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REFLECTIVITY SPECTRA IN AS-POLISHED AND ANNEALED PtMnSb BETWEEN 0.5 AND 25eV MEASURED BY SYNCHROTRON RADIATION

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Abstract–Reflectivity spectra in as-polished and annealed bulk materials of PtMnSb were measured between 0.5 and 25eV. Optical constants were deduced by Kramers-Kronig analysis. Using the optical constants obtained, off-diagonal conductivity σ_{xy} between 1.2 and 6eV was calculated from the Kerr spectra.
KEYWORDS: PtMnSb, REFLECTIVITY, OPTICAL CONSTANTS, KERR SPECTRA, OFF-DIAGONAL CONDUCTIVITY

I. INTRODUCTION

Since the discovery of a large magnetooptical Kerr effect[1], PtMnSb, one of the C1b-type Heusler compound, has been attracting attention of many researchers not only from the applicational point of view but also from the view point of its peculiarity in the band structure often referred to as "half metallic"[2].

Takanashi et al. reported in the previous papers[3,4] that the magnetooptical effect in PtMnSb can be enhanced from the reported value by annealing. In our previous paper, we ascribed the annealing effect to the change in the value of ϵ_{xx}'', the imaginary part of the diagonal element of permittivity tensor, using the reflectivity spectra between 0.5 and 5.5 eV[5]. However, the energy region is too narrow to obtain reliable values of optical constants from the Kramers-Kronig analysis of the reflectivity spectra.

We therefore measured reflectivity spectra in as-polished and annealed sample of polycrystalline PtMnSb for photon energies between 3 and 25 eV using the vacuum-ultraviolet beam from the storage ring at Synchrotron Laboratory of ISSP, University of Tokyo. Optical constants were evaluated by Kramers-Kronig analysis.

Magnetooptical Kerr rotation and ellipticity spectra were measured between 1.2 and 6.0 eV by polarization modulation technique, from which off-diagonal elements of the conductivity tensor were obtained, with the aid of the optical constants obtained above.

II. EXPERIMENTAL

A bulk sample of polycrystalline PtMnSb was prepared by induction melting in an atmosphere of Ar gas as described in our previous paper[5]. The ingot was polished with diamond paste to get a mirror surface. This specimen will be referred to as "as-polished sample" throughout this paper. Annealing was performed to the polished sample in a vacuum furnace at 500 °C for 2 hours. This will be identified as "annealed sample".

Reflectivity spectra for photon energies between 2.5 and 25 eV were measured with the synchrotron radiation at the beam-line BL1 of Synchrotron Radiation Laboratory of ISSP, using a Seya-Namioka type spectrometer. We extended the photon energy region to low energies by combining the spectra with those for photon energies between 0.5 and 5 eV measured by a Hitachi U-3410 spectrophotometer.

We calibrated the absolute value of the reflectivity making use of the values of the optical constants n and k determined at 546 nm by an ellipsometer.

Kramers–Kronig analysis was performed to obtain spectra of n and k. We employed an extrapolation formula of E^{-p} above 25 eV, the parameter p being determined to reproduce the optical constants n or k at 546 nm determined by ellipsometry.

Magnetooptical Kerr rotation and ellipticity were evaluated for photon energy region from 1.2 to 5.9 eV in both as-polished and annealed samples using the polarization–modulation technique. The apparatus is in principle the same as described in ref. [6], with several modification to extend the energy range of measurement to nearly 6 eV. Details of the apparatus will be published elsewhere[7].

III. RESULTS

Reflectivity Spectra

Figure 1 shows reflectivity spectra of as-polished (solid line) and annealed samples (dotted line) of polycrystalline PtMnSb.

Higher reflectivity was obtained in the as-polished sample than in the annealed one throughout the energy range of the measurement, whereas energy positions of the structures showed only a slight difference between two spectra, except for the prominent dip around 12 eV observed only in the annealed material.

Optical constants n and k were deduced from the reflectivity by the Kramers–Kronig analysis as described in the preceding section. Instead of n and k, we illustrate here spectra of ϵ_{xx} in Fig. 2, in which solid curves corresponds to the as-polished sample and the dotted curve to the annealed one.

It is clearly seen in Fig. 2 that the energy position at which ϵ_{xx}', the real part of diagonal permittivity, crosses the abscissa (corresponding to the so-called hybrid plasma frequency) undergoes no change between the as-polished and the annealed material. On the other hand, ϵ_{xx}'', the imaginary part, is subject to a drastic decrease between the two spectra. These features are more pronounced in this figure than in the corresponding spectra of the previous report[5], since the latter had an umbiguity due to the limitted energy range of measurement.

