# Study of valence state and magnetic property of Fe in Fe-doped ZnO thin films

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Diluted magnetic semiconductors (DMSs) based on ZnO have attracted considerable attention in the past years, because some transition metal (TM)-doped ZnO DMSs exhibit ferromagnetism at room temperature (RT) [1]. Recently, Chang *et al*. [2] observed room temperature ferromagnetism in Co and Al co-doped ZnO.

In the present work, 5% Fe-doped and 5% Fe, 1% Al co-doped ZnO epitaxial thin films were fabricated on (0001)-α$Al_2O_3$ (sapphire) substrates by pulsed laser deposition technique. The film thicknesses were about 2000 Å. Here, we report on Fe $L_{2,3}$ x-ray absorption (XAS) and x-ray magnetic circular dichroism (XMCD) experiments of $Zn_{0.95}Fe_{0.05}O$ and $Zn_{0.94}Fe_{0.05}Al_{0.01}O$ thin films to study the electronic structure and the magnetic properties of Fe ions embedded in the lattice of ZnO thin films that show ferromagnetism at room temperature. The X-ray diffraction patterns clearly showed that there was no metallic Fe cluster. From the line shape of Fe $L_{2,3}$-edge XAS in both films, it is confirmed that Fe ions are in both the 3+ and 2+ states while the $Fe^{2+}/Fe^{3+}$ ratio increases in the $Zn_{0.94}Fe_{0.05}Al_{0.01}O$ thin film compared to $Zn_{0.95}Fe_{0.05}O$ and the ferromagnetism comes from both $Fe^{3+}$ and $Fe^{2+}$ ions. In the $Zn_{0.94}Fe_{0.05}Al_{0.01}O$ thin film, the magnetization decreases compared to $Zn_{0.95}Fe_{0.05}O$ although the conductivity increases, indicating that ferromagnetism is not carrier induced.

[1] T. Dietl *et al*., Science 287, 1019 (2000).
[2] G. S. Chang *et al*., J. Phys.: Condens. Matter 21, 056002 (2009).