Temperature Driven *n* to *p* Transition in $(Cd_{0.40}Zn_{0.60})_3As_2$

G. Grabecki [1,2], K. Grasza [1], W. Paszkowicz[1], P. Skupiński[1], A. Avdonin[1], I. Yahniuk[3], E. Łusakowska[1], R. Jakieła[1], A. Barcz[1], A. Reszka[1], M. Majewicz[1], K. Dybko[1], A. Łusakowski[1] and T. Dietl[1,4]

[1]*Institute of Physics, Polish Academy of Sciences, PL-02-668 Warszawa, Poland*
[2]*Department of Mathematics and Natural Sciences, College of Science, Cardinal Wyszynski University, PL-01-938 Warszawa, Poland*
[3]*Institute of High Pressure Physics, Polish Academy of Sciences, PL-01-142 Warszawa, Poland*
[4]*International Research Centre MagTop, PL-02-668 Warszawa, Poland*

Cadmium arsenide (Cd_3As_2) is a three dimensional Dirac semimetal in which the valence and conduction bands cross at two points $k \neq 0$ in the Brillouin zone resulting in the appearance of two topologically protected Dirac cones that merge at energies of tens meV away from the neutrality points [1,2]. Since Cd_3As_2 bulk crystals are strongly *n*-type, the Fermi energy resides above the merging point, so that the Dirac cones' region is not directly accessible by electron transport measurements. On the other hand, Zn_3As_2 is a trivial *p*-type semiconductor with $E_g \approx 1$ eV [3]. Therefore, a transition between the Dirac semimetal and the trivial insulator should occur in the solid solution $(Cd_{1-x}Zn_x)_3As_2$, at some *x* value [4]. Here, we show that a transition from electron-dominated to hole-dominated charge transport occurs for $x = 0.6$ as a function of temperature. Single crystals of $(Cd_{1-x}Zn_x)_3As_2$ have been obtained by the growth from molten phase. An x-ray analysis for a $x = 0.6$ crystal points to a $I4_1/amd$ tetragonal structure, in accordance with the phase diagram of $(Cd_{1-x}Zn_x)_3As_2$ [5]. Magnetotransport measurements have been performed in the temperature range from 4.2 to 300 K, in magnetic fields up to 9 T, and under high hydrostatic pressures up to 0.7 GPa. The mobility spectra determined from resistance tensor components are virtually temperature independent in the range between 300 to 230 K. There is a dominant contribution of electrons with the concentration of about $5 \cdot 10^{16}$ cm^{-3} and mobility 2600 cm^2/Vs. The concentration of holes is two times smaller, $2.6 \cdot 10^{16}$ cm^{-3} at significantly smaller mobility, about 210 cm^2/Vs. For lower temperatures, the conductance drops abruptly down by almost four orders of magnitude and the electron contribution vanishes. At 150 K the hole mobility is very low, $\mu_h = 16$ cm^2/Vs at concentration $5 \cdot 10^{16}$ cm^{-3}. Application of hydrostatic pressure shifts the transition towards higher temperatures by about 0.5 K/GPa. Additionally, we have observed negative magnetoresistance, occurring in low magnetic fields, $B \leq \pm 0.3$ T. It has a non-zero magnitude only in the temperature range between 150 K to 210 K, just corresponding to the transition. Such an effect is expected for Dirac semimetals with Fermi energy positions close to the Dirac points [6]. Our experimental results are analyzed theoretically within an extended Bodnar model [1] taking into account temperature and pressure dependence of band structure parameters.

[1] J. Bodnar, *Proc. Int. Conf. Phys. Narrow-Gap Semicond*., Warsaw, 1977 (PWN, Warsaw 1978), p. 311; Z. J. Wang, et al., *Phys. Rev. B* **88**, 125427 (2013).
[2] S. Borisenko, et al., *Phys. Rev. Lett.* **113**, 027603 (2014).
[3] K. Sieranski et al., *Phys. Rev B* **50**, 7331 (1994).
[4] Thong Lu, Xiao Zhang, and Shuang Jia, arXiv:1507.07169.
[5] W. Zdanowicz *et al., Ann. Rev. Mater. Sci*. **5**, 301 (1975).
[6] H. Li *et al,. Nat. Commun.* **7**:10301 doi: 10.1038/ncomms10301 (2016).