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EPR Lineshape and *g*-Factor of the Single Crystal Mn_XSi_{1-X}

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Abstract : We have measured the linewidth and g-factor of EPR signals of the single crystal Mn_XSi_{1-X} as a function of Mn-composition ($0.4 < x < 0.9$). We have investigated the linewidth of $Mn_{0.49}Si_{0.51}$ as a function of temperature ($100 \leq T \leq 300$ K). From these results EPR linewidth equation could be fitted for experimental data of EPR linewidth. This type of equation is similar to the shape of EPR linewidth of DMS (dulite magnetic semiconductor).

INTRODUCTION

Since 1980, the single crystal and amorphous MnSi have been studied as semiconductoring materials. A lot of results were publicated. It is concluded that this transition metal compound MnSi transforms magnetically below 30 K to a helical structure in zero magnetic field or to an induced ferromagnetic state with an unsaturated magnetic moment of 0.4 μ_B/Mn atom in a field greater than 6.2 kG.[1]

Until now, the magnetic phase diagram of $Mn_{0.5}Si_{0.5}$ has been studied by ultrasonic attenuation, EPR [2], magneto-resistance [3] and partly by neutron diffraction.

Spin-lattice relaxations are induced among Mn^{2-} ions not with so much RKKY interaction as bottleneck effect.[4] In the sample of *a*-MnSi, the EPR lineshapes were

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measured well in the paramagnetic region as well as in the spin-glass region above T_g below 130 K.[4] But the EPR signal of single crystal $Mn_{0.49}Si_{0.51}$ could not measured below 130 K in our measurement.

In this research, the EPR signals of Mn_XSi_{1-X} were measured as a function of temperature and composition x.

EXPERIMENTAL

The single crystals of Mn_XSi_{1-X} with $0 < X < 0.9$ were grown by using the Bridgemann technique. The samples Mn_XSi_{1-X} were analyzed by EPR spectrometer. We used a Bruker EMX-300 system as the EPR spectrometer. The EPR spectrometer was operated with the X-band, which meant about a 9.7-GHz microwave frequency for the EPR resonance, with a 100-kHz modulation.

RESULTS AND DISCUSSION

Fig. 1 show that EPR lineshape of single crystal of Mn_XSi_{1-X} appears as the Lorentzian lineshape. The EPR linewidths were measured as a function of composition x = 0.49 and 0.82 at 300 K.

Fig. 2 shows that the EPR linewidth increases linearly at room temperature as a function of x, but EPR signal couldn't be measured in the region of $x \leq 0.4$. The linewidth are measured from peak to peak in the first derivative curves of the EPR absorption. Fig. 3 shows the EPR lineshapes as a function of temperatures ($100 \leq T \leq 300$) for sample of x = 0.49. In the temperature of $T \leq 130$ K, EPR signals disappear since the other magnetic ordering state (e.g. anti-ferro, or spin glass below T_g) may be formed.

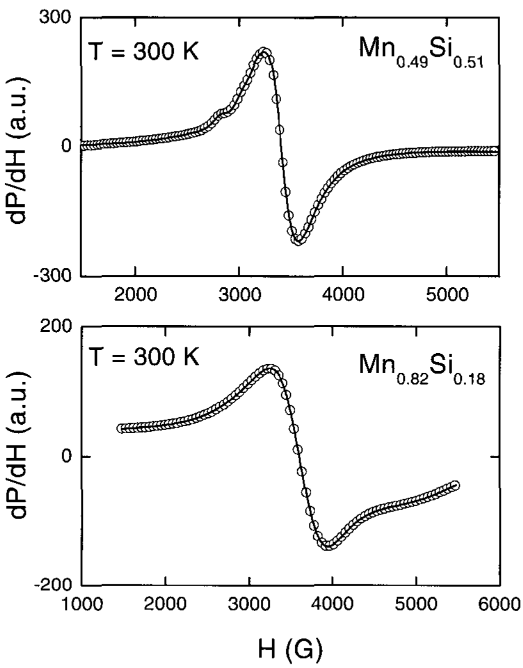

Fig 1. EPR lineshape of Mn_XSi_{1-X} for various values of the composition 0.49 and 0.82 at room temperature.

