Structural and Magnetic Properties of Epitaxial Co_2FeAl Films Grown on MgO Substrates for Different Growth Temperatures

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1. 서론

The objective of this research was to elucidate the correlation between crystalline structure, electronic structure, and magnetic properties of Co_2FeAl films as a function of growing temperature (T_g) by experimentally and theoretically.

2. 실험방법

The Co_2FeAl thin film samples were prepared on 1cm x 1cm MgO (100) single crystalline substrates with various growth temperatures by molecular beam epitaxy (MBE).

3. 실험결과

The degree of atomic site ordering (S) is calculated by the integration of the intensity ratio of the (200) and (400) diffraction peaks in the XRD pattern. The S for the sample grown at 600^{o}C is much higher than that of the sample grown at RT (53%:35%), indicating that the degree of order on the Co sites increase with T_g. The sample grown at RT has a structural or crystalline disorder that disappears with increasing T_g. This disappearance results from the improvement of the structure at the atomic level and represents a transition from short-range to long-range crystallographic order with increasing T_g. Based on TEM and XRD results, the Co_2FeAl film grown at RT is initially in the partially disordered B2 state, but then transitions to a much higher ordered structure with increasing T_g.

From the EELS spectra, we found that the Co L3 and L2 peaks for the sample grown at 600^{o}C was much higher than those of the sample grown at RT,and the I(L3)/I(L2) ratios were 2.3 and 1.9, respectively. Those intensities reflect the occurrence of vacancies in the d-band. Therefore, the higher intensity indicates a larger number of unoccupied 3d states in the sample grown at 600^{o}C. The Fe L3/L2 ratio and peak intensity, however, do not show any significant variation, regardless of T_g. These changes in the I(L3)/I(L2) ratio should be related to the microstructural and chemical evolution associated with the growing temperature, since the TEM and XRD results show a clear trend in the modification of the structure to a more ordered B2 structure with increasing T_g.

As Tg increases, the I(L3)/I(L2) ratio and peak intensity of Co become more dominant than those of the Fe. Moreover,the degree of order on the Co sites increase with Tg. Therefore, the increase in the Co contribution and degree of order on the Co sites with Tg result in the increment of Hc due to the relatively higher magnetic anisotropy of Co than that of the Fe.

We performed inductive magnetization dynamics measurements on Co_2FeAl films. By increasing T_g, damping constant (α) increased. Our T_g dependence of the αcharacteristics differ from the results of other groups, where the αvalues decrease with increasing degree of atomi corder by annealing.[1] We deduce that the increase of α resulted from the increasing Co effects with T_g. α is proportional to the square of the spin-orbit coupling parameter and is a consequence of spin-orbit interaction. Th eorbital moment, resulting from the spin-orbit interaction, is proportional to the difference between the number of states of majority and minority spins at the Fermi level. Fe is a weak ferromagnet with the Fermi level intersecting both the 3d up and down spin bands, while Co is a strong ferromagnet having holes in its 3d down band; hence, the orbital moment in Co is larger than in Fe. Moreover, as the T_g increases, larger numbers of unoccupied 3d states in Co are observed. Therefore, the increase of α with T_g resulted from the increasing spin-orbit interaction of Co.

4. 고찰

Our experimental results will help with the design of high spin polarized with low α materials such as Co_2FeAl full-Heusler alloy and realize a low current density for current induced magnetization switching in a high-density MRAM. These well-defined properties change can be regulated by T_g control and the method presented herein is easily extended to other material systems.

5. 결론

In summary, we clarify the correlation between crystalline structure, electronic structure, and magnetic properties of Heusler Co_2FeAl films as a function of growing temperature. The Co_2FeAl film grown at RT is initially in the partially disordered B2 state, but then it gains a much higher ordered structure with increasing T_g. As T_g increases, higher I(L3)/I(L2) ratio and many more unoccupied 3d states in Co are observed and hence, α increases due to a strong spin-orbit interaction.

6. 참고문헌

[1] S, Mizukami, D. Watanabe, M. Oogane, Y. Ando, Y. Miura, M. Shirai, T. Miyazaki. J Appl Phys. 105, 07D306 (2009).