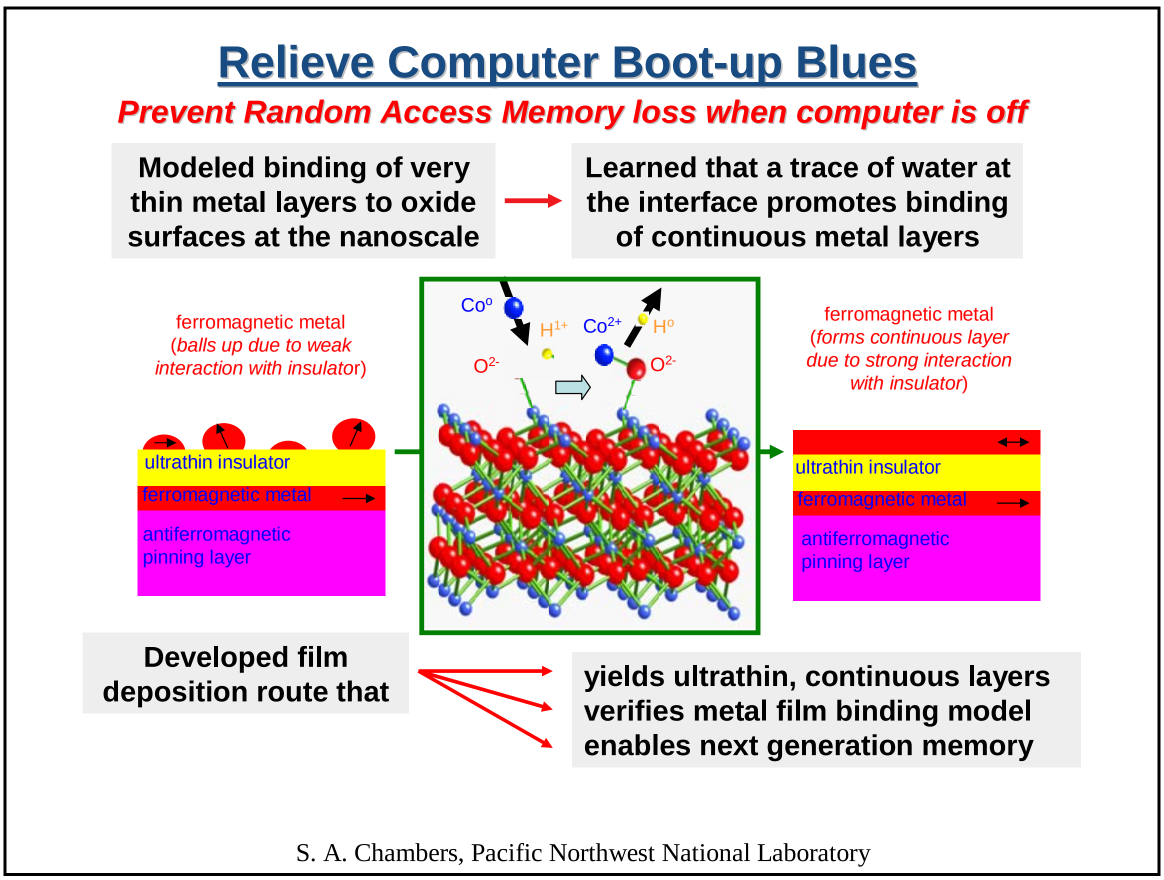
Ultrathin, Laminar Films for Instantaneous Computer Boot-up

Investigator: S. A. Chambers, Pacific Northwest National Laboratory

A new technique has been developed to deposit metal atoms on thin oxide layers, which will help next-generation computers boot up instantly by making entire memories immediately available for use. The method, described in a recent article in *Science*, anchors ultrathin metallic cobalt layers on sapphire by using a surface chemical reaction, which overcomes the island formation problem. The tendency to form discontinuous metal films hinders our ability to form interfaces of ultrathin, laminar metal films on oxides for use in microelectronics and other technologies where nanostructural control is desired. The new inexpensive trick to prevent island formation is as simple as exposing thin oxide films to water vapor before depositing the metal layer. The thin metal layer achieves epitaxial crystallinity after the deposition of only a few atomic layers. This process should be applicable to a wide range of metals on metal oxides

Reference: S. A. Chambers, T. Droubay, D. R. Jennison, and T. R. Mattsson, *Science* 297, 725 (2002).