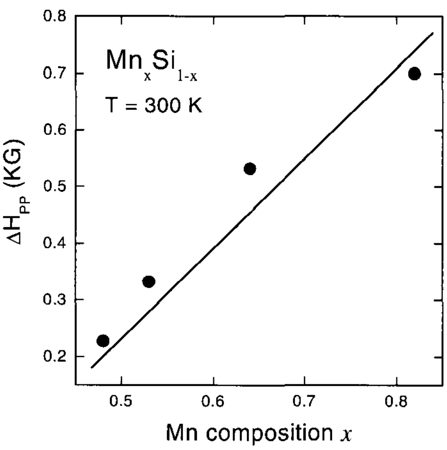

Fig 2. EPR linewidths at room temperature as a function of x.

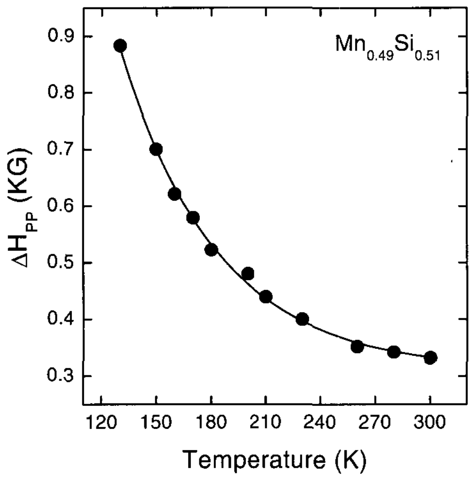

Fig 3. EPR lineshape of Mn_XSi_{1-X} for x = 0.49 at various temperature

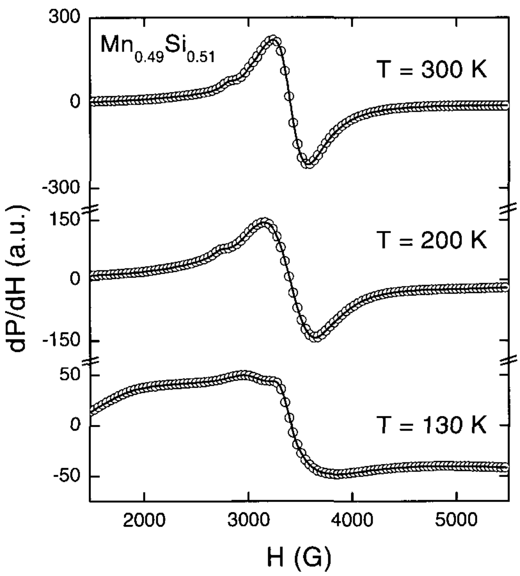

Fig 4. Temperature dependence of the EPR linewidth for $Mn_{0.49}Si_{0.51}$

Fig 4 shows the EPR linewidth as a function of temperatures for the sample of x = 0.49. In the region of x ≥ 0.6, the linewidth is almost fixed in temperature. For the sample of x = 0.49, the EPR linewidth decreases with increasing temperature; this behavior is the so-called bottleneck effect of the spin-lattice relaxation rate at room temperature. Also, the temperature dependence of the EPR linewidth of the sample of $Mn_{0.49}Si_{0.51}$ is shown to be fitted by the fellowing relation:[5]

$$\Gamma(T) = \Gamma_0 + \Gamma_1 \exp\left[-\frac{T}{T_0}\right]$$

where Γ_0 is the high-temperature linewidth and Γ_1 & T_0 are the empirical parameters associated with the spin of spin-glass.

Similarly, Sayad and Bhagat described the unusual temperature dependence of the EPR linewidth on DMS. The g-factors are measured as a function of temperature and composition x as shown in Fig. 5 and Fig. 6, respectively.

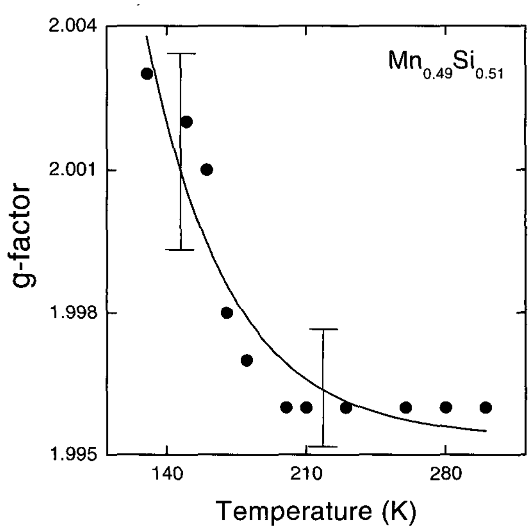

Fig 5. The shift of g-factor as a function of temperature.

