Local Electronic and Structural Studies of Transition Metal Oxides: Magneto-Structural Correlations

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Introduction

A key component of spin valves is a magnetic layer, typically of permalloy ($Ni_{0.81}Fe_{0.19}$), which has its magnetization pinned in a fixed direction by an adjacent antiferromagnetic (AF) pinning layer such as NiO. Pinning takes place through a phenomenon called exchange biasing whose physical mechanism remains poorly understood [1]. Spin-valves processed from high-temperature annealed films show a greatly increased coercivity of the pinned layer but similar exchange bias in comparison with control samples. The relationships between the magnetic and structural properties of NiO, Fe doped NiO and α-Fe_2O_3 is central to understanding the fundamental physics of spin valves.

Methods and Materials

In our study we performed Ni K-Edge XAFS measurements on a pair of 2000 Å films (one annealed) prepared on SiO_2 substrates. The experiments utilized the high energy resolution, stability and small beam size at MHATT-CAT's microfocus facility to carry out x-ray absorption measurements on thin films (NiO spin valves) and on samples at high pressure (up to 2 GPa). The local structure of NiO spin valves and manganite oxides were explored.

In addition to the pilot study performed on the NiO films, we also initiated the first study of the structure of the magneto-resistive manganite system under pressures less than 1.6 GPa [2] utilizing a diamond anvil cell. The system $R_{1-x}D_xMnO_3$ (typically, $La_{1-x}Ca_xMnO_3$) is known to display changes in resistivity with pressure when in the magnetic state. It is thought that changes in the Mn-O-Mn bond angle and consequently a change in the Mn 3d overlap modifies the conduction electron hopping probability.

Results and Discussion

In Fig. 1 we see the XAFS signal for the as-prepared and annealed samples. Note the significant enhancement of the signal upon annealing. This result indicates that pinning is reinforced by an AF layer which is of high structural order. More detailed measurements on samples with a broader range of annealing conditions and thicknesses, combined with structural analysis, will be performed in the future to provide an in-depth correlation between pinning and local structure.

We measured Bi L3-Edge (13.4 keV) near edge absorption spectra of $Bi_{1-x}Ca_xMnO_3$ (x=0.875 canted ferromagnetic insulator). The spectra at 2 GPa (20,000 atm) and 1 atm are shown in Fig. 2. Note that the splitting and relative intensities of the two main peaks do not change significantly with pressure. This implies that there is no significant buckling of the Mn-O-Mn bond angle at these pressures. Simultaneous temperature dependent resistivity and structural studies under pressure will be conducted next in order to define the structural component of the pressure induced changes in transport in these systems.

Fig. 1: XAFS spectrum of NiO on Si.

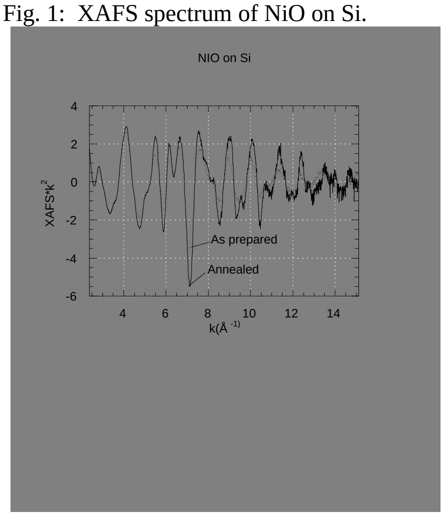
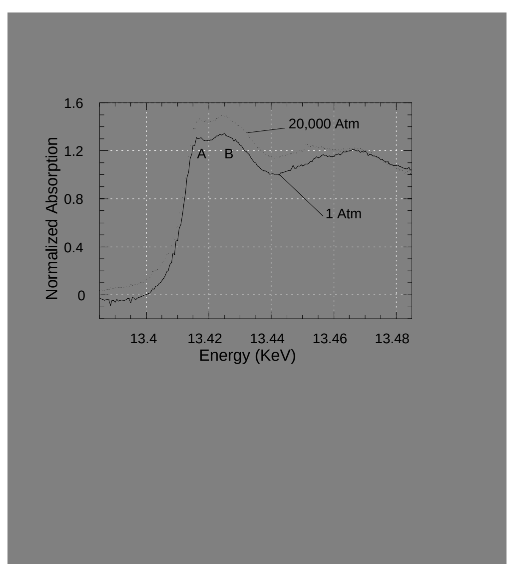


Fig. 2: Near edge spectrum of $Bi_{1-x}Ca_xMnO_3$ At pressure of 2 Gpa and ambient



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