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SPECTRA OF MAGNETOOPTICAL KERR ROTATION AND ELLIPTICITY IN Pt/Co MULTILAYERED FILMS

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Abstract - Spectra of magnetooptical Kerr rotation and Kerr ellipticity in Pt/Co multilayers were measured between 1.2 and 5.4 eV. Using the optical constants obtained by the Kramers-Kronig analyses of reflectivity spectra, the diagonal and off-diagonal elements of optical conductivity tensor were obtained for the first time in this material.

KEYWORDS: MAGNETOOPTICAL KERR SPECTRA, OPTICAL CONSTANTS, Pt/Co MULTILAYERS, OPTICAL CONDUCTIVITY

Introduction

There is a growing interest in Pt/Co multilayers as new materials for high density magnetooptical recording media[1]. However, only a little is known concerning the electronic structures of the material. Zeper et al. reported magnetooptical spectra in Pt/Co multilayers between 1 and 5 eV and compared them with those in a Pt-Co alloy film and a single layer film of Co[2]. Although the overall spectral features of the multilayer is quite identical to the corresponding alloy, it seems there is a slight discrepancy in the high photon-energy region above 4 eV. Recently, Moog et al.[3] calculated the magnetooptical effect of multilayers using the new matrix formalism developed by Zak et al.[4] and found that the observed magnetooptical spectra in the high photon energies cannot be explained solely by the phenomenological multilayer optics unless a strong magnetooptical contribution from the Pt atom is assumed.

We, therefore, concentrated our attention to this short wavelength region and have been making experimental efforts to obtain reliable spectra in this region. In addition to the effort for extending the measurable energy range, are required works to obtain diagonal and off-diagonal elements of conductivity tensor for a detailed discussion of magnetooptical effect in terms of the electronic structures of the material. For this purpose it is necessary to evaluate the spectrum of optical constants n and k for the multilayer. We measured reflectivity spectra, from which we calculated the optical constants as well as real and imaginary parts of the diagonal conductivity element with the help of the Kramers-Kronig analysis. Using these constants we obtained for the first time the off-diagonal element of the optical conductivity tensor in the Pt/Co multilayer.

Experimental

Pt/Co multilayers were prepared using DC magnetron sputtering method. The thickness of constituent layers and the total thickness of multilayers used in the present studies are listed in Table 1.

Magnetooptical spectra were measured with the polarization modulation technique using a piezo-birefringent modulator. Our experimental arrangements were based on those described by the author[5].

Table 1 Data of samples used in the present study.

sample name	Pt/Co layer thickness	Pt-Co composition	total thickness
Pt(10)/Co(5)	9.5Å/4.5Å	60.3/39.7	2000Å
$Pt_{60}Co_{40}$		60.2-39.7	2000Å
Pt(18)/Co(5)	17.0Å/4.4Å	74.0/26.0	534Å
Pt(18)/Co(20)	17.9Å/19.6Å	40.0/60.0	677Å

We used a 150W Xe-lamp made of UV-transparent silica as a light source. For the monochromator we employed a JASCO CT-25CD type double monochromator to reduce the stray light which poses a serious problems in UV measurements with a single monochromator. The maximum magnetic field employed was about 1T, which was sufficient to saturate the magnetization in all the samples employed for the measurement.

We measured optical constants n and k employing a JASCO model PME30S spectroscopic ellipsometer. However, the spectral region of measurement was limited only in the photon energies ranging between 0.7 and 3 eV and insufficient for the analyses to obtain optical conductivities. We therefore measured the nearly normal-incidence reflectivity spectra using a Hitachi type U-3410 spectrophotometer. The data were subject to the Kramers-Kronig analyses, with the extrapolation parameters determined so as to reproduce the optical constants obtained by the ellipsometer. These procedures are similar to those used for the Kramers-Kronig analyses in PtMnSb films described in ref. 6.

