The influence of holmium substitution on critical fields in the $ZnCr_2Se_4$ semiconductor

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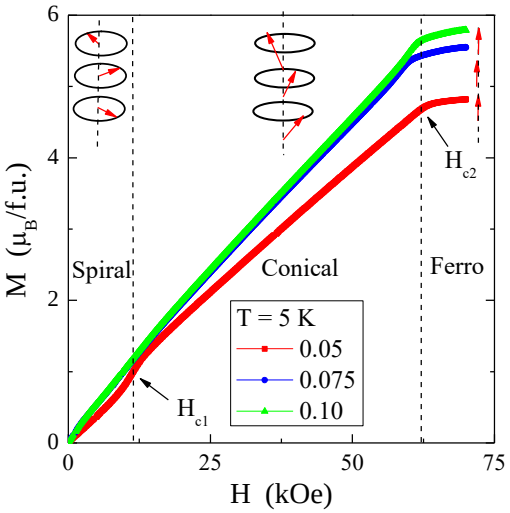
Chromium spinels exhibit a variety of properties as colossal magnetostriction [1], spin Jahn-Teller effect [1], and magnetoelectric or thermoelectric effect [2]. Chromium spinels crystallize in a normal cubic structure, point group: $m3m$, space group: $Fd\bar{3}m$, No. 227. $ZnCr_2Se_4$ is a *p*-type semiconductor with a band gap of E_g = 1.28 eV at room temperature [3] and antiferromagnetic [4] and is therefore a desirable matrix for many spinel series [5].

The static (dc) magnetic susceptibility was measured in the temperature range 2–400 K and in a magnetic field H_{dc} = 1 kOe and recorded in the zero-field cooled mode. In order to determine the position of the critical fields H_{c1} and H_{c2}, measurements of dynamic (ac) magnetic susceptibility were performed in an internal oscillating magnetic field H_{ac} = 3.9 Oe and internal frequency f = 1 kHz at temperatures of 5, 10, 20 and 30 K and in an external static magnetic field up to 70 kOe. All magnetic parameters and the heat capacity were measured using a QD-PPMS measurement system (Quantum Design Physical Properties Measurement System, Quantum Design , San Diego, CA, USA).

$ZnCr_2Se_4$ polycrystals doped with holmium ions of concentration 0.05, 0.075, and 0.10 were successfully synthesized. The ac and dc magnetic and specific heat measurements as well as a full-potential local-orbital (FPLO) calculations showed that doping the $ZnCr_2S_4$ matrix with paramagnetic Ho^{3+} ions with a content of not more than 0.10 and having a screened 4*f* shell revealed a significant effect of orbital and Landau diamagnetism, a strong reduction of short-range ferromagnetic (FM) interactions and broadening and shifting the peak of the first critical field H_{c1} while stabilizing the sharp peak of the second critical field H_{c2}. These results are well correlated with FPLO calculations, which show that Cr sites have magnetic moments of 3.19 μ_B, and Ho sites have significantly larger ones with a value of 3.95 μ_B, while Zn has a negligible magnetic polarization of 0.02 μ_B, and Se induces a polarization of approximately –0.12 μ_B.



The above figure shows the magnetization *M* vs. magnetic field *H* with H_{c1} and H_{c2} critical fields and the evolution of the magnetic structure from spiral via conical to FM order.

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