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Magnetic anisotropy and anisotropic magneto-resistance in non-magnetic III-V/GaMnAs superlattices depending on layer thickness and valence band offset

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As the mechanism of ferromagnetism in GaMnAs the p-d Zener model[1] has been widely accepted, because it successfully demonstrated the magnetic properties, such as their carrier-density dependent Curie temperature and strain-dependent magnetic anisotropy. However, recently several reports [2] have shown that the Fermi level in GaMnAs exists in the impurity bands and the spin splittings in valence bands are small, which are inconsistent with the p-d Zener model, and the controversy grew warm again[3]. In the meanwhile, we have experimentally investigated the cubic magnetic anisotropy fields (Hcs) and the anisotropic magneto-resistances (AMRs) in GaMnAs depending on layer thickness and found their characteristic layer thickness dependence[4]. We also found that Hcs and AMRs are dependent on the valence band offset (ΔE_v) between GaMnAs and GaAs in $(GaAs)_{14}(GaMnAs)_m$ superlattices (SLs) by the theoretical calculation based on the p-d Zener model[5]. In this presentation, we report on the thickness dependence in $(AlAs)_{14}(GaMnAs)_m$ SLs and comparison with the results of $(GaAs)_{14}(GaMnAs)_m$ SLs.

Electronic states in (non-magnetic III-V)$_{14}$(GaMnAs)$_m$ SLs were obtained by conventional kp-perturbation Hamiltonian added p-d exchange interaction. Hcs are evaluated based on magnetization-orientation dependent total energies. AMRs ($\frac{\rho_\parallel-\rho_\perp}{\rho_\parallel+\rho_\perp}\times 100$) are evaluated based on semi-classical Boltzmann theory assuming isotropic and constant relaxation time. Figure 1 shows calculated (a)Hcs, (b)AMRs, respectively (hole concentrations in GaMnAs layers are $p_m = 1.0\times 10^{20}$ [cm^{-3}]), as well as the experimental values for $(GaAs)_{14}(GaMnAs)_m$ SLs as a function of GaMnAs thickness. For the case, $\Delta E_v = 0$ [eV], calculated Hcs and AMRs show gradual decrease with the increase of GaMnAs thickness and these trends are consistent with the experiments of $(GaAs)_{14}(GaMnAs)_m$ SLs. On the other hand, in $(AlAs)_{14}(GaMnAs)_m$ SLs as well as $(GaAs)_{14}(GaMnAs)_m$ SLs for the case, $\Delta E_v = 0.2$ [eV], calculated Hcs and AMRs show oscillatory behaviors with the increase of GaMnAs thickness. In the presentation, we will further discuss on the origin of their oscillations in addition to the experimental results on $(AlAs)_{14}(GaMnAs)_m$ SLs.

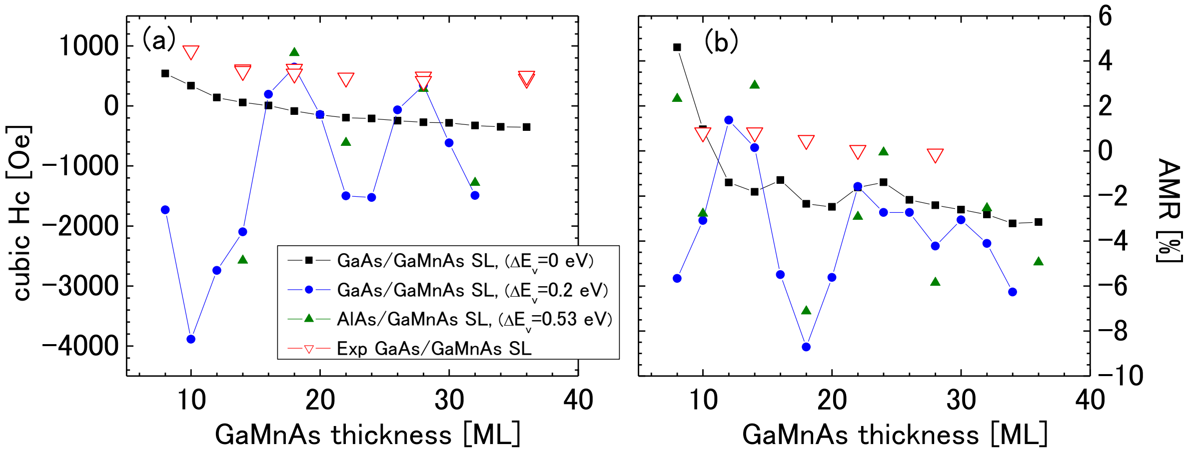

Fig.1 Theoretically obtained (a) cubic magnetic anisotropy fields, Hcs [Oe], and (b) AMRs [%] as a function of GaMnAs thickness in $(GaAs)_{14}(GaMnAs)_m$ SLs for the case, $\Delta E_v = 0$ [eV] (black), for the case, $\Delta E_v = 0.2$ [eV] (blue), and $(AlAs)_{14}(GaMnAs)_m$ SLs, $\Delta E_v = 0.53$ [eV] (green) and their hole concentrations in GaMnAs layers are 1.0×10^{20} [cm^{-3}]. Open red triangles, ▽, indicate experimental values in $(GaAs)_{14}(GaMnAs)_m$ SLs.

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