MAGNETO-OPTICAL EFFECT IN A SINGLE CRYSTAL OF Cr_3Te_4

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Abstract. – Spectra of magneto-optical Kerr effect were measured between 0.5 and 4 eV in a single crystal of Cr_3Te_4 at room temperature. Peak Kerr rotation at the photon energy of 1.3 eV was about 7 min. The magneto-optical spectrum is discussed in terms of the electronic structure.

We have been working with optical and magneto-optical studies in transition atom chalcogenides to clarify the relation between the electronic structures and magnetic properties [1, 2]. Cr_3Te_4 is a ferromagnet with a NiAs-like crystal structure, showing Curie temperature T_c around 316 K [3]. However, to our knowledge there have been no reports on either optical reflectivity or magneto-optical Kerr spectrum in this material. Only available magneto-optical spectra in Cr-Te system are those measured in thin polycrustalline films of CrTe [4, 5]. This paper is concerned with reflectivity and magneto-optical spectra in a single crystal of Cr_3Te_4.

Single crystals of Cr_3Te_4 were prepared by means of chemical transport technique, following the method described in reference [3]. Single crystals with mirror-like surfaces were obtained. The typical size of obtained crystals was about 2 mm × 1 mm × 0.5 mm. The crystal plane of the surface was determined as {001} by X-ray diffraction. The Curie temperature of the obtained crystal determined by the magnetic measurements was 322-333 K. The phase transition from ferromagnetism to canted-antiferromagnetism was observed at about 80 K. The magnetization curve showed a saturation around 0.6 T at 293 K.

Optical reflectivity spectrum was measured on one of the natural surfaces of the crystal for photon energies between 0.2 and 4 eV, by using the specially-designed reflectivity attachments [6]. Polar magneto-optical spectra were also measured on one of the natural surfaces of as-grown crystals by using the polarization modulation techniques [7].

Optical reflectivity spectrum in Cr_3Te_4 between 0.2 and 4 eV is shown in figure 1. The spectrum shows a steep decrease of reflectivity between 0.2 and 0.5 eV followed by a small hump around 0.8 eV and a featureless part with nearly constant reflectivity between 1 and 4 eV. Flatness of reflectivity spectrum in the visible region accounts for the colorless metallic luster of this crystal. Kramers-Kronig analysis has been applied to the reflectivity spectrum to get optical constants in this material. The dashed curve is an extrapolation to low energies by the Drude formula. For high energy side we extrapolated using a formula of E^{-p} with p taken as a parameter. The parameter was determined so as to reproduce optical constants n and κ determined by the ellipsometry at 546 nm. By using n and κ thus obtained real and imaginary parts of the diagonal element of conductivity tensor were calculated and are plotted in figure 2.

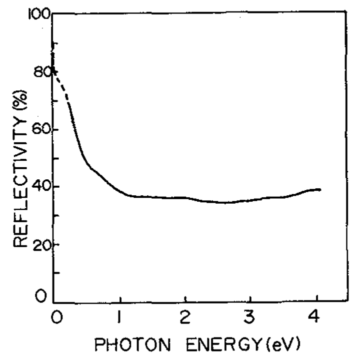

Fig. 1. – Normal incidence reflectivity measured on one of the {001} surfaces of a single crystal of Cr_3Te_4 at room temperature.

The real part of conductivity, which represents the absorption coefficient, increases monotonically from 0.5 to 3.5 eV with small humps around 0.7 and 2 eV. The spectral shape is completely different from that of iron selenide (Fe_7Se_8), in which a narrow and intense absorption band caused by the transition from the filled d-band to empty d-band is observed in low energy region [8].

We also evaluated the concentration of free electrons, n_c at the Fermi level by fitting the low energy conductivity spectrum using Drude formula. This procedure provided the plasma frequency of $\hbar\omega_p = 2.4$ eV, from which $n_c = 0.7$ [electrons per formula unit] was deduced assuming a free electron mass for the effective mass.

Figure 3 shows typical spectra of Kerr rotation and RMCD (reflectance magneto-circular dichroism) measured at room temperature under the magnetic field of 0.5 T. The peak value of Kerr rotation was found to

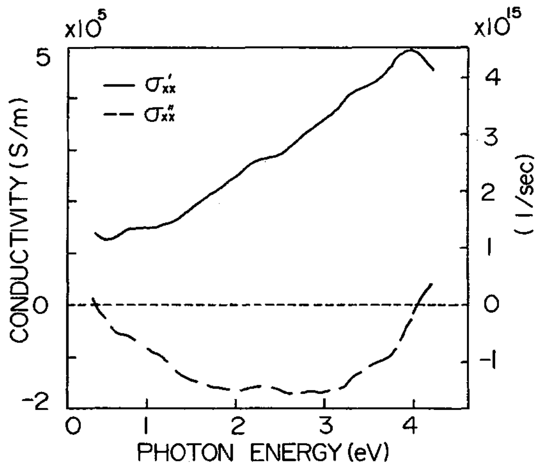

Fig. 2. – Real and imaginary parts of diagonal element of the conductivity tensor in Cr_3Te_4 deduced from the reflectivity. (The left scale is in SI unit and the right scale in CGS unit.)

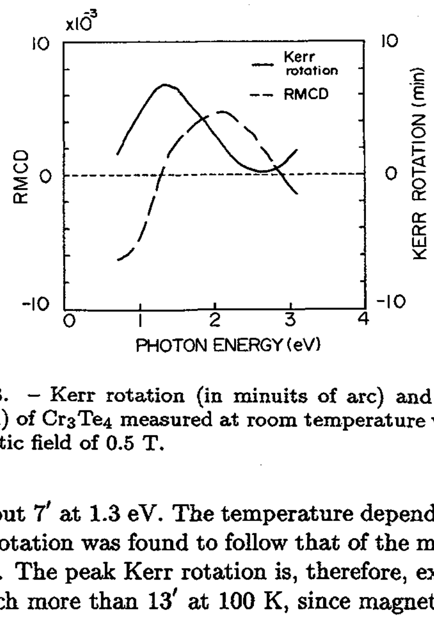

Fig. 3. – Kerr rotation (in minuits of arc) and RMCD (in rad) of Cr_3Te_4 measured at room temperature with the magnetic field of 0.5 T.

be about 7′ at 1.3 eV. The temperature dependence of Kerr rotation was found to follow that of the magnetization. The peak Kerr rotation is, therefore, expected to reach more than 13′ at 100 K, since magnetization at this temperature is twice as large as that at room temperature. RMCD spectrum crosses zero at 1.3 eV, where Kerr rotation has its maximum value.

Since magneto-optical effects in metallic materials are considered to originate from the combined effect of exchange and spin-orbit interactions [9], we postulate that the absorption humps seen in 0.5-3 eV region is associated with band-to-band transition involving the exchange and spin-orbit coupled states in either initial or final states: we, therefore, tentatively assign that the absorption band is caused by a charge transfer transition from the valence band originating from 5p-orbitals of Te atom to the conduction band consisting of 3d-orbitals of Cr.

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