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The Study of Switch Characteristics of the Optical Absorption Bistability in $Zn_{1-x}Mn_xSe$ ($0.001 \leq X \leq 0.01$)

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Abstract: The dependence of the switch characteristics of the optical absorption bistability of the diluted magnetic semiconductor $Zn_{1-X}Mn_XSe$ ($0.001 \leq X \leq 0.01$) is investigated on the content of Mn^{2+}. The switch time can be 0.3 ns for the sample of X=0.001. The relations between the switch time and the concentration of Mn^{2+} are analyzed by a bleaching absorption mode.

1. INTRODUCTION

The characteristics of diluted magnetic semiconductor where some cations of the host lattice are replaced by magnetic ions, such as Mn^{2+} have been investigated extensively[1~3]. $Zn_{1-X}Mn_XSe$ is a member of the family of diluted magnetic semiconductor. The optical absorption bistability related with Mn^{2+} in $Zn_{1-X}Mn_XSe$ was observed in 1990 by the authors[4]. The bistability was attributed to nonlinear absorption cop-0ncerning Mn^{2+} energy band combined with the positive feedback provided by the light reflection from the crystal surface. Even so, but the dependence of the switch time of the optical absorption bistability has not investigated on the value of X in $Zn_{1-X}Mn_XSe$. In this paper, the dependence of the switch time of bistability is studied on the concentration of Mn^{2+} in $Zn_{1-X}Mn_XSe$. The relation of the switch time as the content of Mn^{2+} is explained by a bleaching mode[5].

2. EXPERIMENT

The samples of $Zn_{1-X}Mn_XSe$ used in the experiment are single crystal with high quality which were prepared using a sublimation method[5]. The values of X are determined by AAS (atomic absorption spectra) method and rechecked the electronic probe method. In the measuremental experiment of the optical absorption bistability, the laser beam λ=532 nm of Nd:YAG is employed to excited the samples. The laser pulses transmitting the crystal, the transmitted signals and the incident laser are simultaneously detected by a fast photocell or photo diode. Both of them are showed on the screen of an oscilloscope with resolution of 100 ps. The optical absorption bistabilities of $Zn_{1-X}Mn_XSe$ are measured for three samples, X=0.010, 0.005 and 0.001.

3. RESULT AND DISCUSSION

Figure 1 shows the pulse shape and hysteresis loop of absorptive bistability for X=0.005 in $Zn_{1-X}Mn_XSe$. The pulse shape of the transmitted pulse shape shows the deformity and delay compared to the reference laser pulse. The switch times are measured $\tau_{\uparrow}$=3~6 ns $\tau_{\downarrow}$ =0.3~1.7 ns for x=0.010~0.001, i. e. the switch time decreasing as the concentration of Mn^{2+} decreasing. The switch speed is very fast at low value of X. The switch time can be 0.3 ns for X=0.001 in $Zn_{1-X}Mn_XSe$. The optical

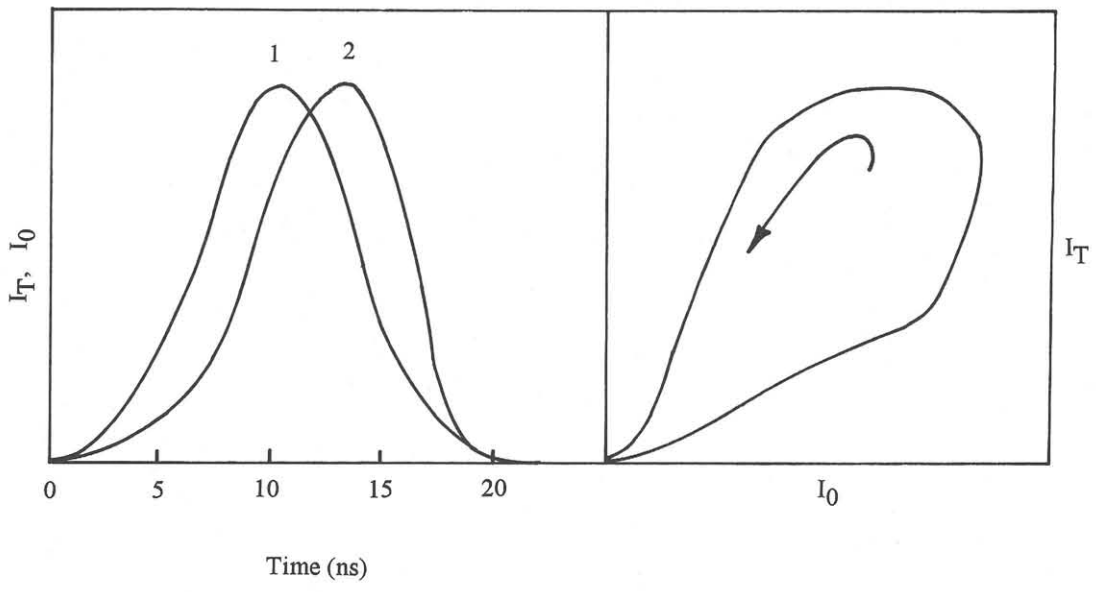

Fig. 1 The pulseshape and hysteriesis loop of bistability in $Zn_{1-X}Mn_XSe$ (X=0.005)
(1) incident laser pulse (2) transmissional pulse

