Magnetic Properties of quasi-periodic Fibonacci Fe-Au Multilayers

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Periodic magnetic multilayers (PM) have been studied since the early 1990s. Especially, considerable attention has been paid to Fe-Au PM because of not only the perpendicular magnetization but also oscillatory coupling between ferromagnetic layers. In contrast to the periodic counterpart, magnetic quasi-periodic multilayers remain experimentally unaddressed although theoretical calculations have predicted anomalous magnetic resistance and ferromagnetic resonance (FMR) [1]. Here, in order to experimentally study quasi-periodic magnetic multilayers, we use the Fibonacci sequence to induce modulation in the interaction in magnetic multilayers. The Fe-Au multilayers modulated using the Fibonacci sequence, herein referred to as Fe-Au inverse Fibonacci-modulated multilayers (IFM), were prepared using ultra-high-vacuum vapor deposition. The Fe-Au IFM and PM were studied using in-situ reflection high-energy electron diffraction, magnetization and FMR measurements.

Figure shows angle-resolved FMR spectra of Fe-Au (a) PM and (b) IFM samples. The θ corresponds to dc magnetic field direction from the surface normal. Figure 1(a) shows that, with θ= 0°, an FMR signal is observed at approximately 600mT. As θ is increased to 90°, the FMR signal shifts to a lower magnetic field. The resonance signal arrives at approximately 250mT when θ= 90°. With a further increase in θ up to 180°, the signal shifts back to a higher magnetic field. This signal shift is attributed to the Kittle mode FMR corresponding to the uniform precession of electron spins in Fe layers. The shift of the FMR signal is caused by the magnetic shape anisotropy in the PM sample, because the shift direction is consistent with large in-plane magnetization revealed by magnetization measurements. Figure 1(b) shows the angle-resolved FMR of the Fe-Au IFM sample. An FMR signal is observed at approximately 200mT with θ = 0°. While this signal is slightly shifted to a higher magnetic field with an increase in θ up to 90°, the shift variation is small. These FMR results in Fig. 1(b) are consistent with the magnetization measurement results demonstrating the isotropic magnetization process. These results demonstrate that the IFM sample has a quasi-isotropic magnetization process while the PM sample has in-plane magnetization [2].

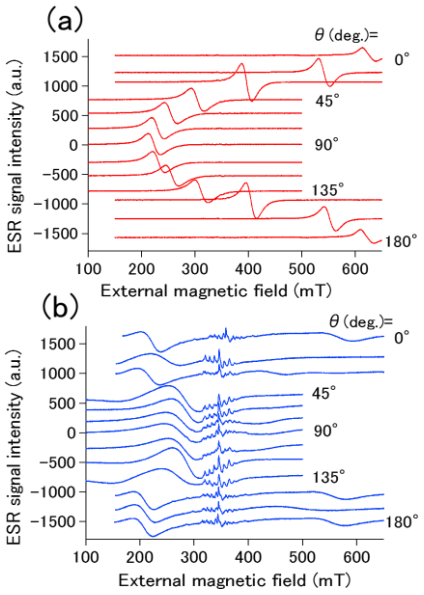

Figure Angle-resolved FMR spectra of (a) Fe-Au PM and (b) IFM samples.

[1] Machado *et al.*, Phys. Rev. B **85,** 224416(2012). [2] Suwa et al., Materials **10**, 1209 (2017).