Analyzing thermal hysteresis of magnetocaloric materials using TFORC: application to (NiMnSi)0.66(Fe2Ge)0.34

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Magnetocaloric materials with first order phase transition typically exhibit a larger magnetocaloric response than their second order phase transition counterparts [1,2]. However, the nature of the phase transition implies thermal hysteresis, which has to be avoided to be able to use the materials in cyclic conditions. Temperature First Order Reversal Curves (TFORC) analysis has been recently proposed to understand the hysteretic behavior of magnetocaloric materials [3]. Initially used as a fingerprinting technique, detailed models of phase transformations [4] enabled the interpretation of the different features found in the experimental results [5]. Despite being conceptually similar to the conventional field FORC, TFORC has some peculiarities related to the temperature dependence of the magnetization of the different phases. In addition, it used to be a very cumbersome technique due to the extensive data processing needed. In this work we show an optimization of a VSM magnetometer, with specific TFORC software and optimized thermal control, which makes TFORC experiments significantly more efficient.The application of TFORC to (NiMnSi)0.66(Fe2Ge)0.34 [6] is illustrated in this talk. The asymmetry of the phase transformation is identified by triangular-like peaks in the heating and cooling TFORC distributions (Figure 1). This alloy has a significant separation between the Curie temperature of the martensite and the magnetostructural transformation, which justifies the lack of negative areas above the peaks. The comparison between heating and cooling distributions also provides additional information about the asymmetry of the martensitic transition.

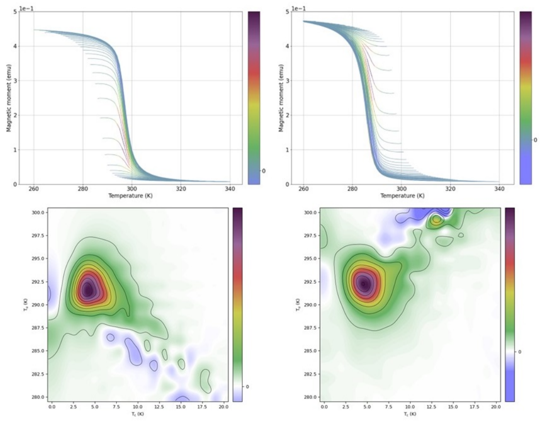

Figure 1: TFORCs in heating and cooling modes of (NiMnSi)0.66(Fe2Ge)0.34 and corresponding TFORC distributions

References

[1] V. Franco, J.S. Blázquez, J.J. Ipus, J.Y. Law, L.M. Moreno-Ramírez, A. Conde, Progress in Materials Science 93 (2018) 112

[2] C. Romero-Muñiz, J.Y. Law, J. Revuelta-Losada, L.M. Moreno-Ramírez, V. Franco, The Innovation Materials 1 (2023) 100045

[3] V. Franco, T. Gottschall, K.P. Skokov, O. Gutfleisch, IEEE Magn. Lett. 7 (2016) 6602904

[4] L.M. Moreno-Ramírez, V. Franco, Metals 10 (2020) 1039

[5] A. Díaz-García, L.M. Moreno-Ramírez, J.Y. Law, F. Albertini, S. Frabbrici, V. Franco, J. Alloys Compd. 867 (2021) 159184