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Magneto-optical Spectroscopy for Condensed-Matter Physics, Optics and Spin-photonics

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The magneto-optical (MO) phenomena have received a great attention over last decade, primarily due to the realization of erasable MO memories. In addition, MO spectroscopy has contributed in recent years to an improved understanding of the electronic structure of a wide class of materials and of many basic problems of the condensed-matter physics and optics ranging from surface magnetism to exchange coupling in multilayered films (MLF).

The MO properties are the study of the interaction of electromagnetic radiation with magnetized matter, but, generally, a term of MO properties is used in a more restricted sense to mean those properties of matter which manifest themselves as Faraday or MO Kerr effects.

Faraday effect is caused by magnetic circular birefringence, *i.e.*, by the difference in refractive indices for the left- and right-circularly polarized light. Therefore, magnetic circular birefringence results in rotation of the polarization plane of linear polarized light on transmission through a matter magnetized in the direction of light propagation.

The changes in polarization on reflection, which are induced by magnetization, are known by a term of MO Kerr effect (1877). According to the relative orientation of the external magnetic field with respect to the incidence plane and reflecting surface, three kinds of the MO Kerr effect can be distinguished, These are polar, longitudinal and equatorial Kerr effects. The polar and longitudinal effects lead to a rotation of the polarization plane and to appearance of the ellipticity for the reflected light in comparison with the linearly-polarized incident light. The nature of these effects is very close to the Faraday effect because they are also caused by the magnetic circular birefringence. Equatorial Kerr effect exhibits a change in intensity and a phase shift of the linearly-polarized light after reflection.

In nonferromagnetic metals the MO effects are weak and hard to be measured, because they originate from a direct influence of the external magnetic field on the orbital and translational movement of electrons which are excited by light. The nature of significantly stronger MO effects in solids with spontaneous magnetization is completely different. The MO effects appear owing to an influence of the spin-orbit coupling on the electron energy structure and on the mechanism of the scattering of itinerant electrons.

There is a correlation between optical and MO absorption in a gyrotropic medium, which is caused by the difference in absorption of the left and right circularly-polarized light, *i.e.*, circular dichroism. In a magnetically-ordered state, the spin-orbit coupling causes a certain splitting of the degenerated states, and a difference in occupation of the majority and minority spin-subbands appears. This difference in band occupation results in number of the electron excitations in each subband, *i.e.*, an absorption for the left and right circularly-polarized light becomes different. In this case the resulting optical absorption peak increases its width and should also be splitted or manifested a certain fine structure. The MO absorption looks like an anomalous dispersion curve with crossing zero-line.

The goals for performing MO measurements are manifold, and, consequently, the techniques used to obtain the desired information are numerous. For practical applications such as erasable Mo disks, the Mo measurements are limited to the determination at room temperature of rotation and ellipticity at one r two laser wavelengths. For spectroscopic and temperature MO measurements, the equipment is significantly complicated (vacuum, monochromator, intensity and focusing problems, temperature control, viewport stress-induced birefringence, etc.). For studying the electronic structure of solids the knowledge of the optical properties of the matter is also necessary.

Two examples will be discussed as applications of the MO effects to condensed-matter physics, optics and even spin-photonics, based on the research results by my Group. The first is the properties of spin-polarized Pt in MO Co/Pt MLF.[1] The MO and optical properties of the Co/Pt MLF with a nearly constant Pt sublayer thickness, as well as pure Co and Pt, and $Co_{0.51}Pt_{0.49}$ alloy films have been investigated in the 1.1 - 4.7 eV energy range experimentally and by solving the multireflection task for various models of MLF. The comparison between experimental and computer-simulated optical properties of the Co/Pt MLF allowed us to evaluate the thickness of the interfacial regions with the alloyed components. The diagonal and off-diagonal components of the optical conductivity tensor were calculated for the spin-polarized Pt layers in the Co/Pt MLF as well as for the pure Co and $Co_{0.51}Pt_{0.49}$ alloy films, and the whole Co/Pt MLF. It was experimentally shown that the structural fcc-$L1_0$ transformation in the $Co_{0.51}Pt_{0.49}$ alloy film caused by an annealing at 610 K for 240 min leads to significant changes in the optical and MO properties of alloy.

Next case is the interfaces of Fe/Si MLF with a strong antiferromagnetic (AF) coupling analyzed by optical and MO spectroscopies,[2] and modifications of the structure and the physical properties if Fe/si MLF by ion-beam mixing.[3] Fe/Si MLF exhibiting a strong AF coupling were investigated by optical and MO spectroscopies. The results were compared with the computer-simulated spectra based on various structural models of MLF. It was shown that neither semiconducting $FeSi_2$ nor ε-FeSi can be considered as the spacer layers in the Fe/Si MLF for the strong AF coupling. The optical properties of the spacer extracted from the effective optical response of the MLF strongly support its metallic nature, A reasonable agreement between experimental and simulated equatorial-Kerr-effect spectra was obtained with the fitted optical parameters of the spacer with the FeSi stoichiometry, Comparison of the extracted optical properties of the spacer with the calculated ones by using the first principles showed that a B2-phase metallic FeSi compound is spontaneously formed at e interfaces during deposition. For the Fe/Si system with ultrthin Fe and I sublayers (thinner than 1 nm), our optical data indicate that the structure of the whole MLF is close to the amorphous and semiconducting ε-FeSi. The influence of ion-beam mixing (IBM) on the structure, magnetic, MO and optical properties of Fe/Si MLF was also investigated. Mixing was performed with Ar^+ ions of an energy of 80 keV and a dose of 1.5 x 10^{16} Ar^+/cm^2. It was shown that IBM destroys the layered structure of the MLF down to a depth of about 110 - 150 nm and leads to the formation f a new phase which is characterized to have a perfect crystalline structure, a low coercivity and a Curie temperature of about 550 K. It is suggested that the phase formed by the IBM I metastable Fe_2Si silicide with a B2 type of structure. Annealing of the ion-beam mixed Fe/Si MLF at 720 K destroys further the undisturbed layered structure at he bottom and also leads to a decomposition of the Fe_2Si phase into a metastable magnetically-hard Fe_5Si_3 silicide and, presumably, Fe_3Si.

1. Y. P. Lee, R. Gontarz, and Y. V. Kudryavtsev, Physical Review B 63, 144402-1 (2001).
2. Y. V. Kudryavtsev, V. V. Nemoshkalenko, Y. P. Lee, K. W. Kim, J. Y. Rhee, and J. Dubowik, Journal of Applied Physics 90, 2903 (2001).
3. Y. V. Kudryavtsev, J. Dubowik, B. Szymanski, Y. P. Lee, J. Y. Rhee, and G. S. Chang, Physical Review B (in press).