Dependence of exchange bias field on antiferromagnetic layer thickness in NiFe/FeMn/CoFe heterostructures grown under a magnetic field

Ki-Yeon Kim1, Hyeok-Cheol Choi2, Sin-Yong Jo2, Seung Ku Kang2, Jong Kahk Keum3, Valeria Lauter4, Haile Arena Ambaye4, Jiyong Gu5, Je-Ho Shin6, Dong-Hyun Kim6, Chun-Yeol You2,7

1Neutron Science Division, Korea Atomic Energy Research Institute, Republic of Korea
2Department of Physics, Inha University, Republic of Korea
3Center for Naanophase Materials Science, Oak Ridge National Laboratory, Oak Ridge, Tenessee 37831, USA
4Quantum Condensed Matter Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA
5Department of Physics and Astronomy, California State University-Long Beach, Long Beach, 1250 Long Beach, California 90840, USA
6Department of Physics, Chungbuk National University, Cheongju 28644, Republic of Korea
7Department of Emerging Materials Science, DGIST, Daegu 42988, South Korea

We have investigated the antiferromagnetic layer thickness dependence of exchange bias field in NiFe (F)/FeMn(t_{AF}, AF)/CoFe(F) trilayered heterostructures with $t_{AF}$ up to 30 nm. It was found that exchange bias field at both F/AF interfaces exhibit anomaly around $t_{AF} = 20, 25$ nm after saturation at $t_{AF}=10$ nm. Considering that the theoretical and experimental results studied so far[1-4], it has been found to be very unusual behavior. Well-known factors such as FeMn(111) texture, FeMn grain size, and F/AF interface roughness are unlikely to explain the observed anomaly. We measured and compared polarized neutron reflectivity of NiFe (F)/FeMn($t_{AF}$ =25nm)/CoFe(F) at positive (300 Oe, R +) and negative (-300 Oe, R -) saturations using Magnetism Reflectometer @BL4A, Spallation Neutron Source (SNS) at Oak Ridge National Laboratory. By comparison, we found that there exists very small, but non-zero spin asymmetry. Spin asymmetry is defined as (R+ - R-)/(R+ + R-). This is unexpected results because spin asymmetry at both saturations should be the same with each other. We attempt to understand our results as follows. In case of $t_{AF} \leq 20$ nm less than AF domain wall length, the intra-layer AF exchange coupling tends to make FeMn(111) fully compensated spin structures. This may be ascribed to the fact that the uncompensated magnetic moments within FeMn(111) layer have seldom been seen in previous reports regarding (NiFe or Co)/FeMn(111) bilayered heterostructures. Meanwhile, partially uncompensated, rotatable AF spins or partial domain wall is likely to be accommodated within FeMn(111) layer in case of $t_{AF}= 25$ nm, close to a AF domain wall length for FeMn(111) texture. We believe that partially uncompensated rotatable spins or partial domain walls possibly lead to the anomaly observed even after saturation of exchange bias field around $t_{AF}=10$ nm in NiFe/FeMn/CoFe heterostructures.

This work was supported by NRF Grants (2012M2A2A6004261) funded by the Korea government.
Fig. 1. Antiferromagnetic layer thickness dependence of the exchange bias field at NiFe/FeMn(open circle) and FeMn/CoFe(solid circle) interfaces in NiFe/FeMn/CoFe heterostructures.

References