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Review of the doctoral thesis of RNDr. Lukáš Beran "Optical and magneto-optical studies of ferrimagnetic garnets for photonic and spintronic applications"

The thesis is devoted to fabrication, characterization and magneto-optical studies of magnetic materials — ferrimagnetic garnets — that are interesting both from fundamental point of view and for their potential application in the field of photonics and spintronics, for example for magneto-optical isolators based on nonreciprocal propagation.

First I briefly summarize the content of the thesis. The thesis starts with an introductory chapter that clearly explains motivation of the objective of the thesis. It is followed by part II with chapters introducing the optics, matter and interaction between light and matter that summarizes the theory used later in the thesis for evaluation of results. Part III is devoted to introduction of the experimental methods, that is, the methods used for fabrication (metal-organic decomposition and pulsed-laser deposition), structural characterization (X-ray diffraction), magnetic characterization (magnetometry), and optical ad magneto-optical characterization (ellipsometry, Kerr rotation and Faraday effect).

Part IV contains the results of the thesis in form of four chapters. Chapter 8 presents the studies of four different yttrium iron garnets thin films, doped with bismuth or cerium and deposited on gadolinium gallium garnet or silicon. In each chapter, the deposition procedure is described in detail and optical and magneto-optical data are presented. Finally, the figure of merit (defined as the ratio of the Faraday rotation and the optical absorption at telecommunication wavelength 1550 nm) is summarized for all samples. Exceptionally high values of figure of merit that exceeded values previously reported for bulk crystals were found in the film of cerium doped garnets deposited on gadolinium gallium garnet. Very high values were found in bismuth doped garnets deposited on silicon. In the latter, using a garnet seed layer was a crucial step in order to obtain well crystallized thin films with low absorption and thus high figure of merit. Obviously, these results are of high importance for integration of electronics using silicon based technology.

Chapter 9 is devoted to fabrication and analysis of thin films with the easy-axis pointing out of sample plane, so called perpendicular magnetic anisotropy, that is necessary for several spintronics application. Thulium, europium and terbium iron garnets were selected for deposition using pulsed laser on gadolinium gallium garnet. Indeed, thin films of all the three used materials exhibited the desired perpendicular magnetic anisotropy. With exception of europium

iron garnet, the thin films exhibited very low coercivity fields of units of mT. The magneto-optical spectra of terbium iron garnet showed the opposite sign compared to the other samples demonstrating that it is above the compensation temperature whereas the others are below.

Chapter 10 reports on temperature dependent studies of the Cerium doped yttrium iron garnet from 300 to 77 K. This film was found to exhibit the reorientation of the easy axis out of plane below 170 K. Additionally, the coercivity field and saturated Faraday rotation increased with the decrease of temperature. The magneto-optical spectra of terbium iron garnet were measured in detail near the compensation temperature that was unusually high (317 K). The spectra were in detailed modelled in Chapter 11 using a semiclassical approach. It was possible to decompose the Faraday effect into contributions from the individual magnetic sublattices. Additionally, the model allowed to describe the magnetization reversal where the the propagation of magnetic domain walls was found to be responsible for the switching.

In summary, the thesis of RNDr. Lukáš Beran reports on a research with a very broad scope that started with the deposition of samples, was followed by their structural characterization, and finally the samples were investigated by means of optical and magneto-optical spectroscopy and their modeling. This research was carried out on a broad range of garnet materials deposited on various substrates. The thesis is clearly written; the text can be easily followed from the introductory chapters all the way to the conclusions. The level of English is very good. The results were published in an impressive number (20) of peer reviewed publications. In conclusion this thesis clearly demonstrates the author's ability to perform an independent creative research with a large number of techniques, obtain new high-quality results and publish them in international peer reviewed journals and thus I without any doubt recommend to accept this work as a successful doctoral thesis.

in Brno, 29.4.2020 doc. Mgr. Adam Dubroka, Ph.D.

For the discussion, I propose the following questions:

- In PLD growth, one of the very important parameters is the laser fluency, typically expressed in J/cm^2. However, I did not find any value of fluency in the thesis. Please estimate the used fluency.
- I am surprised by the long tail of the imaginary part of the dielectric function below the bandgap in Fig. 9.7. that is present in the spectra of all samples except that of the TbIG sample, where the absorption drops to essentially zero. These tails that decrease with decreasing energy resemble the trends seen in the real part of the dielectric function. This typically occurs if either the surface roughness was not taken into account or if an incorrect thickness of thin film was used for the analysis. Please check the analysis and report on the findings.