Photoemission study of Eu2+/3+ states in ferromagnetic (Eu,Gd)Te semiconductor layers

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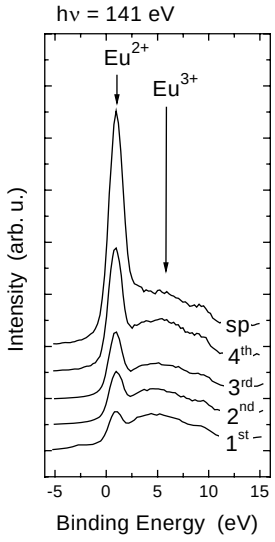
High electron concentration induced antiferromagnetic to ferromagnetic transition in n-(Eu,Gd)Te layers is observed only in stoichiometric layers with Eu and Gd ions in 2+ and 3+ charge states, respectively. Various crystal defects, surface oxidation process and non-stoichiometric growth of layers generate substantial concentration of Eu^{3+} ions. It results in preparation of highly resistive layers exhibiting no ferromagnetism. In this work we experimentally study, exploiting the method of photoemission, the relative proportion of Eu^{2+} to Eu^{3+} ions concentration in (Eu,Gd)Te layers prepared under various growth and preparation conditions.

Samples were grown in home-built MBE system on cleaved (111)-oriented surface of BaF_2 monocrystals using effusion cells for Eu, Gd and Te. For all samples as a buffer was used thin EuTe layer, whereas (Eu,Gd)Te layer was typically up to 0.5 μm thick. The samples were characterized in-situ using reflection high-energy electron diffraction exhibiting well defined streaky patterns indicating on two-dimensional mode of growth as well as ex-situ by x-ray diffraction which revealed very good monocrystallity.



The photoemission spectra of (Eu,Gd)Te were obtained at the FLIPPER II beam line at the HASYLAB. The measurements were performed after sequential annealing and finally after sputtering by Ar ions. For the sample exposed to the air the oxidation of the surface takes place and measured spectra showed the dominant Eu^{3+} contribution in comparison to Eu^{2+} decreasing with successive annealing processes. Surface sputtering by Ar ions removes the oxygen adsorbed at the surface and diffused in the surface region and reveals the photoemission spectra of clean (Eu,Gd)Te layer. For clean surface the Eu^{2+} dominate in the spectra. The contribution of Eu^{2+} 4*f* electrons to the electronic structure of the (Eu,Gd)Te was found at the top of the valence band.

The photoemission spectra showing increase of the Eu^{2+} contribution in comparison to Eu^{3+} in of (Eu,Gd)Te due to sequential annealing (denoted as 1st, 2nd and so on) and after additional sputtering (sp). The data on the plot were collected at the excitation photon energy of 141 eV corresponding to resonance of 4*d*-4*f* Eu transition.

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