

**Abstract: “Electric Field Induced Microstructure Instability: Ion migration, Electrosintering and Grain Growth”**

Without sensing any physical force, a neutral object in an ion conducting solid can move in a uniform electric field by coupling localized interface counterion diffusion with a global ion wind. This happens to pores and gas bubbles in a fast  $O^{2-}$  conductor, yttria-stabilized zirconia (YSZ), which has a robust coupling between the prevailing  $O^{2-}$  wind and  $Zr^{4+}/Y^{3+}$  surface diffusion even though cation's diffusion is frozen everywhere else. Very pronounced migration and electro-sintering in thin ceramics are observed at temperatures and voltages standard for YSZ fuel cells and electrolysis cells. This effect should apply to any electrically-loaded multiphase ionic conducting solid and can lead to phase accumulation and electrode debonding, resulting in unexpected degradation and failures of electrochemical devices. As the velocity-field relation obeys a pseudo Stokes-Einstein equation, being inversely dependent on the object size, an especially enhanced size effect is expected in nano composites. At higher temperatures, enhanced grain growth favouring the cathode side is also observed which implicates a non-equilibrium effect on cation diffusion due to supersaturated defects. At lower temperatures, electro-sintering without grain growth leads to unprecedentedly small grain size for 8YSZ.

**“A Size-dependent Nanoscale Metal-Insulator Transition in Random Materials”**

Insulators and conductors with periodic structures can be readily distinguished because they have different band structures, but the difference between insulators and conductors with random structures are more subtle. In 1958 Anderson provided a straightforward criterion for distinguishing random insulators from random conductors based on the “diffusion” distance  $\zeta$ : for electrons at 0K, insulators have a finite  $\zeta$ , whereas conductors have an infinite  $\zeta$ . Aided by a scaling argument, this concept can explain many phenomena in disordered electronic systems, such as the fact that the electrical resistivity of “dirty” metals always increases as the temperature approaches 0K. But, surprisingly, there have been no attempt to engineer a metal-insulator transition by making the sample size less than or more than  $\zeta$ . Recently, we reported such an engineered transition using six different thin-film systems: two are glasses that contain dispersed platinum atoms, and four are single crystals of perovskite that contain minor conducting components. With a sample size comparable to  $\zeta$ , transitions can be triggered by using an electric voltage or ultraviolet radiation to tune  $\zeta$ ; via the injection and extraction of electrons.

With a film thickness  $\sim \zeta$ , bipolar ReRAM made of these materials have novel features. They do not obey Ohm's law, have superior uniformity of switching parameters, short read/write/erase time (<15 ns), long retention time, and highly adjustable switching voltages and high- $R$  resistance. These features offer new design freedom for integrated circuits.