Magnetic and specific heat properties of holmium doped $ZnCr_2Se_4$ single crystals

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Magnetic spinels attract due to their exotic phenomena and fascinating ground states observed in this class of materials and have potential applications in thermoelectric devices [1-3]. $ZnCr_2Se_4$ is a semiconducting helimagnet with a first order transition at the Néel temperature of 21 K in which the helimagnetic macro-domains break into metamagnetic micro-ones [4]. Substitution of one of the elements can strongly influence on properties of a parent compound, as example in the $ZnCr_2Se_4$:Sn single crystals a spin-glass-like behavior was discovered [5], while in the $ZnCr_2Se_4$:Gd polycrystalline samples an antiferromagnetic (AFM) order and the spin-glass behaviour connected with the strong competition between AFM and ferromagnetic (FM) exchange interactions visible in the splitting of the zero-field-cooling (ZFC) and field-cooling (FC) susceptibilities was observed [6]

Static (dc) magnetic susceptibility was measured in the magnetic field H_{dc} = 100 Oe and recorded in ZFC and FC modes. Dynamic (ac) magnetic susceptibility was measured at an internal oscillating magnetic field H_{ac} = 3.9 Oe with an internal frequency f = 300 Hz. Both dc and ac magnetic susceptibility were measured in the temperature range 2–400 K. Magnetization isotherms were measured in the temperature range 5-275 K in static dc magnetic fields up to 70 kOe. Specific heat was measured using heat capacity option for Quantum Design Physical Properties Measurement System (QD PPMS) which uses a pulse technique with two-tau model fitting.

$ZnCr_2Se_4$ single crystals doped with holmium ions of concentration 0.032, 0.055 and 0.084 (occupying octahedral positions) were successfully synthesized. The ac and dc magnetic measurements as well as the specific heat studies with the increasing holmium content showed: 1) antiferromagnetic order at the Néel temperature of T_N = 21 K, 2) positive value of the paramagnetic Curie-Weiss temperature increasing from θ = 53 to θ = 100 K, 3) a slight decrease of both the critical field H_{c1} characteristic for a metamagnetic transition and the critical field H_{c2} corresponding to the breakdown of the helical spin arrangement, 4) the magnetic contribution to the specific heat visible on the sharp peak at T_N, which is strongly shifted to much lower temperatures as the magnetic field increased and 5) the quite significant Sommerfeld gamma coefficient suggesting the properties of the heavy fermion of the single crystal under study as well as the atom count n_D which was below the expected value of 7.044 indicated some vacancies in the spinel structure of the single crystal under study.

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