Novel Magnetic Behavior Observed in Polycrystalline $NdCo_5$ Compound and $Gd_{90}Co_{2.5}Fe_{7.5}$ Alloy Subjected to a Magneto-Thermal Protocol

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Abstract

The magnetic properties of gadolinium (Gd) have been extensively studied because of its unique and interesting magnetic behavior as well as for its various technological uses, including as the leading refrigerant for near-room temperature magnetic refrigeration, a much more energy efficient and environment-friendly technology compared to conventional refrigeration, based on the gas-expansion-compression cycle. Gadolinium is an attractive magnetocaloric material because it orders magnetically near room temperature (T_C~293 K) and below T_C the magnetization saturation value of Gd is quite large, due its rather large magnetic moment per atom. Previously, we reported that the systematics of the complex magnetic behavior of gadolinium, including the spin reorientation and related features, were revealed by subjecting polycrystalline Gd bulk samples to a magneto-thermal (M-T) protocol, using both dc SQUID and VSM magnetometries [1]. The M-T protocol consisted of cooling the samples from 300 K to 5 K under a negative field of 50 mT and then measuring the temperature dependence of the magnetization, M, in the range of fields +2.5 mT to + 50 mT on warming up to and above the Gd Curie temperature. Gadolinium has a close-packed hexagonal crystal structure that gives to its uniaxial anisotropy. The phenomenon of spin reorientation transition in Gd is known to be directly related to the temperature dependence of the anisotropy constants, K_1 and K_2. Motivated by our previous study on gadolinium and having gained new insight on the effects of changing of the sign of the uniaxial anisotropy on polycrystalline magnetic materials, we applied the M-T protocol to the polycrystalline samples of $NdCo_5$ compound that, similar to gadolinium, possesses a hexagonal structure with an uniaxial anisotropy, displaying two distinct spin-reorientation transitions below room temperature (T_{RS1}~285 K and T_{RS2}~245 K), both of which are associated with the temperature dependence of the two corresponding anisotropy constants [2]. Besides, the $NdCo_5$ compound, we also applied the M-T protocol to the polycrystalline $Gd_{90}Fe_{7.5}Co_{2.5}$ alloy samples, a two-phase material characterized by a majority gadolinium-rich phase, surrounded by a minority phase, containing Gd, Fe, and Co (for field values of 1 T and lower the magneto-caloric properties of this alloy are superior to those of gadolinium) [3]. In this paper, we present the results we obtained on $NdCo_5$ and $Gd_{90}Fe_{7.5}Co_{2.5}$ polycrystalline samples subjected to the M-T protocol, described above, as well as to some modified form of the protocol. After presenting the magnetic data results, we will discuss their importance, in terms of having provided us a better understanding about the systematics of the complex magnetic behavior of these polycrystalline materials, including the critical role played by anisotropy on the spin reorientation phenomenon and related features.

References

[1] V. Provenzano, A. S. Arrott, and H. ElBidweihy, "Magnetic Behavior of Polycrystalline Gadolinium Subjected to a Magneto-Thermal Protocol", IEEE Transactions on Magnetics, Vol. 53, 2017.

[2] J. B. Sousa, J. M. Moreira, A. Del Moral, P. Algarabel, and R. Ibarra, "Spin-reorientation transitions in $NdCo_5$ and critical effects on the electrical resistivity temperature derivative", J. Phys.: Condens. Matter **2** (1990) 3897.

[3] V**.** Provenzano, R. D. Shull, G. Kletetschka, and P. E. Stutzman, "$Gd_{90}Co_{2.5}Fe_{7.5}$ alloy displaying enhanced magnetocaloric properties", J. of Alloys and Compounds, Vol. 622, (2015) p. 1061.