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Effect of uniform pressure on magnetization and magnetic phase diagram of terbium single crystal

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The effect of uniform pressure on magnetization of a terbium single crystal ($\Delta\sigma$-effect) in the temperature range 80–330 K in magnetic fields up to 14 kOe has been studied. Terbium volume magnetostriction which in the vicinity of the Néel temperature in the magnetic field $H = 13$ kOe acquires enormous values of $\omega = 650 \times 10^{-6}$, was calculated on the basis of experimental data for $\Delta\sigma$-effect. It has been shown that in terbium the dependence of the magnetic anisotropy constant on pressure in the base-plane is well described by the magnetic anisotropy single-ion theory. The terbium magnetic phase diagram exhibits an anomaly in the vicinity of $T \approx 223$ K caused by helicoid angle passage of 18° value. The effect of pressure on temperatures of magnetic phase transitions, critical fields of helicoidal antiferromagnetic ordering destruction, paramagnetic Curie temperature and efficient magnetic moment has been studied.

1. Introduction

The investigation of the uniform pressure effect on the magnetic properties of rare-earth metals (REM) and their alloys has been limited so far, mainly, by the determination of the shifts of magnetic transformation temperatures while magnetization has always been measured in weak magnetic fields, and factually, it was the dependence of differential permeability on pressure in the Curie and Néel temperature range [1] that was measured. Due to the enormous magnetic anisotropy of rare-earth metals, measurements of the affect of changing magnetization under the influence of pressure even in the range of relatively strong magnetic fields ≈ 25 kOe on polycrystal samples of REM [2,3] do not allow one to differentiate accurately between the contributions to this effect caused by the influence of pressure on magnetic anisotropy constants and on saturation magnetization. At the same time, until now there has been no sufficiently accurate magnetic phase diagram of single crystal Tb, the nature and type of the effect of commensurability of the magnetic and crystal structures on the different physical properties of terbium have not yet been revealed. According to reference data, the point of the phase transition, ferromagnetism (FM)–helicoidal antiferromagnetism (HAFM), at the temperature Θ_1 lies in the temperature range 210 [4]–222 K [5], and the temperature of the transition, HAFM–paramagnetism (PM), Θ_2 in the range 223.3 [4]–230 K [6]. Data on the value of critical field of destruction of the H_{cr} HAFM structure also differ significantly [7–10]. The problem of the nature of magnetic phase transition in the point Θ_2 is under discussion [11–13].

To solve this problem it is necessary to study the given effect on REM single crystal samples of high purity over a wide range of magnetic fields.

Such studies allow one to obtain very important data for checking theoretical models on the nature of the magnetic phase transitions and on the dependence of the exchange interaction integrals and magnetic anisotropy constants on atomic volume.