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X-ray Characterization of Oxide-based Magnetic Semiconductors

Y.U. Idzerda, A. Lussier, J. Dvorak, A. McClure, M. Liberati, J. Holroyd,
Montana State University

E. Arenholz,
ALS/LBNL

S.R. Shinde, S.B. Ogale, and T. Venkatesan,
University of Maryland, College Park

Although the evidence for magnetic semiconductors (not simply semiconductors which are ferromagnetic) is compelling, there is much uncertainty in the mechanism for the polarization of the carriers, suggesting that it must be quite novel. Recent experimental evidence suggests that this mechanism is similar to the polaron percolation theory proposed by Kaminski and Das Sarma,[1] which was recently applied specifically to doped oxides by Coey et al.[2] where the ferromagnetism is driven by the percolation of polarons generated by defects or dopants. We have used X-ray absorption spectroscopy at the L-edges and K-edges for low concentrations transition metal (TM) doped magnetic oxides (including TiO_2, $La_{1-x}Sr_xO_3$, HfO_2, and In_2O_3). We have found that in most cases, the transition metal assumes a valence consistent with being at a substitutional, and not interstitial site. We have also measured the X-ray Magnetic Circular Dichroism spectra (including TM doped GaN and GaAs systems). Although these materials show strong bulk magnetization, we are unable to detect a robust dichroism feature associated with magnetic elements in the host semiconductor. In the cases where a dichroism signal was observed, it was very weak and could be ascribed to a distinct ferromagnetic phase (TM metal cluster, TM oxide particulate, etc.) separate from the host material. This fascinating absence of a dichroic signal and its significant substantiation of important features of the polaron percolation model may help to finally resolve the issue of ferromagnetism in magnetically doped oxides.

[1] Kaminski and S. Das Sarma, Phys. Rev. Lett. **88**, 247202 (2002).
[2] J. M. D. Coey, M. Venkatesan, and C. B. Fitzgerald, Nature Materials **4**, 173 (2005).