

Valence of RE ions on surface and in volume of semiconductor compounds

B. A. Orłowski^{1*}, E. Guziewicz¹, A. Reszka¹
and B. J. Kowalski¹

¹Institute of Physics, Polish Academy of Science,
Al. Lotników 32/46, 02-668. Warsaw, Poland

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*e-mail: obro@ifpan.edu.pl

The rare earth RE (4f) atoms impurities introduced to the valence band of semiconductor compounds can contribute as an ions with 2+ or 3+ valence. The open shell 4f electrons introduce magnetic properties to the valence band of volume crystal as well as to the crystals of reduced dimension like surface 2D, wires (1D) or dots (0D). As an impurity in semiconductor compounds $A_{II}B_{VI}$ or $A_{III}B_V$ RE ions prefer to take a site of cation with its valence as well in the volume of a crystal as like a deposited atoms on clean surface of the crystal. Thermal annealing of the samples leads to the transition of ions to the valence of semiconductor crystal cation. The application of Fano type Resonant Photoemission Spectroscopy (RPS) for study valence of RE(4f) ions needs to apply continuous spectrum synchrotron radiation in the range of energy between 100 and 200eV.

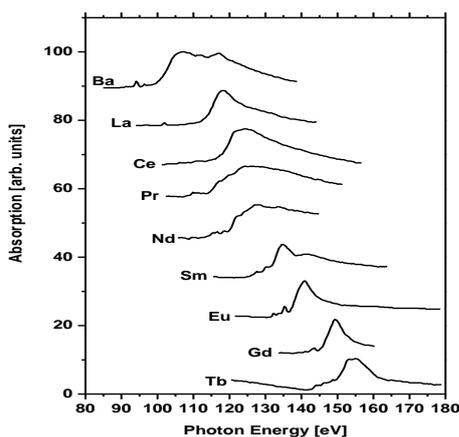


Figure 1. Set of selected rare earth atoms 4f electrons absorption spectra.

The Fig. 1 presents regions of energy corresponding to the optical transitions 4f - 4d absorption spectra for set of metal atoms, starting from Barium up to Terbium [1].

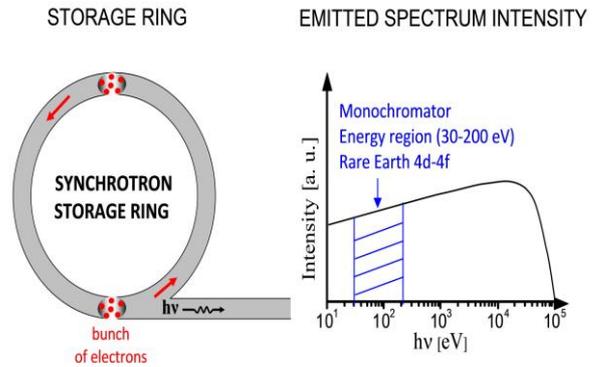


Figure 2. Storage ring and emitted spectrum with marked region of energy used in the experiment.

The Fig. 2 illustrates the synchrotron source (Hamburg, DESY) of strong continuous radiation spectrum in the wide photon energy range used to measure the Fano type resonant photoemission spectra in indicated radiation energy range [1,2]. The results are presented as a set of Energy Distribution Curves spectra measured for the valence band region of following semiconductor crystals GaN, CdTe and PbGdTe, doped by following Re atoms: Eu and Sm. For GaN and CdTe crystals surface the set of spectra were measured for Sm atoms sequentially deposited on the crystals surface. The obtained spectra were divided on two groups of peaks corresponding to two resonant energy of radiation $h\nu$ equal 136eV or 141eV. This groups correspond to the Sm 4f-4d transitions of Sm ion with valence 2+, corresponding to $h\nu$ energy 136eV and 3+ corresponding to $h\nu$ energy 141eV. The spectra obtained for $Pb_{1-x}Eu_xTe$ crystal presents the effect of Eu^{3+} ion transition to the Eu^{2+} ion, under the crystal annealing. The results allow to determine contribution of RE(4f) electrons structure to the valence band of the semiconductor crystals.

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- [1] B. A. Orłowski *Spektroskopia fotoemisyjna rezonansowa typu Fano in Promieniowanie synchrotronowe w spektroskopii i badaniach strukturalnych*, editors B. J. Kowalski, W. Paszkowicz, E. A. Gorlich, (Polish Synchrotron Radiation Society, 2011) (in Polish).
- [2] E. Guziewicz, B. A. Orłowski, B. J. Kowalski, I. A. Kowalik, A. Reszka, L. Wachnicki, S. Gieraltowska, M. Godlewski, R.L. Johnson, *Appl. Surf. Science* **82** (2013) 326.