Polarized Neutron Reflectivity Study of Magnetic Structure in $Fe_3Si/FeSi_2$ 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 $Fe_3Si/FeSi_2$ 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 Fe_3Si being half as that of Fe. In our previous research, we have confirmed that the Fe_3Si layers were epitaxially grown not only on Si(111) but also up to the top layer across the $FeSi_2$ layers [4] and F/AF interlayer couplings were induced by controlling the thickness of the $FeSi_2$ layers. In this study, the interlayer coupling in $Fe_3Si/FeSi_2$ 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 [Fe_3Si(25 Å)/$FeSi_2$(7.9 Å)]$_{20}$ artificial lattice film was deposited on an n-type Si(111) substrate by FTDCS using Fe_3Si and $FeSi_2$ 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 $K\alpha$ 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 Fe_3Si 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. In addition, we are planning to observe magnetism on the surface of the superlattice using magnetic kerr microscopy. We will indicate the magnetic structure of the superlattice in detail at the conference.

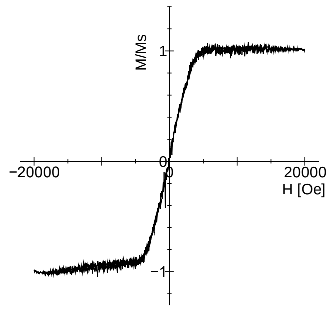
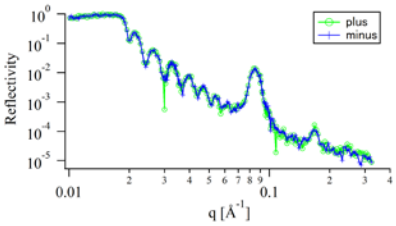
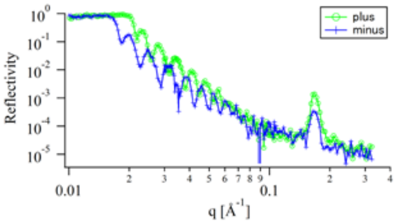


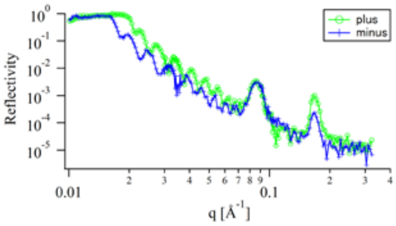
Fig. 1. Magnetization curves of Fe_3Si (25 Å)/$FeSi_2$ (7.9 Å)] superlattices, measured at room temperature.



(a) RT, no magnetic field



(b) RT, 1 T



(c) 100 K, 1 T

Fig. 2. Polarized neutron reflectivity spectra of Fe_3Si (25 Å)/$FeSi_2$ (7.9 Å)] superlattices. measured (a) under 0.005 T applied magnetic fields at room temperature, (b) under 1 T at room temperature, and (c) under 1 T at 100 K.

[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.