Dilute Magnetic Semiconductors: Ferromagnetism and New Spintronics Materials

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Being an interdisciplinary field of science and technology, spintronics (spin-transport electronics) has been the subject of intensive studies. Among the variety of spintronics-related aspects, in the talk the emphasis will be placed on properties of the semiconductor spintronics materials, classified as following: concentrated magnetic semiconductors, semimetals and half-metals, semimagnetic semiconductors, dilute magnetic semiconductors (DMS) [1]. In DMS the hybridization of the impurity d-electrons with the heavy hole band states in semiconductor host is responsible for the exchange of electrons between the impurities, whereas electron interactions in d-shells make its spin selective. The nature of ferromagnetism, that occurs in p-type DMS with an increase in the transition metal content, is governed by the proposed kinematic exchange involving the kinetic energy gain of the heavy hole carriers caused by their hybridization with 3d electrons of impurities (see [1-3] and Refs. therein). The Curie temperatures $T_C$ are calculated for such DMS both n-type ((Ga,Mn)N) and p-type ((Ga,Mn)As and (Ga,Mn)P) as functions of the impurity and hole concentration in agreement with available experimental data. The state-of-the-art in the field of synthesis and research of “new” materials ([1, 4] and Refs. therein) with announced “high $T_C$” is also outlined. The kinematic exchange theory gave some hints for synthesis of new DMS. The DMS (In,Mn)Sb has been synthesized. Their magnetic and transport properties are presented. The magnetic field effects in DMS are estimated with particular attention to chalcopyrite based DMS such as (CdGe,Mn)As$_2$. The effect of the dimensionality driven increase of $T_C$ is derived for spintronics materials such as digital alloys (delta-doped DMS) and DMS heterostructures. The formation of magnetic nanoclusters in DMS’s is discussed. The study is supported by Project RFBR05-02-17 666.