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ANISOTROPY OF BONDS AT ANTIFERROMAGNETIC TRANSITION IN MnTe-BASED LAYERS

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Keywords: fcc Heisenberg systems, polarization dependent EXAFS, cubic MnTe layers, antiferromagnetic interaction

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MnTe is a well known magnetic semiconductor, which in the bulk form crystallizes in the hexagonal (NiAs) structure. Due to an application of non-equilibrium growth technique, like molecular beam epitaxy (MBE), thin layers and quantum structures containing zinc-blende MnTe (the metastable phase of this compound) can also be obtained. All zinc-blende manganese chalcogenides are rare examples of fcc Heisenberg systems with strongly dominating antiferromagnetic (AF) exchange interaction between the magnetic nearest-neighbours (corresponding to the second neighbours in the crystal lattice) and significantly weaker exchange interaction between the magnetic next-near-neighbours (this interaction is also of the antiferromagnetic type and corresponds to the fourth neighbours in the lattice). This kind of the exchange interactions between Mn ions results in magnetic AFIII-type structure below the magnetic phase transition temperature.

In the case of zinc-blende MnTe the Mn spins are not able to satisfy simultaneously all the AF interactions with their nearest magnetic neighbors. As a consequence the magnetic frustration phenomenon occurs at low temperatures (Fig. 1). Perfect AF order exists in planes perpendicular to Z direction, the phenomenon of frustration is well seen for atoms lying in planes parallel to this direction (for example, on the left side Mn atom 4 there are two Mn spin oriented “down”, and on the right side two other spins oriented “up”). The magnetic structure shown in Fig. 1 is stable only after taking into account also the magnetic interactions between the next-near neighbors.

This phenomenon exists in the magnetically ordered phase in all face-centered cubic magnetic semiconductors (like, *e.g.*, EuTe or MnO). Due to particular physical properties such systems as, *e.g.*, zinc-blende MnTe, or MnTe-based diluted magnetic semiconductors are of great interest and are often considered as a basis (or an important constituent) of many optoelectronic or spintronic applications.

In the case of a few micrometer thick MnTe single layers the magnetic phase transition temperature (Néel temperature) is equal to about 65 K. MnTe crystal lattice is cubic above Néel temperature when the sample is in the paramagnetic state. When cooling this material, the situation changes due to strong magnetic interactions. Below the phase transition temperature three types of antiferromagnetic domains are formed. Elementary magnetic unit cells are two times greater than the crystalline (cubic) ones (see Fig. 1). They have an orthorombic symmetry and are oriented along [100], [010] or [001] axis, respectively. The populations of these three types of magnetic domains are not equivalent. This difference results from the residual strain, introduced by a presence of the substrate and the buffer layer with different lattice parameter values as well as by the difference in thermal expansion coefficients. Moreover, an orthorombic deformation of the magnetic unit cells appears in MnTe at low temperatures as it has been established by means of X-ray and neutron diffraction. Due to the non-equivalent orientation of magnetic domains (magnetic unit cells), two values of MnTe lattice parameter were observed. The difference of the lattice parameter value in-plane and along the layer growth direction (out-of-plane) according to X-ray diffraction data is about 0.03 Å at low temperatures ($T \sim 10$ K). In the case of zinc blende MnTe (which exhibits a regular symmetry at room temperature) one can expect a typical structure distortion below Néel temperature and a tetragonal unit cell at low temperatures. It is exactly what is observed in X-ray and neutron diffraction measurements [1-5].

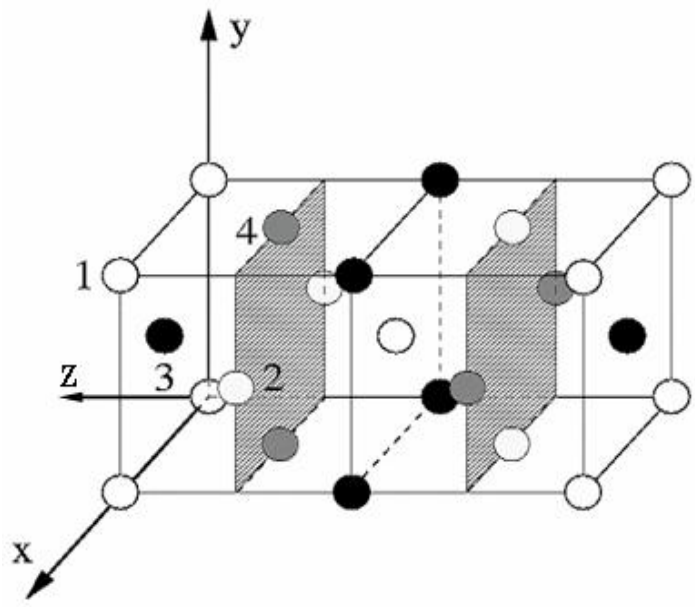

Figure 1. The magnetic unit cell for zinc blende MnTe (only positions of Mn ions in the crystal lattice are shown). Full circles and open circles correspond to "up" and "down" Mn spin orientations, respectively. Spins 1 and 2 are oriented in a parallel manner (and are both antiparallel to spins 3 and 4). The magnetic frustration is well seen for atoms in planes perpendicular to XY plane. (*e.g.* for atom 4).

The diffraction measurements provide information about changes in the distance between planes of atoms. In the presented paper the changes in interatomic distances were examined with particular interest devoted to Mn-Mn distances.

The advantage was taken from the linear polarization of synchrotron radiation and precise crystallographic orientation of MnTe layers. Therefore, the goal of presented studies was to investigate the orientation and the temperature dependence of Mn-Te and Mn-Mn bond lengths for thick MnTe layers with a zinc-blende structure, grown by MBE technique. For such a purpose EXAFS measurements were performed along two crystallographic directions in (001) and (111)-oriented MnTe epilayers. These experiments were performed on the same samples as these used for the neutron scattering studies [3-5]. Knowing the interatomic distance enhanced in particular sample orientation in respect to the synchrotron radiation, below the Néel temperature and above, we can address the question does the anisotropy of bonds exists also above the Néel temperature and a long range antiferromagnetic order made it simply visible for neutron and X-ray diffraction measurements or does this anisotropy appear as a result of the antifferomagnitic interaction only.

Acknowledgements: This work was partially supported by the State Committee for Scientific Research (Republic of Poland) *(Grants No 72/E-67/SPB/5.PR UE/DZ 27/2003-2005 and PBZ/KBN/044/P03/2001)* and by G1MA-CI-2002-4017 (CEPHEUS) of the European Commission.

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