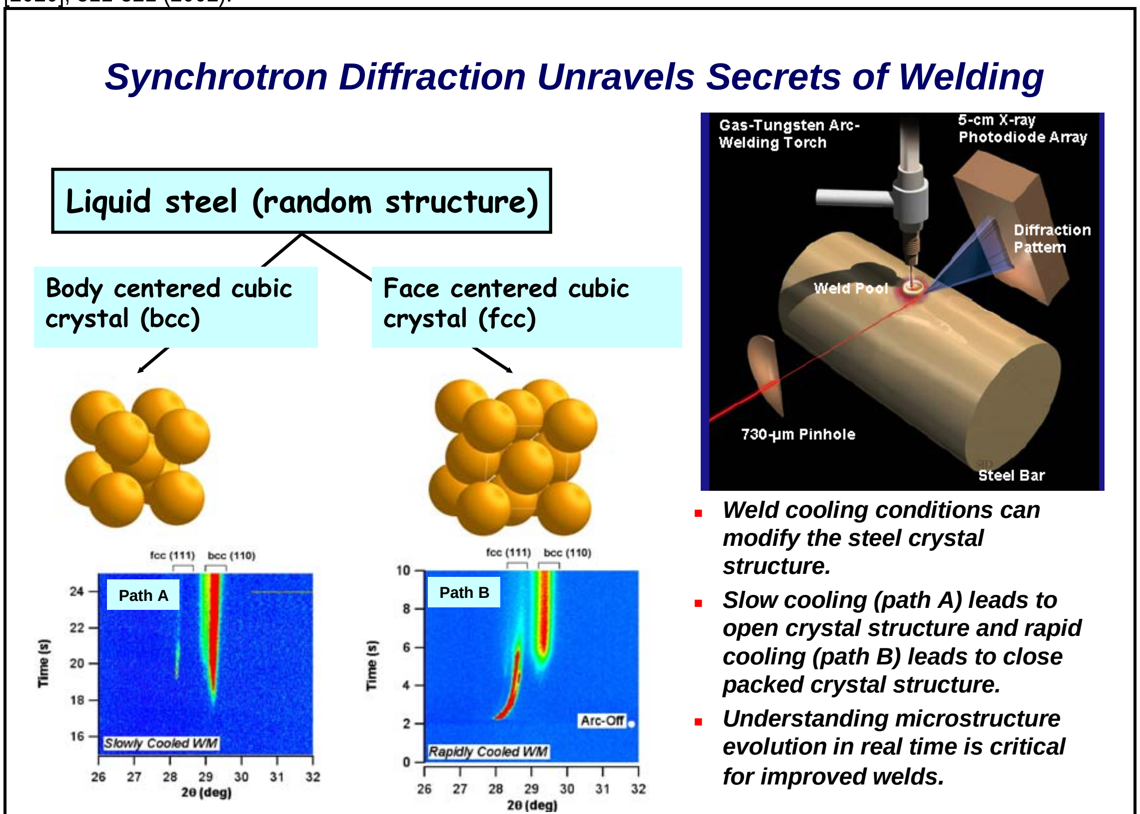


Synchrotron Diffraction Research Unravels Secrets of Welding

Investigators: S. S. Babu, J. M. Vitek, S. A. David, ORNL and J. W, Elmer, LLNL

Time-resolved X-ray diffraction has been used to reveal, in real time, the *in situ* phase evolution during melting and subsequent solidification of a multi-component steel weld. Welding is a critical joining technology used worldwide in industries such as energy, automotive, aerospace, construction, and chemicals. Rapid cooling during welding induces numerous non-equilibrium phase transformations. Theories have been developed to describe this transition by extending equilibrium thermodynamics without direct experimental verification. Time-resolved X-ray diffraction, using synchrotron radiation, was used for the first time to monitor in-situ phase evolution during melting and subsequent solidification of a multi-component steel weld with a time resolution of 0.05 seconds. The in-situ observations revealed the conditions under which non-equilibrium face-centered cubic structure and equilibrium body-centered cubic structure formed. The results show that extensions of equilibrium thermodynamics to rapid cooling conditions are not valid for steel welds containing fast diffusing (carbon) and slow diffusing (aluminum) atoms. Since microstructure controls the weld properties and performance, this new ability to observe the competition of multi-component phases at the microstructural level will make possible designing stronger and tougher welds, chemically tailored for optimum performance.

