Magnetic Ordering and Magneto-Transport Properties Of $Ge_{1-x-y}(Si_xMn_y)Te$ Bulk Crystals

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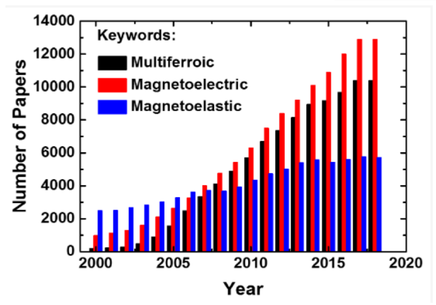
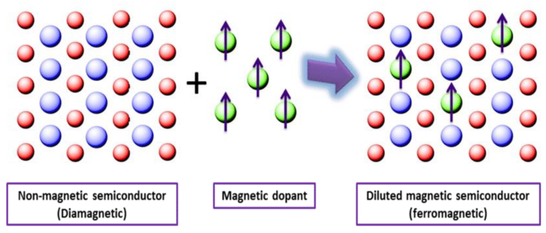
Abstract

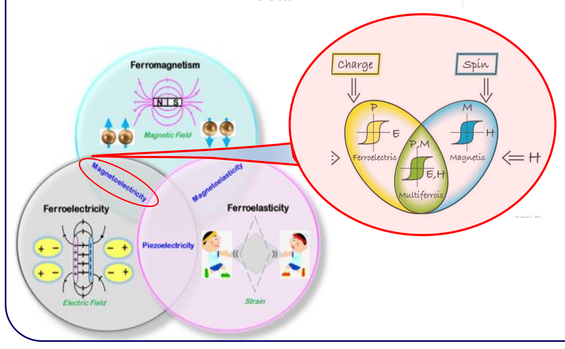
IV-VI materials doped with magnetic impurities hold potential for spintronic applications particularly by integrating the memory component within the semiconducting m atrix. This works intends to investigate the carrier mediated magnetic interactions in GeTe lattice alloyed with Mn ions. We present $Ge_{1-x-y}Si_xMn_yTe$ bulk crystals by altering th eir chemical composition in the range $0.056 \leq x \leq 0.10$ and $0.0036 \leq y \leq 0.046$. The magnetic phase transition temperature rises from T_C = 25 K to about 160 K for the highest i mpurity level. The analysis of inverse of susceptibility with modified Curie-Weiss law finds ferromagnetic-like interaction in the alloys. The magnetically glassy samples were interpreted with frequency dependent susceptibility. This identified Mydosh parameter, R = 0.2 - 0.6 which indicate the formation of clusters in the glassy samples. The high fie ld magnetization data has been used to calculate the number of active magnetic ions in semiconductor matrix. Finally the magnetotransport measurements were carried out and investigate the weak localization effect as well as anomalous contribution to the total hall effect at low field and at low temperature.

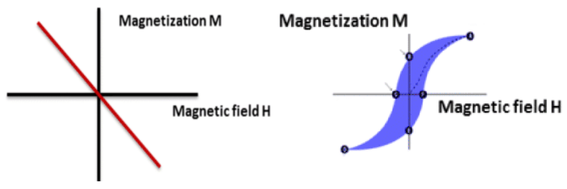
Introduction and Motivation

Why Multiferroics









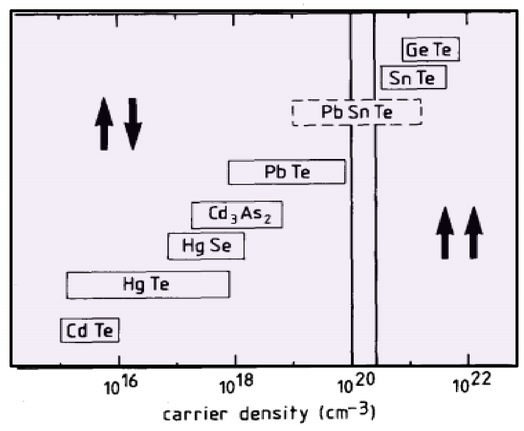
- **Semiconducting**
- **Diamagnetic**

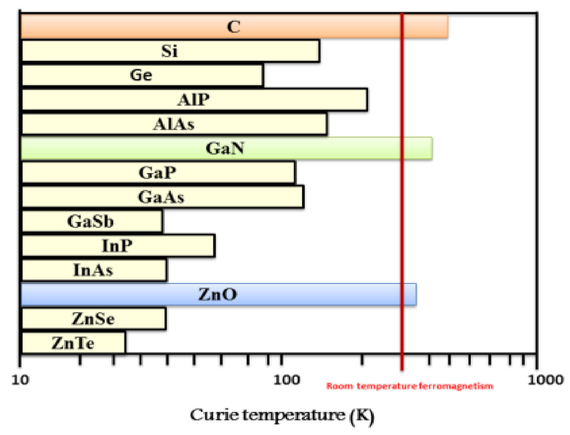
- **Semiconducting**
- **Ferromagnetic**

[1] W.J.M. de Jonge et al., *Journal of Magnetism and Magnetic Materials*, **100**, 322-345 (1991).
[2] Dietl, T., et al.,*Science*. **287,** 1019–1022 (2000).

