# XPS studies of (Zn,Co)O/Si interfaces

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Zinc oxide doped with cobalt has been intensively studied because of a theoretical prediction of its intrinsic ferromagnetic behavior. The ferromagnetic response at room temperature in (Zn,Co)O has been measured and reported by several groups. The origin of the ferromagnetism is not fully understood and usually related to defects in the ZnO lattice, metal inclusions of the nanometer size or formation of foreign (Co,O) phases. However, it has been demonstrated that uniformity of transition metal distribution plays a crucial role in the magnetic response of the (Zn,Co)O system [1].

We investigated (Zn,Co)O films grown on silicon substrates by Atomic Layer Deposition (ALD) using organic zinc and cobalt precursors. The samples with different thickness and cobalt content (2%-18%) were obtained at various temperatures ($200^oC$-$300^oC$) and with different sequences of ALD cycles [2]. The XPS depth-profiling measurements were performed in order to get a simultaneous information on the uniformity of Co distribution and the chemical state of cobalt. The (Zn,Co)O films were sequentially etched by $Ar^+$ ions and after each sputtering step XPS spectra were recorded [3]. The relative atomic concentration of zinc, oxygen and cobalt were evaluated from the *Zn2p*, *O1s*, *Co2p* and *Si2s* core level XPS spectra. Cobalt was found to be present across all investigated films, but its distribution was different for ferromagnetic and paramagnetic samples. In the (Zn,Co)O films that give ferromagnetic response at room temperature, the relative increase of Co concentration was detected within the (Zn,Co)O/Si interface area, which was about three times higher than in the rest of the sample. Such a Co rich layer was not observed for the samples with paramagnetic response. The analysis of the *Co2p* XPS spectrum reveals a metallic cobalt at the (Zn,Co)O/Si interface. The X-ray Absorption Spectroscopy (XAS) and X-ray magnetic circular dichroism (XMCD) measurements were performed at the surface of ferromagnetic (Zn,Co)O film and inside the crater made by the XPS profiling. The Co L-edge XAS spectra indicate that the number of *Co(3d)* holes decreases sharply at the (Zn,Co)O/Si interface and approaches the value for Co metal. The Co L-edge XMCD was detected at the interface, allowing for the determination of the spin and orbital moments per Co atom. We conclude that the magnetic signal derives from cobalt enriched layer at the (Zn,Co)O/Si interface.

The work was supported by the EU through the Innovative Economy grant (POIG.01.01.02-00-008/08) and FunDMS Advanced Grant within the “Ideas” $7^{th}$ Framework Programme of the EC.

**References**

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