Efficient tuning of electronic, transport, and thermoelectric properties of Weyl semimetal $Co_2MnAl_{1-x}Si_x$ composition-spread thin film

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The thermoelectric generation based on the anomalous Nernst effect (ANE) has become one of the promising approaches to realize efficient energy harvesting from waste heat due to its several advantages over conventional devices based on the Seebeck effect (SE)[1-2]. However, till date, the observed ANE thermopower is very small and a systematic material investigation to realize large anomalous Nernst coefficient is necessary. Recent study suggests, with proper tuning of Fermi level (E_F) near Weyl points in Weyl semimetal one can realize large ANE[3-5]. In this regard, we introduce an efficient approach to tune E_F for Weyl semimetals and demonstrate the approach through a layer-by-layer combinatorial deposition of a $Co_2MnAl_{1-x}Si_x$ (CMAS) thin film with x varied from 0 to 1 on a single substrate. The structural characterization reveals the formation of single-phase CMAS alloy throughout the composition range. Hard X-ray photoemission spectroscopy directly confirmed a continuous shifting of E_F from Co_2MnAl to Co_2MnSi with a maximum shift of 0.40 eV which is consistent with the theoretical prediction. We also measured the anomalous Ettingshausen effect (AEE), the reciprocal of ANE, for the all x range using just a single strip along the composition gradient by means of the lock-in thermography technique[6-7]. Only one LIT image tells us that large AEE is obtained between x = 0.06 to 0.12, which well agrees with the composition dependence of the ANE signals, measured by making many parallelly aligned Hall bars elongated to the orthogonal direction to the composition gradient. The findings clearly demonstrate that the AEE measurement using the composition spread film is an effective approach to investigate the composition dependence of ANE and find the highest performance without fabricating many films and performing systematic measurements. These demonstrations will accelerate to find best composition and exploration of new materials to obtain giant ANE/AEE.

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