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Ni_2MnIn Heusler alloy films, studied by optical and magneto-optical spectroscopies

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I. Introduction

Ni_2MnIn Heusler alloy is considered as a promising candidate for spin-injector layer in spintronic and/or optoelectronic modulator devices [1]. It is very important to investigate Ni_2MnIn alloy films with different structural orders because of a close relationship between the structural disorder, and the electronic structures and the magnetic properties. In this study, the structural dependences of magneto-optical (MO) and optical properties of Ni_2MnIn alloy films were investigated.

II. Experiment

Ni_2MnIn alloy films were prepared by flash evaporation of the crushed alloy powders. To obtain films with a distinct order, the deposition was performed onto substrates heated up to 730 K, while a significantly-disordered alloy film was prepared by vapor-quenching deposition onto substrates cooled by liquid nitrogen. The actual substrate temperature was estimated to be 150 K. The deposition onto substrates kept in between two temperatures allowed us to fabricate the alloy films with an intermediate degree of structural order. Structural characterization of the bulk and the film samples was carried out by using x-ray diffraction (XRD) and transmission electron microscopy. Details of the MO and the optical measurements can be found elsewhere [2].

III. Results and Discussion

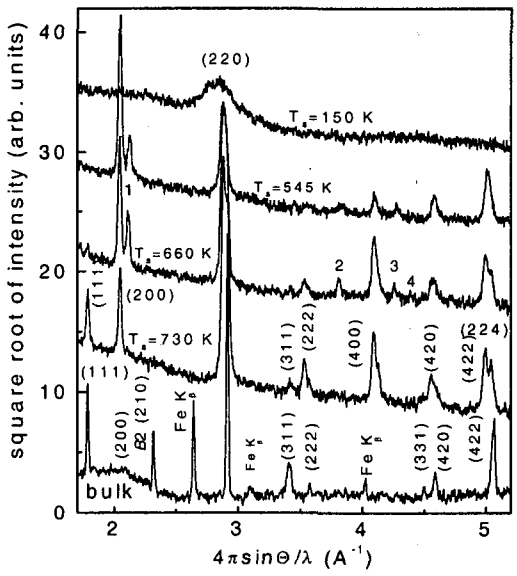

Fig. 1. XRD spectra for bulk and film Ni_2MnIn alloy samples, prepared at different substrate temperatures.

The XRD spectrum for the bulk sample indicates the formation of a well-ordered structure : all the diffraction lines belong to the $L2_1$ phase, except for (210) whose appearance might be explained by the presence of a certain disorder of the $B2$ type (see Fig. 1). Ni_2MnIn alloy films deposited at 730 K show a well-ordered single-phase $L2_1$ structure. A decrease in the substrate temperature from 730 to 545 K still preserves the crystalline structures. However, the main diffraction lines become wider, and additional diffraction lines, marked by number 2 - 4 [2 - (321), 3 - (410) or (223), and 4 - (141) or (303). Line 1 is not identified] emerge, indicating the formation of a structure with the $B2$-type ordering. This is also accompanied by a noticeable reduction in the mean grain size. Finally, the quench deposition leads to amorphous alloy films.

The optical-conductivity (OC) spectrum for the Ni_2MnIn alloy film with $L2_1$ type of structure is characterized by two interband absorption peaks at 1.8 and 3.2 eV (Fig. 2). The OC spectrum for the bulk alloy looks similar to this, but is red-shifted by 0.2 eV. The structural disordering (for example, from the

sample deposited at 730 or 660 K to that at 545 K) causes a red-shift of both interband absorption peaks by about 0.2 eV and reduces the intensity of the low-energy one. A further increase in the structural disordering (*i.e.*, to the amorphous sample) results in a red-shift of the high-energy maximum by 0.4 eV and disappearance of the low-energy absorption peak. At the same time, the overall magnitude of OC in the near-IR (NIR) region becomes even greater than those of the ordered states.

The equatorial-Kerr-effect (EKE) spectra for the most-ordered Ni_2MnIn alloy film (T_s = 730 K) and the bulk sample manifest two negative peaks at 1.6 and 2.8 - 3.0 eV, and a narrow intense positive peak in the NIR region (Fig. 3). The origin of a relative shift of the high energy peak in the EKE spectra between film and bulk samples is probably the same shift in the OC spectra, and relevant to different lattice constants. The structural disordering of *B*2-type leads to a very rapid decrease in the magnitude of MO effect, and the EKE for amorphous Ni_2MnIn alloy films was not detected at all. The EKE spectrum of the crystalline Ni_2MnIn alloy films with *B*2-type order also exhibits the double-peak structure, although the intensity is rather low.

IV. Summary

The XRD spectrum show that the film deposited at a high temperature is in an ordered structure, while the film deposited at a low temperature is amorphous-like. It was observed that the structural transformations, $L2_1 \rightarrow B2$ and then $B2 \rightarrow$ amorphous, lead, at first, to a decrease and then to disappearance of the ferromagnetic order (at least, above 293 K).

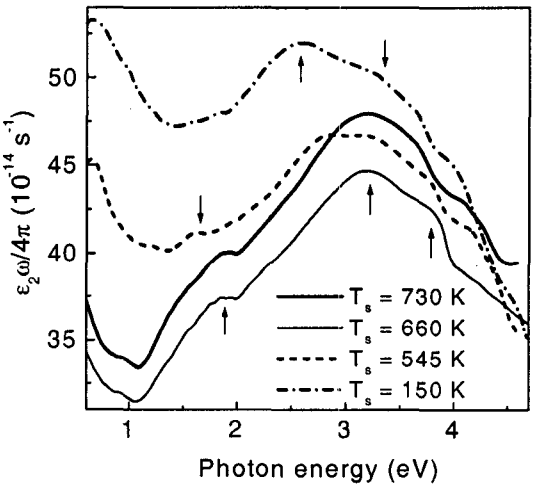

Fig. 2. Optical-conductivity spectra for Ni_2MnIn alloy films deposited at different substrate temperatures.

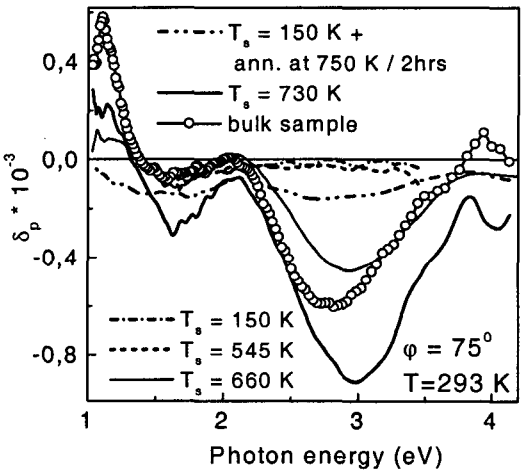

Fig. 3. EKE spectra for Ni_2MnIn alloy films deposited at different substrate temperatures, taken at room temperature and an incidence angle of Φ = 75°.

References

[1] I. Galanakis: *Scientific Highlight of the Month* (February, 2003).

[2] Y.V. Kudryavtsev, Y.P. Lee and J.Y. Rhee: Phys. Rev. B 66, 115114 (2002).