Magnon drag: a new route for the enhanced Seebeck effect

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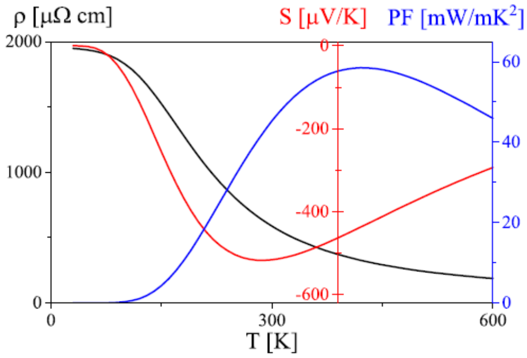
When we consider thermoelectric properties microscopically, difficulty arises because there are various contributions to heat current depending on the Hamiltonian. However, it has been shown that these contributions are classified into two groups [1,2]. One group contains the heat currents of electronic origin, which give the Sommerfeld-Bethe (SB) relation leading to Mott formula for the Seebeck coefficient in the low-temperature limit. The other contains the heat currents that do not lead to the SB relation. The magnon and phonon heat current belongs to the latter causing the magnon- and phonon-drag effect. Recently, it was found that a thin-film Fe-Heusler alloy, $Fe_2V_{0.8}W_{0.2}Al$, shows a large figure of merit (ZT) at around 350K [3]. The origin of this large ZT will be related to the anomalous temperature dependence of Seebeck coefficient, which has a peak structure with a large value at around 350K. This temperature dependence suggests the origin of the large Seebeck coefficient is due to magnon drag. We studied the magnon drag effect in Fe-Heusler alloy based on the linear response theory of Kubo-Luttinger in the presence of an impurity band, which is beyond Boltzmann transport regime.[4] Figure below shows the obtained temperature dependences of resistivity (black line), Seebeck coefficient (red), and power factor (PF, blue). Comparing with experimental results, we expect that the origin of the exceptional thermoelectric properties of Fe-Heusler alloy is likely due to the magnon drag related to the tungsten-based impurity band.

In natural chalcopyrite mineral, $Cu_{1+x}Fe_{1-x}S_2$ (x = 0.08), a large Seebeck effect was also reported around the room temperature [5]. For this material we clarify that the observed large Seebeck coefficient is due to the antiferromagnetic magnon drag collaborated with the impurity band. By deducing the lifetime of magnon from the experimental result of the thermal conductivity, we evaluate the Seebeck coefficient due to the antiferromagnetic magnon drag by the linear response theory. We find that the obtained theoretical result is quantitatively consistent with the experimental one near the room temperature.



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