Using θ_K, η_K, and optical constants n and k we evaluated the optical conductivities(in the unit of s^{-1}) by using following formulae:

$$\sigma_{xx}' = (\omega/2\pi)nk, \qquad \sigma_{xx}'' = (\omega/4\pi)(1-n^2+k^2) \tag{1}$$

for diagonal elements and

$$\sigma_{xy}' = (\omega/4\pi)(A\theta_K+B\eta_K) \qquad \sigma_{xy}'' = -(\omega/4\pi)(B\theta_K-A\eta_K) \tag{2}$$

for off-diagonal elements, where A and B are given as

$$A = k(1-3n^2+k^2), \qquad B = n(1-n^2+3k^2). \tag{3}$$

Results and Discussion

In Fig. 1 are illustrated spectra of polar magnetooptical Kerr rotation θ_K and ellipticity η_K in Pt(10)/Co(5) multilayer and the Pt_{60}-Co_{40} alloy. As listed in Table 1 these two samples have the identical ratio of Pt and Co and the same total thickness of 200 nm. In both films, the Kerr rotation takes a maximum around 4 eV, while the Kerr ellipticity crosses zero around 3.3 eV. Although the overall features of both spectra are quite similar to each other, the absolute values of rotation and ellipticity in the alloy film are about 25 % greater than those of the corresponding multilayer.

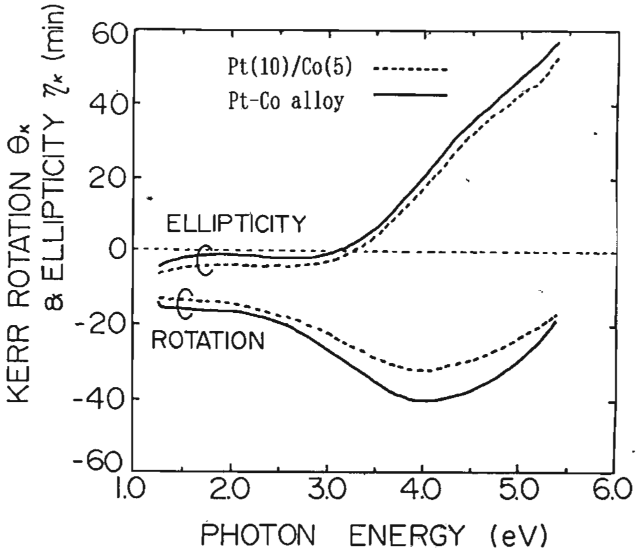


Fig. 1 Spectra of magnetooptical polar Kerr rotation and ellipticity in the Pt(10) /Co(5) multilayer and the $Pt_{60}Co_{40}$ alloy.

Figure 2 shows magnetooptical spectra of two samples of 50 nm-thick multilayers with designed thickness ratios of Pt(18)/Co(5) and Pt(18)/Co(20), which are identical to those of the samples reported by Zeper et al.[2]. The peak energy position of Kerr rotation in the Pt(18)/Co(5) film is slightly higher than that of the Pt(18)/Co(20) film. The peak Kerr rotation values of both films are almost the same. More distinct difference between two samples can be observed in the Kerr

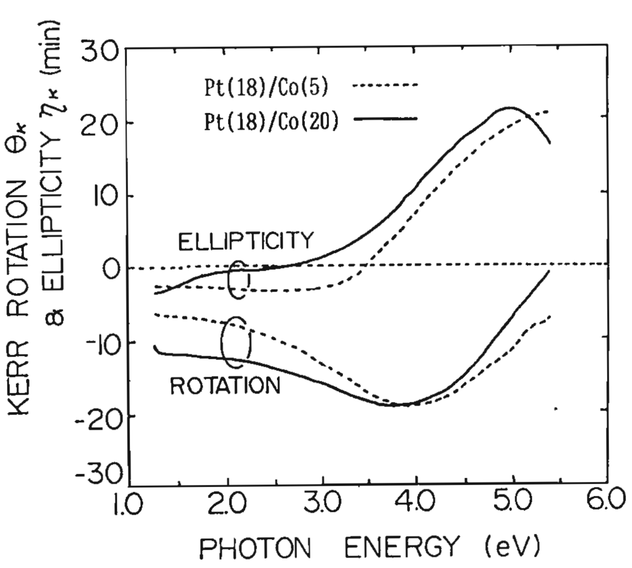


Fig. 2 Spectra of magnetooptical polar Kerr rotation and ellipticity in the Pt(18) /Co(5) and Pt(18)/Co(20) multilayers.

