Sm-Co-based amorphous alloy films for zero-field transverse thermoelectric generation

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In recent years, the research on spin caloritronics is showing a new direction with the demonstration of many magneto-thermoelectric effects by advanced heat measurement techniques[1-3]. However, the practical application of these effects requires systematic device engineering and introduction of new materials as most of the conventional materials have very low thermoelectric conversion efficiency. As an effort to find good spin-caloritronic materials, Miura *et al*.[4] found that $SmCo_5$-type magnets exhibit a large anomalous Ettingshausen effect (AEE), which is a transverse thermoelectric effect that generates a heat current in the direction perpendicular to the applied charge current and magnetization.

In this study, we report systematic investigations on AEE in Sm-Co-based amorphous films, while polycrystalline bulk magnets were used in the previous study[4]. Here, we have investigated the composition dependence of AEE for the amorphous Sm_xCo_{1-x} ($0 \leq x \leq 100$) composition-spread film, fabricated by the combinatorial sputtering technique[5,6], and confirmed that $Sm_{20}Co_{80}$ exhibits the largest AEE signal. For the optimized composition, Co is systematically replaced with Fe by fabricating $Sm_{20}(Co_{1-y}Fe_y)_{80}$ ($0 \leq y \leq 100$) composition spread film and observed a significant enhancement in the AEE-induced temperature modulation for 23 at% Fe substitution. For further confirmation, we have fabricated a uniform $Sm_{20}(Co_{77}Fe_{23})_{80}$ film and directly measured the anomalous Nernst effect (ANE), the Onsager reciprocal of AEE. A relatively large ANE coefficient of 1.5 μV/K was observed for this film, which is consistent with the estimation from the composition-spread film (~1.3 μV/K). We have further demonstrated the performance of a prototype ANE-based heat-flux sensing device[7] fabricated on 50-μm-thick flexible polyethylene naphthalate substrate. The presence of high in-plane remanent magnetization and coercive force in our films makes it advantageous over conventional materials for applications including heat flux sensors, as these materials can generate thermoelectric output without an external magnetic field. Importantly, these amorphous films can be fabricated on any surfaces. Thus, exploring the possibility of hybrid films consisting of these films and other magnetic materials will be useful to construct ANE/AEE devices that operate at zero magnetic field.

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