Functional Oxide Thin Films

Jiwei Lu
University of Virginia
Engineering Physics
Department of Materials Science

Oxides thin films offer various functionalities and have been widely used in the today's electronic devices for information processing. In this presentation, I choose a few examples to show the facets of interesting physical properties of oxides and the potential applications in the future Electronics and Spintronics.

The discovery of spin torque transfer (STT) opens a new avenue of the scaling of Magnetic Random Access Memory (MRAM), which could become a universal memory. However, the very large critical current (10^{-6} A/cm^2) required to switching the magnetic layer remains a challenge to implement this technique in the next generation of MRAM. We are investigating novel oxide films which could replace the existing magnetic layers and tunnel barriers. We are investigating a group of oxides such as VO_2 for the tunnel barrier, and $RuCrO_2$ for magnetic layer. VO_2 undergoes an insulator to metal (M-I) transition at about 340 K. We have recently discovered that VO_2 also undergoes an electronically driven M-I transition at current densities around 10^4 A/cm^2, which will significantly reduce the switching energy/voltage compared to the state-of-art MgO barrier. CrO_2 is a half metal (100% spin polarization) but is rather difficult to prepare with surfaces that retain the stoichiometric oxygen composition and the half metallic behavior. We have recently prepared $RuCrO_2$ (RCO) films that retain both the ferromagnetism and metallic behavior of $CrO_{2,}$ but are easy to prepare in our novel deposition systems and are atomically smooth. Another method to lower the current density needed for spin momentum transfer switching is to have a dynamically variable magnetization for the switching layer of the tunnel junction. It has recently been demonstrated that the switching field for a nanocomposite of ferromagnetic and multiferroic oxides can be significantly modified with a small electric field. For example, the composite ferroelectromagnet has been made from $BaTiO_3$ (or $BiFeO_3$) and $CoFe_2O_4$. This new discovery provides an alternative path to reduce the switching current and power by reducing significantly the magnetic anisotropy of magnetic layers using an applied electric field.

Materials that have a non-linear, electric field tunable permittivity are of great interest for tunable microwave devices and circuits applications, such as phase shifters, filters, and tunable matching networks. A novel material, $Bi_{1.5}Zn_{1.0}Nb_{1.5}O_7$ (BZN) with the cubic pyrochlore structure, which is not a ferroelectric, has recently attracted consideration attention for its high permittivity and low losses. BZN thin films prepared by *rf* magnetron sputtering showed a relatively high permittivity of ~180 and an extremely low dielectric loss of ~ 5×10^{-4} at 1 MHz. This dielectric loss was unusually low for complex oxide thin films at room temperature and was of the same magnitude of BZN ceramics. BZN thin films exhibited a tunability of 55% at the applied electric field of 2.4 MV/cm. I will also discuss the impact of thermal strain on its low temperature dielectric relaxation.