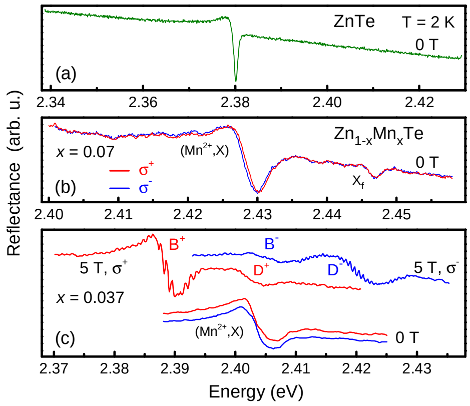
Fine Structure Splitting of Bright and Dark Mixed Excitons Bound to Single Mn^{2+} Ions in Bulk Semimagnetic Semiconductor: $Zn_{1-x}Mn_xTe$

L. V. Khoi and R.R. Gałązka

Institute of Physics, Polish Academy of Sciences, Aleja Lotników 32/46, PL–02668 Warsaw, Poland

In the $Zn_{1-x}Mn_xTe$ crystals, Mn^{2+} ions with the electronic configuration $3d^5$ substitute for Zn^{2+} cations with the electronic configuration $3d^{10}$. This makes Mn^{2+} sites to act like electron-attractive isoelectronic centers (Mn-EAICs). Under illumination, the Mn-EAICs can attract a photogenerated electron. Subsequently, the attracted electron binds a hole to form a Mn^{2+}-bound exciton complex, (Mn^{2+},X). If the electron-hole exchange coupling is taken into consideration, the (Mn^{2+},X) complexes are classified into two types: (Mn^{2+},$X_b(F_1)$) and (Mn^{2+},$X_d(F_2)$), where $X_b(F_1)$ and $X_d(F_2)$ are the spin-singlet (bright) and spin-triplet (dark) excitons. Here, $F_1 = 1$ and $F_2 = 2$ are the total angular momenta of the excitons. In this communication, we present results of magneto-reflectance (MR) studies of the $Zn_{1-x}Mn_xTe$ crystals grown by high-pressure Bridgman method. The MR-data indicate that under the combined action of the $X_b(F_1)$-, $X_d(F_2)$-Mn^{2+} spin flip (SF) interactions, and of spin orbit coupling within the Mn $^4T_1$ excited state, the $X_b(F_1) \leftrightarrow X_d(F_2)$ and $^6A_1 \rightarrow {}^4T_1$ transitions can occur. Under applied magnetic field the $X_b(1)$ and $X_d(2)$ exciton states are split into eighteen and twenty eight fine structure lines, respectively.



Figures 1(a) and 1(b) present reflectance (R) spectra collected from the ZnTe and $Zn_{0.93}Mn_{0.07}Te$ samples. It is observed that while the ZnTe R-spectrum exhibits only one narrow (~2 meV) free exciton line at 2.380 eV and no signature of the 2*s* excited state (~2.3893 eV), the $Zn_{0.93}Mn_{0.07}Te$ R-spectrum exhibits two broad strong and weak lines located at 2.430 eV and 2.447 eV. The energy separation between these lines is too large to account for the weak line of the 2*s* excited state. Therefore, we attribute the weak line to the free exciton (X_f) and strong line to the $X_b(1)$ bright and $X_d(2)$ dark excitons, resulted from the SF interactions inside the (Mn^{2+},$X_d(2)$) and (Mn^{2+}, $X_b(1)$) complexes. These SF interactions can be represented by the following reactions:

$$X_d(2) + {}^6A_1(5/2) \rightarrow X_b(1) + {}^4T_1(J_{LS} = 5/2) \qquad (1)$$

$$X_b(1) + {}^6A_1(5/2) \rightarrow X_d(2) + {}^4T_1(J_{LS} = 5/2, 3/2) \qquad (2)$$

We observe that the application of an external magnetic field up to 6 T does *not* change the position of X_f line, but slightly decreases its amplitude. In contrast, the strong line is split into four components: B^+ and B^-, resulted from the reaction (1), and D^+ and D^-, resulted from the reaction (2). The B^+ and D^- components exhibit eighteen and twenty eight fine structure lines (see Fig. 1(c)). The shifts of these components relative to the zero-field position in magnetic field scale with the magnetization of the sample. Our results can be interpreted basing on the j-j coupling scheme and selection rules for the rotational transitions [1].

[1] K. A. Baryshnikov, L.Langer, I.A. Akimov, V.L. Korenev, Yu. G. Kus, N.A Averkiev, D. R. Yakovlev, and M. Bayer, Phys. Rev. B 92, 205205 (2015).