Opponent's Review of Doctoral Thesis

Candidate: Mgr. Eva Butková, Ph.D.

Title: Spectroscopic studies of new generation of optical and magneto-optical materials

Department / Institute: Institute of Physics of Charles University. Department of Materials Science and Technology of Nagaoka University of Technology.

Supervisors of the doctoral thesis: RNDr. Martin Veis, Ph.D., Division of Magneto-optics, Institute of Physics of Charles University & Dr. Takayuki Ishibashi, Ph.D., Department of Materials Science and Technology, Nagaoka University of Technology

Reviewer: Mgr. Jan Zemen, Ph.D.

The candidate carried out a systematic study of the full permittivity tensor spectra for three types of materials: amorphous metallic alloys $Gd_xFe_{(100-x)}$, magnetic garnets $Y_{(3-x)}Bi_xFe_5O_{12}$, $Nd_2BiFe_{(5-x)}Ga_xO_{12}$, $Nd_{0.5}Bi_{2.5}Fe_{(5-x)}Ga_xO_{12}$, and magnetic semiconductors $Ce_{(0.95-x)}Hf_xCo_{0.05}O_{(2-\delta)}$. These materials have a significant potential for applications in novel optical and magneto-optical devices. The candidate grew majority of the samples in thin film form using DC and RF sputtering, metal organic decomposition, and pulsed laser deposition. Subsequently, a combination of spectroscopic ellipsometry, magneto-optical Kerr effect spectroscopy and Faraday effect spectroscopy was used to evaluate the diagonal and off-diagonal elements of the permittivity tensor for energies from 1.5 to 5.5 eV. The choice of the growth and measurement methods is adequate and the candidate acquired an extensive set of new skills.

All the experimental data were analysed by fitting to a microscopic theory which relates the permittivity tensor spectra to the electronic state splitting and transition probabilities. This microscopic insight allowed the candidate to explain the trends in the measured optical properties depending on the variation of the chemical composition of the films. The thesis is not focused on achieving a certain optical or magneto-optical property of a functional material or on building a certain photonic device. However, the detailed analysis of the link between the film composition and its optical response makes the thesis a valuable resource for development of devices including holographic displays, magnetic memories or non-reciprocal photonic elements.

The formal layout of the thesis is appropriate. The text is divided into chapters devoted to the fundamental physical phenomena underlying the study (in particular, the Yeh's 4x4 matrix formalism that describes the interaction of electromagnetic radiation with magnetic multilayers is outlined), to experimental methods, thin film preparation, the results, and finally to the discussion. There is a high number of tables and figures which help to organise the obtained optical parameters. The figures have sufficient resolution. The legends are clear. In some cases, the curves are distinguished only by colour – using different line styles or markers would improve the legibility of the plots. The bibliography is treated appropriately (journal style). The scientific language is adequate, there are only minor typos.

I have the following questions:

1) The tensor in equation (2.13) is not antisymmetric. Is this a misprint?
2) The surface roughness is modelled in the Yeh's formalism as an additional top layer of certain thickness. This thickness seems to be treated as a fitting parameter. In some cases it agrees with surface roughness obtained by AFM but in other cases it is zero as shown in Table 6.2.7. You say that this zero thickness corresponds to epitaxial growth of films on GGG substrate. But the film is 200nm thick. Is it likely that there is really no surface roughness?
3) In figure 6.1.7, the coercivity of $Gd_xFe_{(100-x)}$ increases with increasing x up to x=25 which might be due to the stronger spin-orbit coupling (Gd is much heavier than Fe) despite the half filled 4f orbital. Then the coercivity reduces above the compensation point (at x=26.7). What could be the cause of this reduction?
4) In figure 6.2.22, the content of Ga seems to have great impact on the MOKE rotation for Bi1* and much smaller impact for Bi2.5*. Can you provide a comment or a microscopic insight?

Overall, I congratulate the candidate and the supervisors on completing a thesis of such high quality and I recommend grade A (1). Following a successful defence of the doctoral thesis I recommend the granting of the Ph.D. degree.

28.2.2022, In Prague, Jan Zemen