

The rotating magnetocaloric effect of RNi₅ intermetallic compounds

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It is known that the physics of magnetic phenomena consider two main types of magnetocaloric effect (MCE). The first one is the MCE of paraprocess, i.e., MCE related to the process of ordering magnetic moments during magnetization of a magnetic material in a magnetic field, which were disordered as a result of thermal fluctuations. The second type is the rotating (anisotropic) MCE caused by the magnetization rotation as a result of the magnetization of the magnetic materials along the hard magnetization axis of the magnetic materials. The MCE of paraprocess is fairly well studied, while the rotating MCE remains rather poorly understood. First of all, this is related to difficulties in creating samples and methods for such investigations. Recently, polycrystalline magnetocaloric materials with rotating MCE have attracted more attention due to their more convenient sample preparation than monocrystalline materials[1]. It is known that the rotating MCE of magnetic materials is largely determined by the magnitude of the magnetic anisotropy energy. Moreover, it is relevant to study magnetic materials that exhibit high MCE values in the field of magnetic phase transitions at low temperatures for practical application in technological processes of liquid hydrogen. Therefore, our study will focus on textured polycrystalline DyNi₅. DyNi₅ is a ferromagnet with a Curie temperature $T_C=13$ K. For DyNi₅ the “easy plane” type of magnetocrystalline anisotropy (MCA) is characteristic [1]. At a temperature of 6 K, a spin reorientation transition is observed in DyNi₅ with a rotation of the magnetization vector from the [120] axis to the [100] axis. Our previous study conducted on a DyNi₅ single crystal showed that saturation along the hard magnetization axis ([001]) at a temperature of 4.2 K is not achieved even in fields above 56 T. This indicates a high energy of the MCA of the DyNi₅ compounds. We also showed that the rotating MCE of the DyNi₅ single crystal, defined as the difference between the MCE measured along the easy and hard magnetization axes, reaches 9 K in a field of 10 T. This suggests that high values of rotating MCE can be obtained in textured polycrystalline DyNi₅.

In our case, samples of polycrystalline DyNi₅ with induced magnetic anisotropy were obtained by directional crystallization. Grain orientation was investigated using EBSD. To investigate MCE in medium magnetic fields (up to 1.8 T), we used a magnetic field source based on permanent magnets and an apparatus for direct MCE measurements placed on a rotary table [2]. Measurements were carried out in different directions relative to the main axis of the magnetic texture. Direct measurements of the MCE revealed that the MCE of polycrystalline DyNi₅ in the Curie temperature range (14 K) is 5 K at 1.8 T (Fig.1). At the same time, the rotating MCE reaches 1 K at 1.8 T (Fig.1, Ins.). This value is comparable to the rotating MCE previously observed in NdCo₅ single crystals [3].

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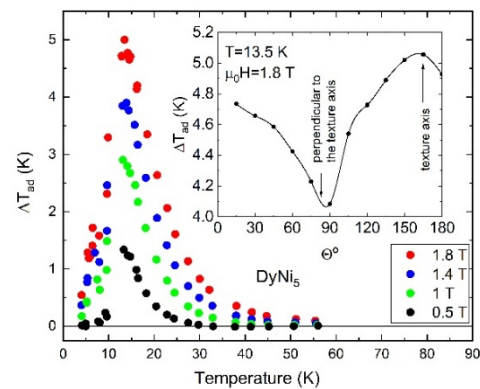


Figure 1 Temperature dependence of ΔT_{ad} for polycrystalline DyNi₅ measured along the texture axis in a field of 0.5–1.8 T. Inset: Angular dependence of ΔT_{ad} measured in a field of 1.8 T applied in different directions relative to the texture axis at 13.5 K.

[1] G. Aubert, D. Gignoux, B. Hennion, et al. Solid State Commun., 37 (1981), p. 741

[2] Yu.S. Koshkid'ko, J. Ćwik, et al. JMMM 433 (2017) 234–238.

[3] Nikitin, S., Skokov, K., Koshkid'ko, Yu., et al. PRL 105 (2010) 137205