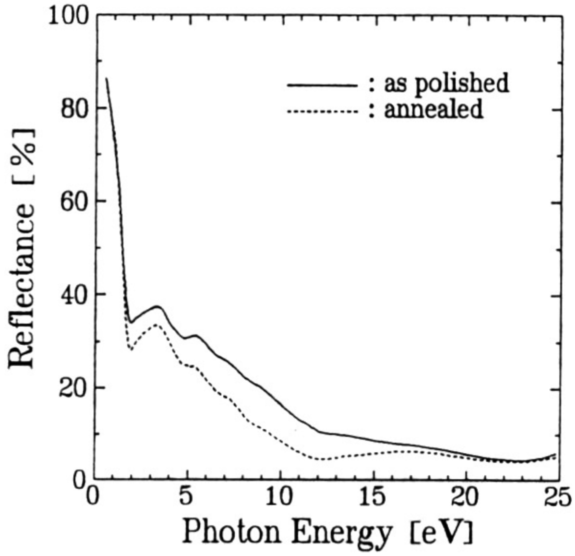

Fig. 1 Reflectivity spectra of as-polished (solid line) and annealed (dotted line) samples of PtMnSb for photon energies between 0.5 and 25eV.

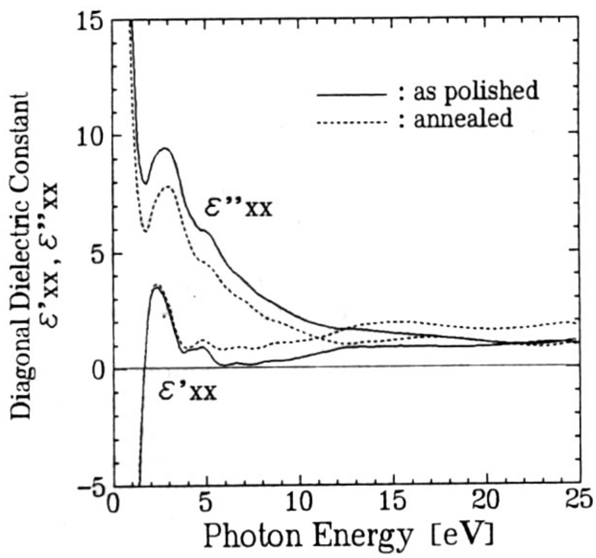

Fig. 2 Spectra of real and imaginary part of ϵ_{xx} in as-polished (solid line) and annealed (dotted line) samples of PtMnSb.

Magnetooptical Spectra

Magnetooptical Kerr rotation and ellipticity spectra between 1.2 and 5.9 eV are shown in Fig. 3, solid and dotted curves representing as-polished and annealed specimen, respectively. This is the first report of magnetooptical spectra in this material above 4.5 eV. The peak Kerr rotation of the polished sample takes a value of 124 minutes of arc at around 1.75 eV, at which ϵ_{xx}' crosses zero as shown in Fig. 2. Another peak of Kerr rotation with an opposite sign is observed at around 4.6 eV, peak value being -50 min in the annealed specimen. The Kerr rotation crosses zero again at 5.5 eV, at which Kerr ellipticity shows a maximum.

From the Kerr rotation and ellipticity spectra shown in Fig. 3, we calculated the spectra of ϵ_{xy}, the off-diagonal term of dielectric constant, with the help of optical constants obtained in the preceding subsection. The results are illustrated in Fig. 4. Despite the considerable difference in the peak rotation between as-polished and annealed specimen, the off-diagonal permittivity spectra thus calculated show striking similarity for the two sample studied.

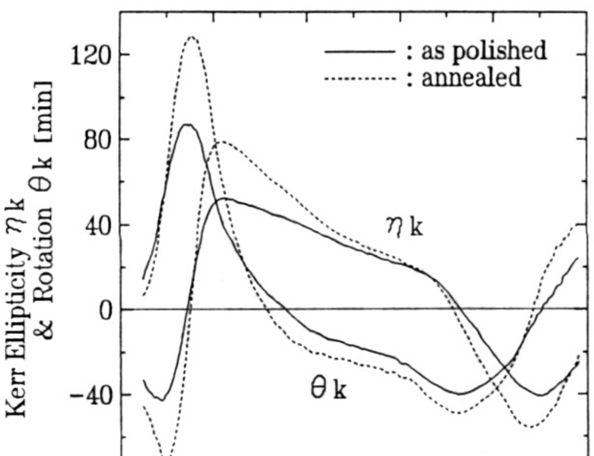

Fig. 3 Magnetooptical Kerr rotation and ellipticity spectra between 1.2 and 5.9 eV in as-polished (solid line) and annealed (dotted line) specimen of PtMnSb.

