].

Contributing Agency: DoD / NRL