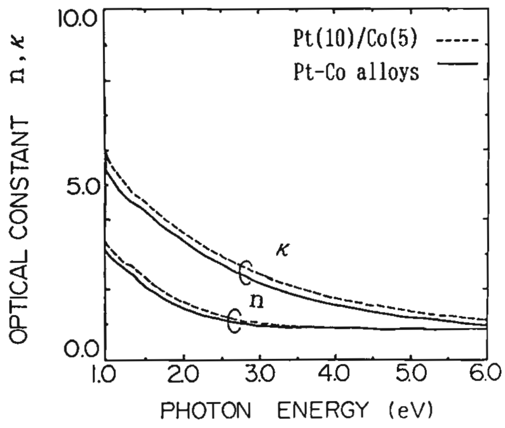


Fig. 3 Spectra of optical constants n and k in thePt(10)/Co(5) multilayer and the Pt_{60}-Co_{40} alloy deduced from the reflectivity spectra by Kramers-Kronig analyses.

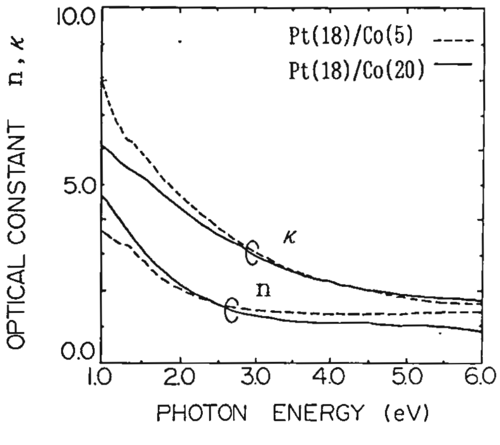


Fig. 4 Spectra of optical constants n and k in the Pt(18)/Co(5) and Pt(18)/Co(20) multilayers.

ellipticity spectra. The film with thicker Co layers shows a well-defined peak at 5 eV. The energy position where the ellipticity crosses zero is lower in the thick-Co multilayer than in the thin-Co one. These results are in good agreement with those of Zeper et al.

The spectra of optical constants n and k deduced from the reflectivity data by the Kramers-Kronig analyses in the Pt(10)/Co(5) multilayer and the Pt_{60}-Co_{40} alloy are shown in Fig. 3, while those in the Pt(18) /Co(5) and Pt(18)/Co(20) multilayers in Fig. 4.

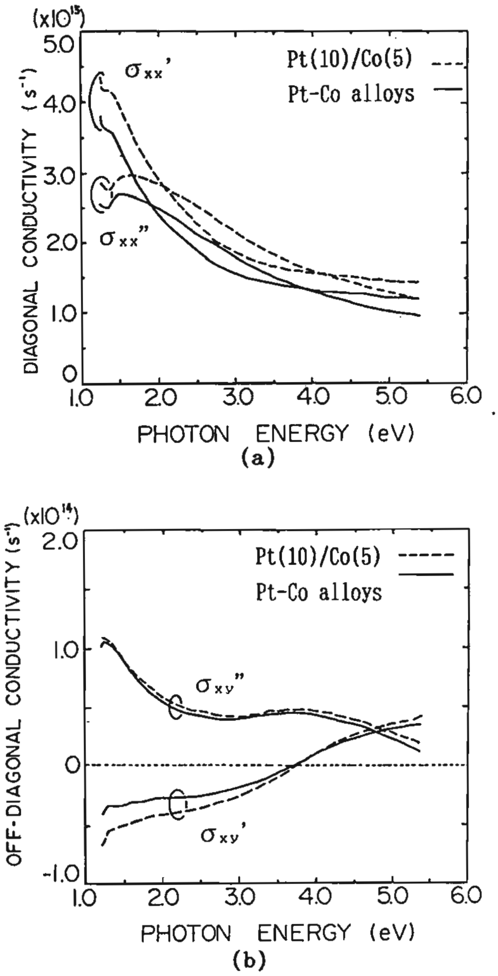
Using the formulae (1) and (2) we evaluated diagonal and off-diagonal elements of the conductivity tensor, which are illustrated in Figs. 5 and 6 for pairs of films shown in Figs. 1 and 2, respectively. In each figure, (a) shows the diagonal term and (b) the off-diagonal term.

