Correlations between RE-TM Electronic States in $RE_3Ni_5Al_{19}$ Studied by X-ray Spectroscopy

M. Szubka,[1] T. Klimczuk,[2] M. Oboz,[1] J. Kubacki,[1] and T. Sobol[3]

[1] *August Chełkowski Institute of Physics, University of Silesia, Katowice, Poland*

[2] *Institute of Nanotechnology and Materials Engineering, Gdańsk University of Technology, Gdańsk, Poland*

[3] *SOLARIS National Synchrotron Radiation Centre, Kraków, Poland*

The aim of this work was to develop a technology for obtaining single crystals of the $RE_3Ni_5Al_{19}$ series (RE = Gd, Tb, Dy) in collaboration with the Institute of Nanotechnology and Materials Engineering at Gdańsk University of Technology. The single crystals were grown using the Al self-flux method. Low-temperature magnetic susceptibility measurements revealed intriguing magnetic properties of the obtained compounds. Due to the complex magnetic transitions involving two magnetic contributions—one originating from Ni atoms and the other from the rare-earth elements (Gd, Tb, Dy)—spectroscopic methods were employed to determine the ordering temperatures of the individual components. Changes in the electronic structure of the single crystals were investigated by X-ray photoelectron spectroscopy (XPS) at temperatures above and below the magnetic phase transitions. The measurements be carried out at room temperature and at low temperatures corresponding to the temperature ranges between individual phase transitions (20 K, 22 K and 27 K for the $Gd_3Ni_5Al_{19}$ sample and 20 K, 29 K, and 32 K for the $Tb_3Ni_5Al_{19}$ sample). Detailed analyses were performed for the Gd 4d, Dy 4d, Tb 4d, Ni 2p, and Al 2p core-level photoemission lines, as well as for the valence band region. In addition, X-ray absorption spectroscopy (XAS) and resonant valence band photoemission studies were conducted using photon energies corresponding to the M absorption edges of Gd, Tb, and Dy, and the L edge of Ni. The observed temperature-dependent modifications of both core-level and valence band spectra demonstrate a strong correlation between changes in the electronic structure and magnetic phase transitions. The results indicate that nickel actively participates in the magnetic ordering processes and that the magnetic transitions are of a sequential and complex nature, involving coupled contributions from the Ni 3d states and the rare-earth 4f electrons. Differences observed between compounds containing different rare-earth elements highlight the crucial role of the RE component in determining the character and temperature of the magnetic transitions. Overall, the obtained results provide deeper insight into the interplay between electronic structure and complex magnetic ordering in the $RE_3Ni_5Al_{19}$ series.

The experiments were performed at the National Synchrotron Radiation Centre SOLARIS and were co-financed by the Research Excellence Initiative of the University of Silesia in Katowice. The authors acknowledge P. Zajdel for his valuable help and support in the analysis of the experiments.