Tuning the crossover critical point of magnetocaloric materials with the high-entropy concept

Zhengying Tian [1 2], Jia Yan Law [3], Victorino Franco [3], Fengxia Hu [1 2], Baogen Shen [1 2]

[1] *Beijing National Laboratory for Condensed Matter Physics & State Key Laboratory of Magnetism, Institute of Physics, Chinese Academy of Sciences, China*
[2] *School of Physical Sciences, University of Chinese Academy of Sciences, China*
[3] *University of Seville, Spain*

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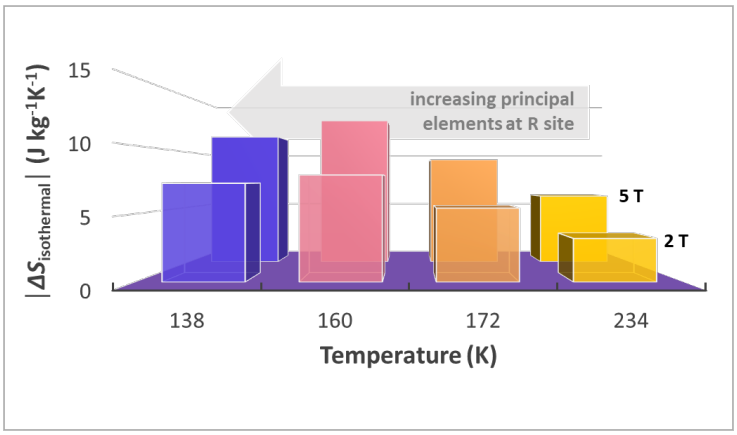
In recent years, the interest in using the magnetocaloric effect (MCE) for gas liquefaction has sparked renewed attention in cryogenic magnetocaloric materials [1,2], including the RCo2 Laves phase (where R is a lanthanide). By changing R along the lanthanide row in the periodic table, these compounds can undergo first-order (FOMT) or second-order (SOMT) thermomagnetic phase transitions. Massive MCE have been discovered for R = Dy, Ho, and Er, which display FOMT while R = Gd and Tb display SOMT. Therefore, the critical point, also known as the regime where FOMT crossovers to SOMT, would be expected to occur after Tb on the lanthanide row, in increasing atomic number, but simultaneously with Tb. Lanthanides with large intrinsic magnetic moments are frequently used in magnetocaloric high-entropy alloys (HEA) to find new compositions and properties [3,4]. This approach, however, can lead to subpar MCE performance as the overall magnetization of the alloy dilutes.Our work takes a step forward by applying the HEA design concept at the R-site in RCo2, discovering the shift of the crossover critical point to a larger MCE in multiprincipal-R-Co2. As a result, other compositions of this Laves phase family are found to exhibit weakly hysteretic behavior. These findings contrast with the typical subpar MCE performance in magnetocaloric HEAs when designed in the center of the multiprincipal elements phase diagram. Furthermore, we evaluated the critical point and the order of thermomagnetic phase transition quantitatively using the recently discovered exponent n criteria [5,6], avoiding the long controversy in the nature of the thermomagnetic phase transitions in the RCo2 family.



Magnetocaloric effect of multiprincipal R in RCo2

References

[1] C. Romero-Muñiz, et al., The Innovation Materials, 1 (2023) 100045.

[2] J.Y. Law, V. Franco, Handbook on the Physics and Chemistry of Rare Earth Elements, Volume 64 (2023) 175-246. *Commemorative Volume to V.K. Pecharsky*.

[3] J.Y. Law, V. Franco, Journal of Materials Research, 38 (2023) 37.

[4] J.Y. Law, V. Franco, APL Materials, 9 (2021) 080702.

[5] J.Y. Law, et al., Nature Communications, 9 (2018) 2680.

[6] V. Franco, Journal of Physics D: Applied Physics, 50 (2017) 414004.