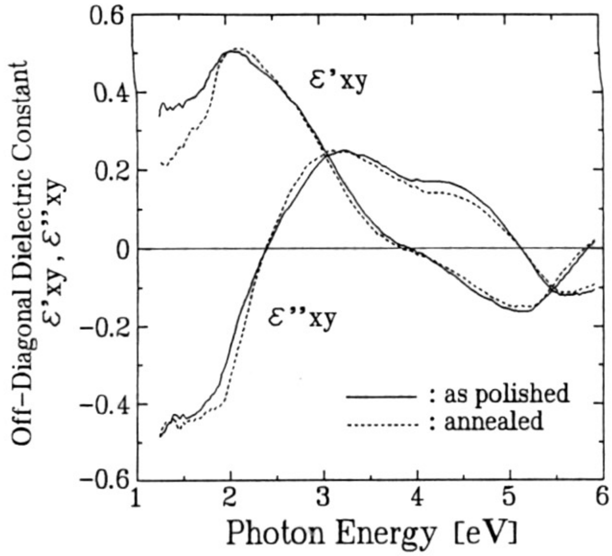

Fig. 4 Spectra of real and imaginary part of off-diagonal element in as-polished (solid line) and annealed (dotted line) samples of PtMnSb.

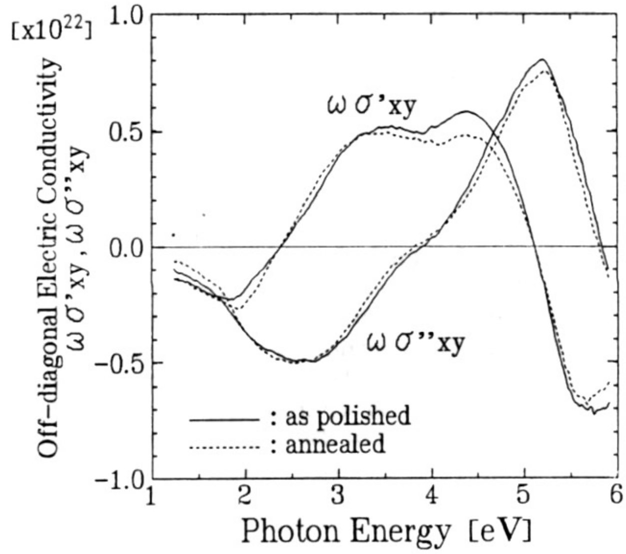

Fig. 5 Spectra of σ_{xy} in as-polished (solid line) and annealed (dotted line) sample of PtMnSb calculated from Fig. 4.

IV. DISCUSSION

In Fig. 5 we present spectra of $\omega\sigma_{xy}$ instead of ϵ_{xy}, since $\omega\sigma_{xy}''$ is more suited than ϵ_{xy}' for the purpose of discussing the origin of the magnetooptical effect in metallic materials, the former being directly related to the joint density of states[8].

The FWHM (full width at the half maximum) of the $\omega\sigma_{xy}''$-peak at 2.7 eV is about 1 eV, considerably broader than the FWHM of Kerr rotation peak at 1.75 eV. This clearly shows that the Kerr rotation peak at 1.75 eV is brought about by the plasma enhancement effect pointed out by Feil et al.[9]. Since Kerr rotation and ellipticity are given by

$$\varphi_K + i\eta_K = \epsilon xy \,/\, \sqrt{\epsilon xx}\cdot(1 - \epsilon xx),$$

Kerr effect is enhanced if ϵxx takes a small value or a value near unity, even though the off-diagonal element remains unchanged. At the plasma frequency the real part of ϵxx vanishes. Therefore Kerr effect will become large if $\epsilon xx''$ takes a small value. In fact the value of $\epsilon xx''$ at the photon energy where the $\epsilon xx'$ becomes zero, of annealed sample is reduced by more than 20 % from that of as-polished sample. This is the reason why the peak Kerr rotation is enhanced in the annealed material. The reduction of $\epsilon xx''$ may be associated with the improvement of crystallinity by annealing.

Another peak of $\omega\sigma xy''$ is observed at 5.2 eV. The two magnetooptical structures at 2.7 and 5.2 eV corresponds to the two strong absorption peaks observed at 3 eV and 5 eV in the $\epsilon xx''$ spectrum of Fig. 2, respectively.

Comparing with the joint density of state(JDOS) curve[10], the first peak can be assigned to the transition between Sb-origined valence band and Mn-3d-origined conduction band in the minority-spin band. On the other hand, the second peak may be related to a transition from Pt-5d-origined band to the Mn-origined band in the minority-spin band.

V. CONCLUSION

Reflectivity spectra for photon energies between 0.5 and 25 eV were measured in as-polished and annealed polycrystaline bulk sample of PtMnSb using the synchrotron radiation. Magnetooptical Kerr rotation and ellipticity between 1.2 and 5.9 eV were measured by means of polarization modulation technique.

Diagonal and off-diagonal element of dielectric permeability tensor were evaluated from the experimental data. Two transitions at around 3 and 5 eV were identified in both spectra.

Enhancement of magnetooptical effect due to the plasma resonance is clearly observed. The increase of the peak Kerr rotation in annealed specimen was explained by the decrease in the value of $\epsilon xx''$.

The origin of the two structures in dielectric tensor was discussed in terms of the electronic structures.

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