Reference: S.S. Babu, et al., *Acta Materialia* 50, 4673-4781(2002). S.S. Babu et al., *Proc. Royal Soc. Lond. A* . 458 [2020], 811-821 (2002).



S. S. Babu, J. M. Vivek, S. A. David (ORNL) and J. W. Elmer (LLNL)

Precision Electrical Measurements with Nanometer Spatial Resolution Discover New Properties

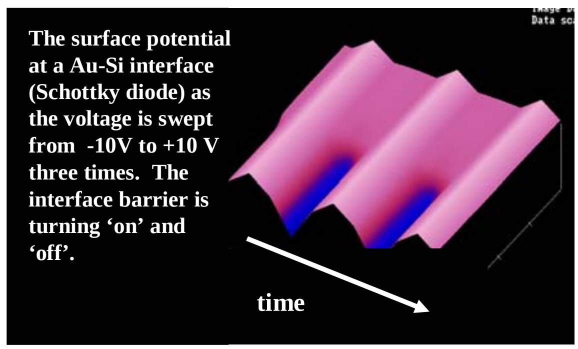
Investigator: Dawn A. Bonnell, University of Pennsylvania

For the first-time, suppression in dielectric-constant has been observed directly at grain boundaries, contradicting traditional assumptions generally made about grain-boundary behavior. This discovery was enabled by new techniques, developed to measure local electromagnetic properties. These new techniques now permit a fundamental understanding of the mechanism by which solid-solid interfaces and crystalline defects control the behavior of nanostructured as well as macroscopic materials. Scanning impedance microscopy and nano-impedance spectroscopy were developed and utilized to access the frequency dependence of electron transport in order to examine mechanisms of electron trapping and scattering with unprecedented nanometer spatial resolution. In combination with the temperature dependence of these local properties, the frequency dependence yields fundamental insight into electron transport. The energy of the valence and conduction bands at individual defects was determined using the voltage dependence of the contrast in scanning impedance images of current through a molecular wire, such as a single walled carbon nanotube.

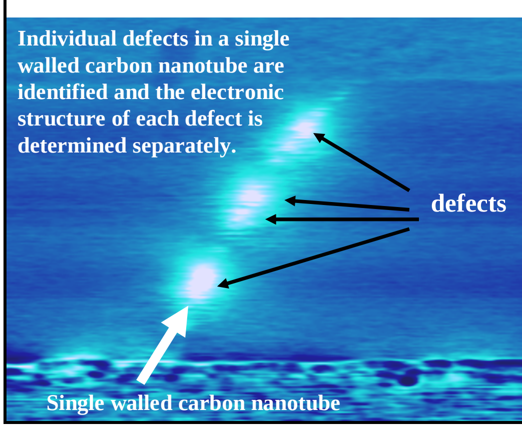
References: M. Freitag, S. Kalinin, D. Bonnell, A. T. Johnson *Phys Rev Letters* 89, 216801(2002); R. Shao, S. Kalinin, D. A. Bonnell *Appl. Phys. Lett.* 82, 1869 (2003); D. Bonnell, S. Kalinin *Z. Metallkd 94*, 226 (2003).

Transport Mechanisms in Nano Devices: Scanning Impedance Microscopy

D. Bonnell, The University of Pennsylvania



SIM probes electronic transport processes over 6 orders of magnitude of frequency and has been used to probe interactions of electrons with atomically abrupt interfaces, grain boundaries and individual defects in molecular wires, nanowires and nanotubes.



The frequency dependence of both the amplitude and phase change across an interface, boundary, or defect can be used to probe transport processes at nm scales. Resistance (R), capacitance (C), and trap state relaxation time (ω), for the boundary below are determined from the spectra.