Pulsed Magnetic Fields: A Key to Understanding Magnetocaloric Materials

Benedikt Beckmann

Institute of Materials Science, Technical University of Darmstadt, 64287 Darmstadt, Germany

benedikt.beckmann@tu-darmstadt.de

Magnetocaloric cooling utilizes the thermodynamic response of materials to magnetic fields, particularly those undergoing first- or second-order phase transitions, and is being explored as a solid-state alternative for refrigeration at both ambient and cryogenic temperatures [1,2]. Within this field, pulsed magnetic fields play a critical role in material characterization, especially for the direct assessment of the adiabatic temperature change [3], which is, besides the isothermal entropy change, the key figure of merit and vital for both scientific insight and technological application.

This presentation highlights recent experimental results across a variety of magnetocaloric compounds [4–9], with an emphasis on direct adiabatic temperature change measurements conducted in pulsed magnetic fields. These experiments have revealed the maximum magnetocaloric effect of optimized first-order phase transition materials [4,5], and they have also served to assess the performance of a novel and rare-earth-free compound with a second-order phase transition designed for hydrogen liquefaction [6]. Additionally, these studies have exposed intrinsic limitations of first-order phase transition materials at cryogenic temperatures, where hysteresis effects and related heat dissipation pose significant challenges [7]. The findings point to the importance of integrating complementary analysis methods, as shown in [8,9], to accurately quantify both the adiabatic temperature change and isothermal entropy change, thereby supporting the advancement of magnetocaloric materials for cryogenic applications

This work was financially supported by the Deutsche Forschungsgemeinschaft (DFG) through the CRC/TRR 270 (Project ID 405553726), and by the European Research Council (ERC) through the Advanced Grant “Cool Innov” (Grant No. 743116).

References

[1] X. Tang, H. Sepehri-Amin … K. Hono, Nature Communications 13 (2022), 1817

[2] J. Y. Law, L. M. Moreno-Ramírez …V. Franco, Journal of Applied Physics 133 (2023), 040903

[3] C. Salazar Mejía, T. Niehoff … T. Gottschall, Journal of Physics: Energy 5 (2023), 034006

[4] B. Beckmann, A. Taubel … O. Gutfleisch, Acta Materialia 282 (2025), 120460

[5] A. Taubel, B. Beckmann … O. Gutfleisch, Acta Materialia 201 (2020), 425

[6] J. J. B. Levinsky, B. Beckmann … G. Blake, Nature Communications 15 (2024), 8559

[7] B. Beckmann, D. Koch … O. Gutfleisch, Acta Materialia 246 (2023), 118695

[8] T. Niehoff, B. Beckmann … T. Gottschall, Advanced Functional Materials (2025), 2505704

[9] B. Beckmann, J. Lill … O. Gutfleisch, ACS Applied Materials & Interfaces 16 (2024), 38208