Enhancement of the anomalous Nernst effect in Fe_4N films on $SrTiO_3$(001) substrates

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Recently, the development of thermoelectric power generation (TEG) devices utilizing the anomalous Nernst effect (ANE) is attracting increasing interest. However, a current critical technical issue for practical application to ANE-based TEG is a much small value of the thermoelectric power of ANE (S_{ANE}) compared with that of the conventional Seebeck effect (SE)-based TEG. We focus on Fe_4N as a new material with a large S_{ANE}. Fe_4N is composed of earth abundant elements and relatively large S_{ANE} of 2.2 μV/K was experimentally reported in a Fe_4N film on a MgO(001) substrate [1]. In addition, large transverse Peltier coefficient of 2.4 A/(m·K) was theoretically predicted [2]. In this study, enhancement of ANE in epitaxial Fe_4N films grown on oxygen deficient $SrTiO_3$(STO)(001) substrates has been found.

The epitaxial Fe_4N films with a thickness of 27 nm were grown at 450 ºC on MgO(001), $MgAl_2O_4$(MAO)(001), and STO(001) substrates by molecular beam epitaxy (MBE). Subsequently, a 2-nm-thick Al capping layer was formed on the Fe_4N layer in a sputtering chamber connected to the MBE chamber. The samples were microfabricated into a Hall bar shape using photolithography and ion milling for the measurements of ANE, SE, and the anomalous Hall effect. During the ANE measurements, external magnetic fields were applied in the direction perpendicular to the film surface and temperature gradient was applied to the in-plane Fe_4N[110] direction.

The S_{ANE} values of the Fe_4N films on MgO(001), MAO(001), and STO(001) were 1.4, 1.7, and 2.8 μV/K, respectively. The thermoelectric powers of SE (S_{SE}) of these samples were also measured, and the values were −2.9, −2.6, and −27.3 μV/K, respectively. The large S_{ANE} of STO(001)/Fe_4N is attributed to its negatively large S_{SE}. This large $|S_{SE}|$ might be caused by the oxygen deficient STO layer with a large effective mass at the bottom of the conduction band [3], which is formed during the growth of the Fe_4N layer at the relatively high temperature (450 ºC). The S_{SE} value and the thickness of the oxygen deficient STO layer are estimated to be approximately −120 μV/K and 20 nm, respectively [4,5]. It is suggested that S_{ANE} of ferromagnetic films can be enhanced by the use of the oxygen deficient STO layer with large $|S_{SE}|$.

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