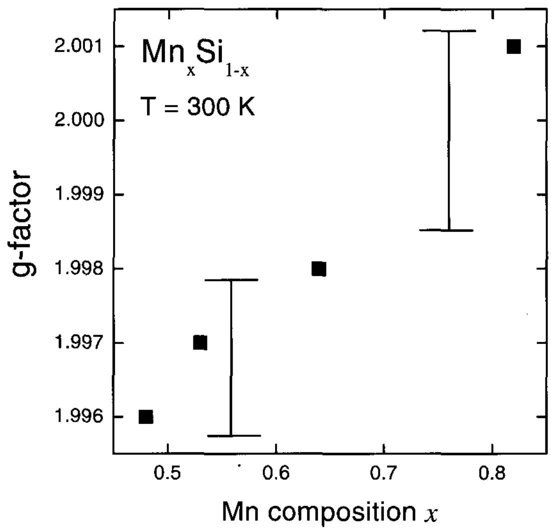

Fig. 6. The shift of g-factor as a function of Mn composition x.

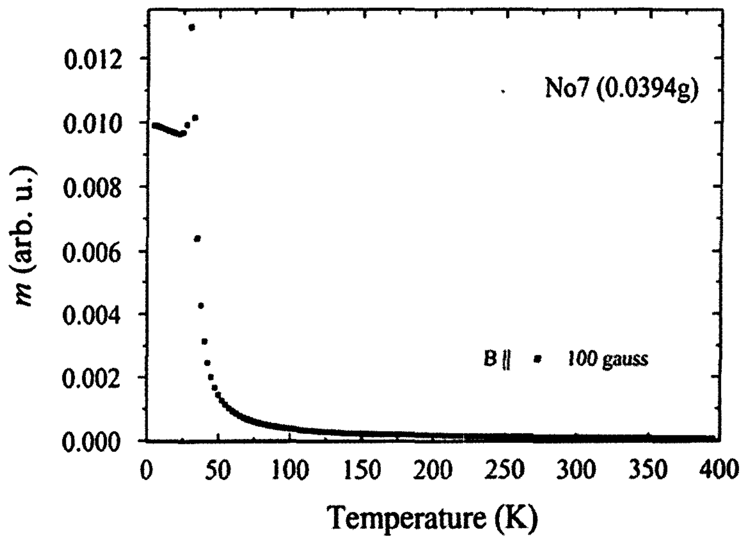

Fig. 7 The Magnetization of $Mn_{0.64}Si_{0.3}$ as a function of temperature

Since the EPR lineshape is so broad and crude, the range of error is wide. Therefore g-factors seem to be almost same. Magnetization of $Mn_{0.64}Si_{0.36}$ is measured with SQUID in the temperature range of $0 \leq T \leq 400$ K in Fig. 7. This result shows us magnetic ordering state below 50 K. But the sample of $Mn_{0.75}Si_{0.25}$ shows us magnetic ordering state below 100 K.

CONCLUSIONS

EPR-signals of Mn_XSi_{1-X} were measured as functions of the Mn composition x ($0.4 < x < 0.9$) and as a function of temperatures ($100 \leq T \leq 300$) by using EPR spectrometer. The EPR lineshapes were Lorentzian over all the composition x and g-factors are almost constant in temperature range of 100 ~ 300 K. Our results of the EPR linewidth increased as a function of x with increasing Mn composition, but decreased with increasing temperature.

From these results, EPR linewidth of the sample with x = 0.49 shows bottleneck effect at room temperature. EPR linewidth in this sample could be fitted for equation (1). Although *a*-MnSi has magnetic ordering state below 30 K and show us well EPR signal in the temperature range below 130 K [4], single crystal of Mn_XSi_{1-X} (x=0.49) couldn't show EPR signal in this temperature range. This fact may suggest that single crystal of Mn_XSi_{1-X} may have certain magnetic ordering structure although we could not find it in Fig. 7.

Acknowledgements

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REFERENCES

1. D. Bloch, J. Voiron, V. Jaccarino and J. H. Wernick, Phys. Lett. 51A, 259(1975)
2. K. Moriwaki, K. Okuda, M. Date and Y. Ishikawa, Report in Phys. Soc. Japn Meeting, April(1976)
3. M. Kohgi and Y. Ishikawa, Report in Phys. Soc. Japan Meeting, Oct.(1975)

4. M. C. Aronson, M. B. Salamon, J. J. Hauser, Physical Review B 34, 4645(1986)
5. P. K. Son, K. C. Heo, C. I. Ok, G. S. Jeen and J. W. Kim, Journal Korea Phys. Society 37 287(2000)