# Magnetic properties of singlecrystalline $Cd_xMn_yCr_zSe_4$ ($0.03 \leq y \leq 0.12$)

**I. Jendrzejewska[1], E. Maciążek[1], T. Groń[2], P. Zajdel[2], H. Duda[2], J. Kusz[2] and A. Kita[1]**

[1]*University of Silesia, Institute of Chemistry, ul. Szkolna 9, 40-006 Katowice, Poland,*
[2]*University of Silesia, Institute of Physics, ul. Uniwersytecka 4, 40-007 Katowice, Poland*

$CdCr_2Se_4$ spinel is a ferromagnetic semiconductor with the Curie temperature $T_C$ = 130 K, Curie-Weiss temperature θ = 200 K, saturation magnetization $M_S$ = 5.30 $\mu_B$/f.u. at 4.2 K and the effective magnetic moment $\mu_{eff}$ 5.49 = $\mu_B$/f.u. [1-3]. It has a structure of $AB_2X_4$ type with a lattice constant of 10.721-10.750 Å, in which the Se-anions form a cubic close-packed lattice, with the Cd-cations occupying the tetrahedral sites and the Cr-cations occupying the trigonal antiprismatic sites [2]. In $CdCr_2Se_4$ the magnetic order results from the competition of nearest neighbors positive Cr-Se-Cr interaction and more distant negative Cr-Se-Cd-Se-Cr exchange interaction [3]. Substitution of the manganese for the divalent cadmium ion showed the ferromagnetic order in polycrystalline $Cd_{0.85}Mn_{0.01}Cr_{1.97}Se_4$ spinel with the Curie temperature $T_C$ = 135 K, Curie-Weiss temperature θ = 145 K, saturation magnetization $M_S$ = 7.49 $\mu_B$/f.u. at 4.2 K and the effective magnetic moment $\mu_{eff}$ 5.76 = $\mu_B$/f.u. [4].

Magnetization measurements were carried out using a Quantum Design System (MPMS XL). Static (dc) magnetic susceptibility was measured in the magnetic field $H_{dc}$ = 100 Oe and recorded in zero-field-cooled (ZFC) mode. 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 5–400 K. Magnetization isotherms were measured in the temperature range 5-275 K in static (dc) magnetic fields up to 70 kOe.

Magnetic measurements showed that the $Cd_xMn_yCr_zSe_4$ single crystals ($y$ = 0.03, 0.06, 0.09 and 0.12) are ferromagnets with the Curie temperature $T_C$ = 130 K, Curie-Weiss temperature θ = 161-183 K, saturation magnetization $M_S$ = 3.83-5.45 $\mu_B$/f.u. at 5 K and the effective magnetic moment $\mu_{eff}$ 4.62-5.30 = $\mu_B$/f.u., weakly dependent on the manganese substitution. The imaginary component of ac magnetic susceptibility showed strong energy loss in the long range of magnetic order, connected, for example, with the magnetic-domain-wall motion or with rotation of magnetization within domains [5]. The most interesting observation of magnetic measurements was magnetic hysteresis, which showed the existence of spontaneous magnetization and the coercive field in all crystals $Cd_xMn_yCr_zSe_4$, *i.e.* the typical ferromagnetic properties. Based on the experimentally set of magnetic hysteresis loops the values of spontaneous magnetization $M_S$ = 0.08 $\mu_B$/f.u. at 5 K and coercive field $H_C$ 19 Oe were determined. The resulting hysteresis loops have a shape typical for affecting ferromagnetic material containing clusters of different sizes. Similar loops for $Cd_{1-x}Mn_xGeAs_2$ crystals were found [6].

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