P5

ELECTRONIC STRUCTURE OF Mn DEPOSITED ZnMnO FILMS GROWN BY ALD TECHNIQUE – A RESONANT-PHOTOEMISSION-SPECTROSCOPY STUDY

I.A. Kowalik [1,2*], E. Guziewicz [1], Ł. Wachnicki [1], K. Kopalko [1], A. Wójcik [1], E. Łusakowska [1], and M. Godlewski [1]

[1] *Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, PL-02-668 Warsaw, Poland*
[2] *MAX-lab, Lund University, Box 118, SE-22100 Lund, Sweden*

Keywords: zinc oxide, manganese, resonant photoemission, electronic structure, atomic layer deposition

**) e-mail: iwona.kowalik@maxlab.lu.se*

Zinc oxide (ZnO) structures have attracted rapidly increased attention in the last few years. This wide-band gap semiconductor (ultraviolet region E_g ~3.3 eV at room temperature) is a promising material not only as a base material for realizing transparent DMSs but also because of its electrical, optoelectronic and photochemical properties. These aspects led to many applications of this material for solar cells, transparent electrodes, gas sensors, varistors, piezoelectric transducers and optoelectronic blue/UV light emitting and light detecting devices. Mn doped ZnO is also regarded as promising material for spintronic applications since room temperature ferromagnetism was predicted for this material.

We report on resonant photoemission study of ZnMnO thin films grown at low temperature by Atomic Layer Deposition (ALD) method on Si and GaAs substrates [1]. The clean surface of ZnMnO was gradually covered with Mn in a few steps up to a thickness of 4 ML. Such a structure was then annealed in two steps – first one up to 250°C and the second one at about 450°C.

Resonant photoemission measurement, carried out for photon energies close to Mn $3p \rightarrow 3d$ transition, was applied to observe changes of Mn 3*d* states distribution in the valence band region after each stage of the experiment. The sets of photoelectron energy distribution curves (EDC) were measured for clean ZnMnO/GaAs and ZnMnO/Si surfaces and as function of Mn coverage for ZnMnO/Si structure at photon energy range 40-130 eV. Comparison of EDC taken at resonance and antiresonance for clean and Mn-enriched ZnMnO surface enabled us to reveal the Mn 3*d*-related contribution to the spectra. We observe that after annealing the Mn contribution at the Fermi edge disappeared, what indicates that whole deposited Mn built up into the ZnMnO matrix. This suggests that in case of ZnMnO grown by the ALD technique Mn easier builds up into ZnO layer than it was observed for ZnMnO monocrystal [2].

After each stage of the experiment we observed also the Mn 3*p* state at higher binding energy. At 3 ML of Mn deposition two Mn 3*p* peaks appeared (at about 41 and 48 eV of binding energy), which were getting stronger when the Mn coverage was getting thicker. This is an evidence that two different manganese states are observed in the ZnMnO interface region. After annealing one of the Mn 3*p* peaks disappeared, which means that only one manganese state is present in the obtained ZnMnO material.

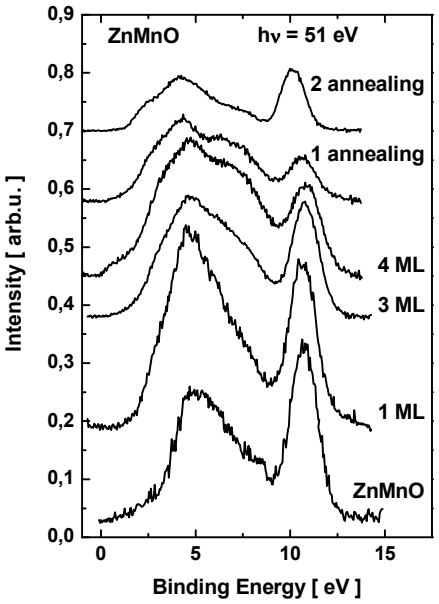

Figure 1. EDC set obtained for ZnMnO/Si sample covered stepwise covered with Mn and annealed, measured for 51 eV of photon energy (the resonance conditions).

Acknowledgements: The work was supported by polish grant of Ministry of Science and High Education 1 P03B 015 29 and by the European Community - Research Infrastructure Action under the FP6 "Structuring the European Research Area" Programme (through the Integrated Infrastructure Initiative "Integrating Activity on Synchrotron and Free Electron Laser Science").

References

[1] A. Wójcik *et al*., "Magnetic properties of ZnMnO films grown at low temperature by atomic layer deposition", *Appl. Phys. Lett.* **89** (2006) 051907.

[2] E. Guziewicz *et al*, "Zn(Mn)O surface alloy studied by synchrotron radiation photoemission", *Acta Phys. Polon.* **108** (2005) 689.