Anomalous Ettingshausen Effect in Ferrimagnetic Co-Gd

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Newly discovered spin-caloritronic phenomena have stimulated renewed interest in the thermoelectric effects in ferromagnets, *e.g.* anomalous Nernst effect (ANE) and anomalous Ettingshausen effect (AEE). These thermomagnetic effects are possibly beneficial for thermoelectric conversion applications. The ANE-based thermoelectric conversion requires a material exhibiting a large ANE coefficient. Recent studies report that large ANE was achieved not only for ferromagnets but also for a chiral antiferromagnet [1]. The very small M of the chiral antiferromagnet may lead to a practical advantage that ANE-thermopiles can be integrated densely. Thus, if a large thermomagnetic effect is obtained in an antiferromagnet or a compensated ferrimagnet, such a material is a candidate for realizing high-performance thermoelectric conversion applications.

In this study, we focus on ferrimagnetic Co-Gd amorphous alloys, where the Co and Gd momentsare coupled antiferromagnetically [2]. AEE of Co-Gd amorphous alloy thin films was visualized employing the active infrared emission microscopy called lock-in thermography [Refs. 3-6]. The magnetic, transport and thermoelectric properties were measured for the Co-Gd with various compositions, and the composition dependence of AEE for the Co-Gd was investigated.

Al / $Co_{100-x}Gd_x$ / Al layers were deposited on a thermally oxidized Si substrate using an ultrahigh vacuum compatible magnetron sputtering system. First, a 4 nm-thick Al buffer was deposited on the substrate. Then Co and Gd were co-deposited to form the $Co_{100-x}Gd_x$ layer with a thickness of 30 nm. Finally, a 4 nm-thick Al capping layer was deposited on the Co-Gd layer. All the layers were deposited at room temperature.

We found that the sign of AEE is determined by the magnetic moments of Co sublattice, as well as those of the magneto-optical Kerr effect and the anomalous Hall effect, and the magnitude of AEE does not decrease even when x is close to the magnetization compensation composition. Our experimental results suggest that the magnetically-compensated ferrimagnets become candidates for high-performance thermomagnetic materials with tiny magnetization [7].

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