absorption bistability in $Zn_{1-X}Mn_XSe$ is attributed to the bleaching of the optical nonlinear absorption of Mn^{2+} while the positive feedback is provided by the light from perfect crystal surface. Such optical nonlinear absorption is observed in the absorption spectra of $Zn_{1-X}Mn_XSe$ as Figure 2. Two absorptive bands are observed in the absorptive spectra. One band which centers at 20000 cm^{-1} is attributed to the transition of $^6A_1 \rightarrow {}^4T_2$ of Mn^{2+}. The other which centers at 19000 cm^{-1} is assigned to the transition of $^6A_1 \rightarrow {}^4T_1$ of Mn^{2+}. The absorption bistability is related to the transition of $^6A_1 \rightarrow {}^4T_1$.

In order to explain the absorption bistability, We use a bleaching mode which was used by T. Hönig et,al for CdS:In[5]. it is assumed that the energy level of $^4T_1$ of Mn^{2+} will extend to a band as the content of Mn^{2+} increasing as figure 3. A quasi-Fermi level E_f' is defined in the energy band. The quasi-Fermi level is related to the number of the states in the band filled in by electrons of Mn^{2+}. The quasi-Fermi level will shift to high energy when the number of the states filled in by electrons increases. The quasi-Fermi level is an important parameter to explain the dependence of bistability switch time on the concentration of Mn^{2+}. When the exciting energy and positive feedback energy from the crystal surface increasing to

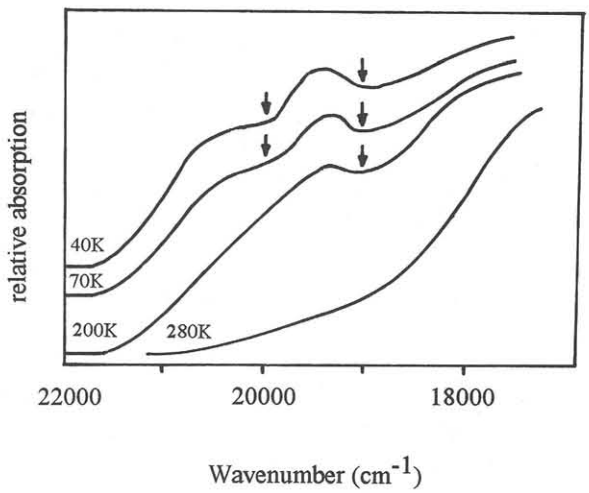

Fig.2 the absorption spectra for $Zn_{1-X}Mn_XSe$ (X=0.005) at 40K, 70K, 200K and 280K

$h\omega > E_f' - E^{6}_{A_1}$, the probability of transition of Mn^{2+} is high and the sample remains in a high absorption state. As the number of excited Mn^{2+} increasing, the number of the states in the band filled in by electrons increases and the quasi-Fermi level will shift to high energy. When

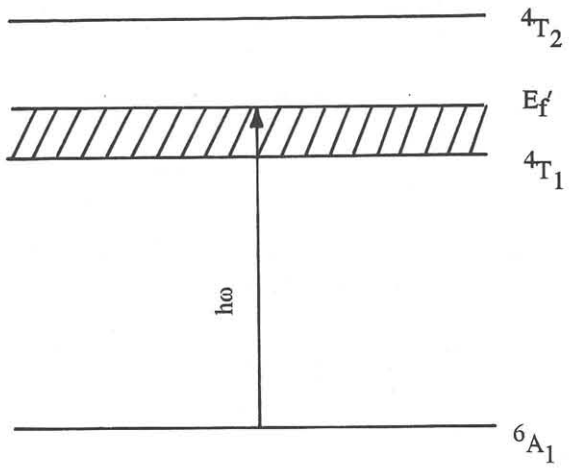

Fig. 3 The energy level of Mn^{2+} in $Zn_{1-X}Mn_XSe$

$h\omega < E_f' - E^{6}_{A_1}$ due to E_f' shifting, the probability of transition of Mn^{2+} is low, the absorption of the sample becomes very low and absorption state is switched to low absorption. As the value of X in $Zn_{1-X}Mn_XSe$ increasing, the states needed to be filled is increased to satisfy the condition of $h\omega < E_f' - E^{6}_{A_1}$ in order to switch the absorption state, so the switching time also is increased. The similar analysis can be performed for the switch process returning to a high absorption from a low absorption state, the same dependence relation of the bistability switching time on the value of X can be obtained. As discussed above, the switching time increases as the value of X increasing and it is explained by the bleaching mode.

CONCLUSION

In summary, $Zn_{1-X}Mn_XSe$ is a kind of very promising material for application to the optical bistability. The switching time increases as the content of Mn^{2+} increasing. The switching time can be 0.3 ns for X=0.001. The relation between switching time and the value of X can be explained by a bleaching mode.

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