第76回応用物理学会秋季学術講演会 講演予稿集 (2015 名古屋国際会議場)

Spin-Seebeck effect in cobalt-ferrite epitaxial thin films with different preferential axes

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One of the most attractive outputs from "insulator spintronics" [1] is recently-proposed thermoelectric (TE) generation using magnetic insulators (MIs) as TE power sources since it has potential advantages in versatility, costs, and ubiquitousness compared with conventional semiconductor-based TE devices [2]. This epoch-making MI-based TE generation is initiated by a heat-mediated pure-spin-current creation in MIs, called spin-Seebeck effect (SSE) [3, 4], and then followed by the electric conversion via the inverse spin-Hall effect (ISHE) [5,6] in a paramagnetic metal such as Pt adjacent to the MI. Although the SSE has been demonstrated in soft MIs so far [3, 4, 7–9], SSE in hard MIs [10, 11] is recently attracting much attention from the viewpoint of both physics and application. In this study, we focused on cobalt ferrite (CFO), an exceptionally hard magnetic spinel ferrite, as an anisotropy tunable SSE material and experimentally demonstrated the longitudinal SSE (LSSE) in a bilayer of Pt/CFO grown on different substrates. Epitaxially-strained CFO thin films were prepared on $MgAl_2O_4$ (MAO)(110) and MgO(001) substrates by reactive rf sputtering technique. The CFO(110)/MAO(110) exhibited an in-plane uniaxial anisotropy whereas CFO(001)/MgO(001) showed a perpendicular anisotropy. Thermally generated spin voltages in those CFO films were measured via the ISHE in the polycrystalline Pt deposited on the top. External-magnetic-field (H) dependence of the LSSE voltage (V_{LSSE}) with $H \parallel [001]$ in Pt/CFO/MAO sample exhibited a magnetic hysteresis loop with a high squareness and a large coercivity, whereas that in Pt/CFO/MgO showed a nearly closed loop, reflecting the different magnetic preferential axes induced by the oppsite epitaxial strains [12,13]. The magnitude of V_{LSSE} has a linear relationship with the temperature difference (ΔT), giving the relatively large $V_{LSSE}/\Delta T$ of about 3 μV/K for CFO(110) which was kept even at zero external field. The temperature dependence of V_{LSSE} measured for various preferential axes will also be presented.

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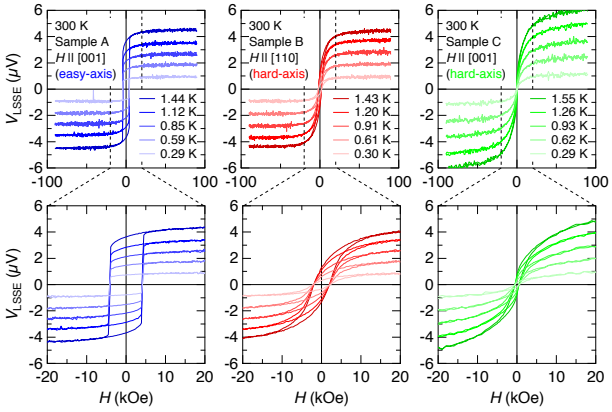

Figure 1: External-magnetic-field dependence of longitudinal spin-Seebeck signal (V_{LSSE}-H) measured at 300 K in Pt/CFO bilayers grown on MAO(110) (blue and red) and MgO(001) (green) substrates.