

Temperature-dependent Interlayer Coupling in Fe₃Si/FeSi₂ Superlattices

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Since the discovery of a giant magnetoresistance (GMR) effect associated with an exchange coupling between ferromagnetic layers separated by a nonmagnetic metal spacer, the interlayer coupling has attracted considerable attention from physical and practical viewpoints. The interlayer coupling is described by spin-dependent quantum well states in the spacer. In the case of non-metallic spacers, there often appears a different type of interlayer coupling from that in artificial lattices with metallic spacers. An artificial lattice comprised of Fe-Si materials is one of the representatives. To date, Fe/Si [1] and Fe/Fe_{1-x}Si_x [2] multilayers have been studied. In them, strong antiferromagnetic (AF) interlayer couplings including biquadratic ones, which are different from those in artificial lattices with metallic spacers, are induced. We have conducted research on Fe₃Si/FeSi₂ artificial lattices [3]. As compared to the previous artificial lattices based on Fe-Si materials, they have the following advantages: (i) a reduced mismatch in the electrical conductivity; (ii) a strong AF interlayer coupling strength in spite of the saturation magnetization of Fe₃Si being half as that of Fe. In our previous research, we have confirmed that the Fe₃Si layers were epitaxially grown not only on Si(111) but also up to the top layer across the FeSi₂ layers [4] and F/AF interlayer couplings were induced by controlling the thickness of the FeSi₂ layers. In this study, the interlayer coupling in Fe₃Si/FeSi₂ artificial lattices deposited on Si(111) by facing targets direct-current sputtering (FTDCS) was investigated at low temperatures. We report the temperature-dependence of the interlayer coupling.

A [Fe₃Si(25 Å)/FeSi₂(7.9 Å)]₂₀ artificial lattice film was deposited on an n-type Si(111) substrate by FTDCS using Fe₃Si and FeSi₂ alloy targets (3N) with atomic ratios of Fe/Si = 3:1 and 1:2 respectively. The deposition was carried out in the same manner as that in our previous studies [3,4]. The layered and crystalline structures were evaluated by X-ray diffraction (XRD) using Cu K α radiation. The magnetization curves were measured at temperatures lower than 300 K using a vibrating sample magnetometer (VSM).

The polarized neutron reflectivity spectrum of the superlattice exhibits two peaks due to antiparallel alignment of Fe₃Si layer magnetizations, as shown in Fig. 2(a). The layer magnetization is changed from antiparallel to parallel alignments by applying a magnetic field of 1 T, which results in a single peak, as shown in Fig. 2(b). Surprisingly, with decreasing temperature under the magnetic field of 1 T, two peaks are observed in the spectra as shown in Fig. 2(c), which evidently indicates that the antiparallel alignment is reformed even under the 1 T magnetic field. As a reason for it, the antiferromagnetic interlayer coupling induced between the ferromagnetic Fe₃Si layers is strengthened with decreasing temperature. The details will be indicated at the conference.

[1] E. E. Fullerton et al., J. Appl. Phys. **73** (1993) 6335.

[2] Y. Endo et al., Phys. Rev. B **59** (1999) 4279.

[3] T. Yoshitake et al., Appl. Phys. Lett. **89** (2006) 235110.

[4] K. Takeda et al., Jpn. J. Appl. Phys. **46** (2007) 7846.

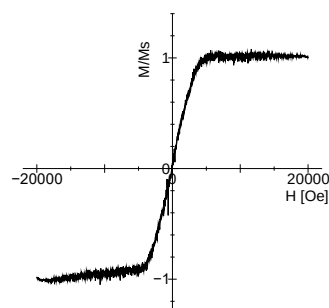
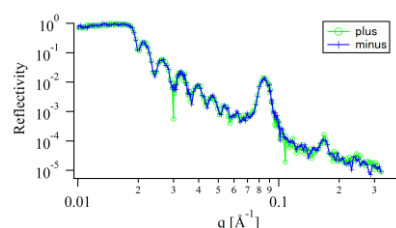
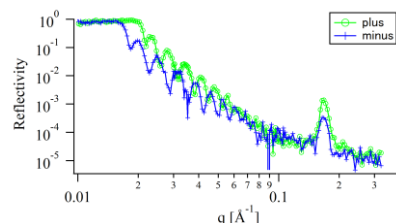


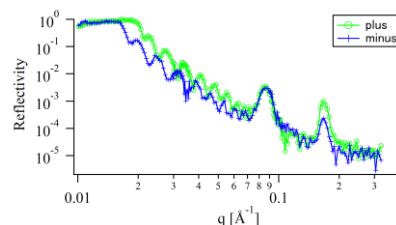
Fig. 1. Magnetization curves of Fe₃Si (25 Å)/FeSi₂ (7.9 Å) superlattices, measured at room temperature.



(a) RT, no magnetic field



(b) RT, 1 T



(c) 100 K, 1 T

Fig. 2. Polarized neutron reflectivity spectra of Fe₃Si (25 Å)/FeSi₂ (7.9 Å) superlattices, measured (a) under no applied magnetic fields at room temperature, (b) under 1 T at room temperature, and (c) under 1 T at 100 K.