The maximum of the absorptive part of the diagonal conductivity element is around 1.5eV and the maximum value is around $3\times10^{15}s^{-1}$, which is approximately of the same order of magnitude as that of Co ($5\times10^{15}s^{-1}$)[6].

To our astonishment, spectra of the imaginary(absorptive) part of the off-diagonal conductivity have quite identical values for the Pt(10)/Co(5) and the corresponding alloy, despite the measured spectra of Kerr rotation and ellipticity show a considerable difference.

We also find a striking agreement between the Pt(18)/ Co(5) and Pt(18)/Co(20) multilayers in the energy position where the real part of off-diagonal element crosses zero: They share the same value (3.7 eV), although the ellipticity crosses zero at quite different energy position in the two multilayers.

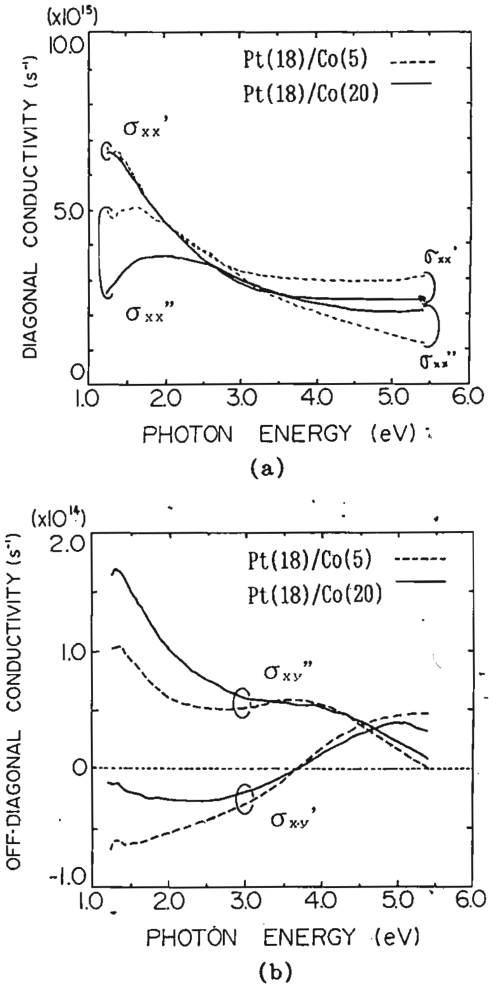
The off-diagonal element σ_{xy} is associated with microscopic origin. The imaginary part represents the difference between the transition probabilities for left- and right-circularly polarized light. The similarity of the off-diagonal conductivity between the multilayer and the alloy leads us to conclude that the magnetooptical effect of the multilayer comes from that of the alloy which may be formed at the interface.



(a)

(b)

Fig. 5 Real and imaginary parts of the (a) diagonal and (b) off-diagonal elements of optical conductivity in the Pt(10)/Co(5) multilayer and Pt_{60}-Co_{40} alloy.



(a)

(b)

Fig. 6 Real and imaginary parts of the (a) diagonal and (b) off-diagonal elements of optical conductivity in the Pt(18)/Co(5) and Pt(18)/Co(10) multilayers.

The fact that the spectrum of σ_{xy}" consists of two peaks around 1.2 eV and 3.8 eV reminds us the calculated σ_{xy}" of Pt-Fe alloy[8], in which two peaks appear at 2 eV and 4 eV. The calculated value of σ_{xy}" is of the order of 1 x 10^{14} s^{-1} in good agreement with the experimental value.

Evaluation of conductivity through the relativistic energy-band calculation is strongly needed in order to associate the experimental magnetooptical effects with electronic structures in multilayers.

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