Thermoelectric Properties of Yb*TM*$_2$Zn$_{20}$ (*TM*= Co, Rh, Ir) Under Magnetic Field

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Introduction

Thermoelectric devices allow direct conversion between heat and electricity, providing important alternatives for green energy technologies. Yet the efficiency during such energy conversion is limited by the competition between high electrical conductance and low thermal conductance of thermoelectric materials. Recently, we reported enhanced thermoelectric performance of heavy-fermion compounds Yb*TM*$_2$Zn$_{20}$ (*TM* = Co, Rh, Ir), in which we observed the second highest power factor and figure of merit thus far at 35 K. [1] Through structural, electrical, and thermal properties analysis, our results show that strongly hybridized f-electron intermetallic compounds coupled with "rattling" features in the cage-like structures offer a unique approach to high power factors while maintaining small thermal conductivity values -- ideal systems for thermoelectric applications.

Experimental

Seebeck coefficient (S), thermal conductivity (κ), and resistivity (ρ) of single-crystalline YbIr$_2$Zn$_{20}$ and YbCo$_2$Zn$_{20}$ were measured as a function of magnetic field (0 T to 18 T) at varied temperatures (2 K to 300 K). These measurements were performed at the NHMFL DC Field Facility using the VTI and the 18 T magnet (SCM 2).

Results and Discussion

Previous magneto-resistance measurements show that the ρ of the Yb*TM*$_2$Zn$_{20}$ compounds decreases significantly with increasing magnetic field at higher temperatures while becoming field-independent at lower temperatures. This leads to an improved thermoelectric figure of merit ($ZT = S^2T/\rho\kappa$) assuming constant S and κ values. For YbIr$_2$Zn$_{20}$, a curvature in the magneto-Seebeck coefficient started developing with decreasing temperature, resulting in an increased S with increasing magnetic field up to 10 T (Fig. 1). Such increase peaks at 15 K. Meanwhile, the magneto-thermal conductivity increases but with much lower magnitude. For YbCo$_2$Zn$_{20}$, on the other hand, κ decreases with increasing magnetic field when the temperature is above 15 K. The changing of the S with regards to the magnetic field is much more pronounced compared with that in YbIr$_2$Zn$_{20}$.

Conclusions

Increased magneto-Seebeck coefficient and decreased magneto-thermal conductivity were observed in YbIr$_2$Zn$_{20}$ and YbCo$_2$Zn$_{20}$. [2] This may suggest that ZT can be further improved under applied magnetic field. Magneto-Seebeck coefficient data show signatures of phonon-drag effect. This result also suggests that other types of tuning (e.g., chemical) will be useful to further optimize the ZT values.

Acknowledgements

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References

[1] Wei, K., *et al*., npj Quantum Materials, under revision (2018).
[2] Wei, K., *et al*., manuscript under preparation.

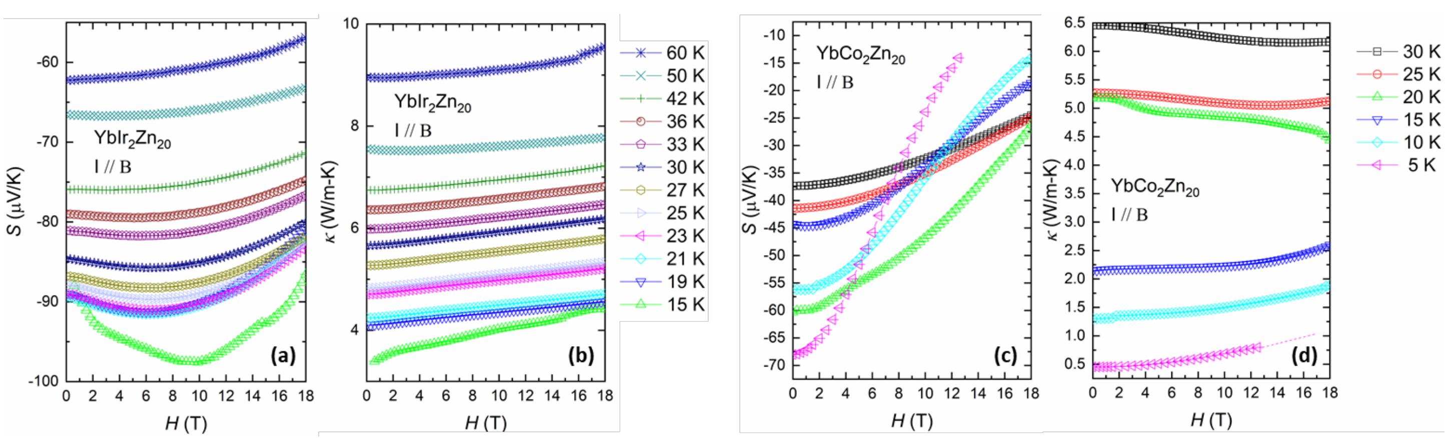

Fig.1 (a) Magneto-Seebeck coefficient of YbIr$_2$Zn$_{20}$; (b) magneto-thermal conductivity of YbIr$_2$Zn$_{20}$; (c) magneto-Seebeck coefficient of YbCo$_2$Zn$_{20}$; and (d) magneto-thermal conductivity of YbCo$_2$Zn$_{20}$ at selected temperatures. Both the thermal gradient and the current are parallel to the applied magnetic field.