Why IV-VI semiconductors

- Magnetic ion concentration
- Magnetic coupling strength
- Curie temperature
- Tailoring properties





[2] Dietl, T., et al.,*Science*. **287,** 1019–1022 (2000).

Results and Discussion

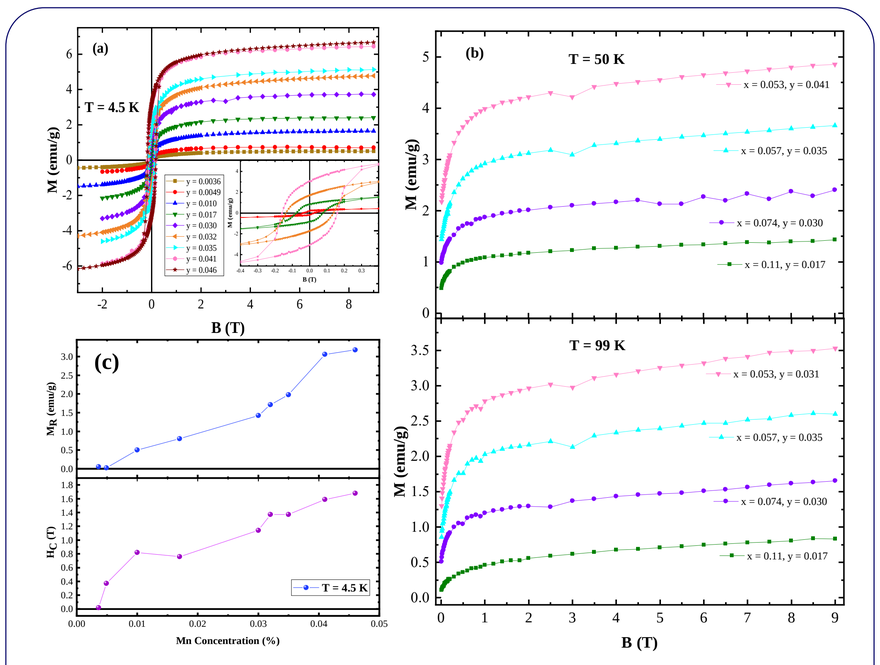
Magnetic Properties

x	y	y_θ	C (10^{-4}) [emu.K /g]	Θ [K]
0.10	0.003	0.001	0.28 ± 0.04339	43.5 ± 1.3
0.114	0.0049	0.002	0.52 ± 0.11335	76.9 ± 5.3
0.109	0.010	0.005	1.03 ± 0.41082	112.8 ± 15.6
0.11	0.017	0.004	1.52 ± 0.03789	139.6 ± 0.2
0.074	0.030	0.001	2.33 ± 0.13583	149.8 ± 0.3
0.064	0.032	0.012	2.65 ± 0.35116	170.2 ± 3.5
0.057	0.035	0.013	2.8 ± 0.19656	171 ± 1.3
0.053	0.041	0.019	4.2 ± 0.10903	172.8 ± 0.5
0.056	0.046	0.018	3.9 ± 0.18725	174.9 ± 0.7

Curie Weiss law

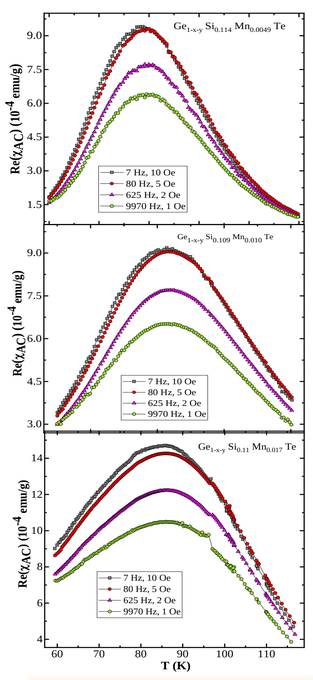
$$\chi_1(T) = \frac{C}{T - \Theta} + \chi_{dia}$$

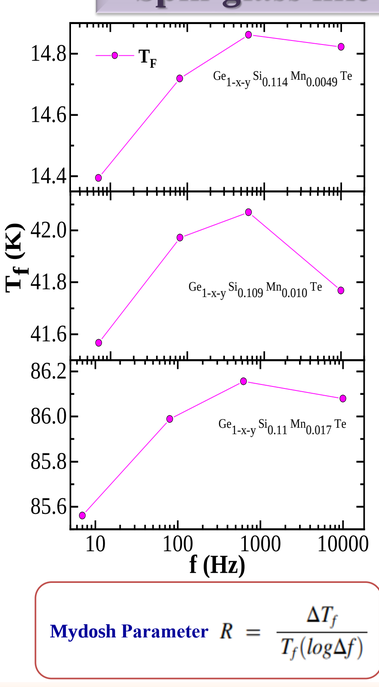
(a) Temperature dependent magnetic susceptibility Re(χ_{AC}) of $Ge_{1-x-y}Si_xMn_yTe$, (b) Critical and freezing temperature as a function of Mn concentration, (c) Curie Weiss fitting in paramagnetic regime (d) Curie Weiss Temperature vs Mn concentration and (e) Curie Weiss constant and effective Mn content vs Mn concentration

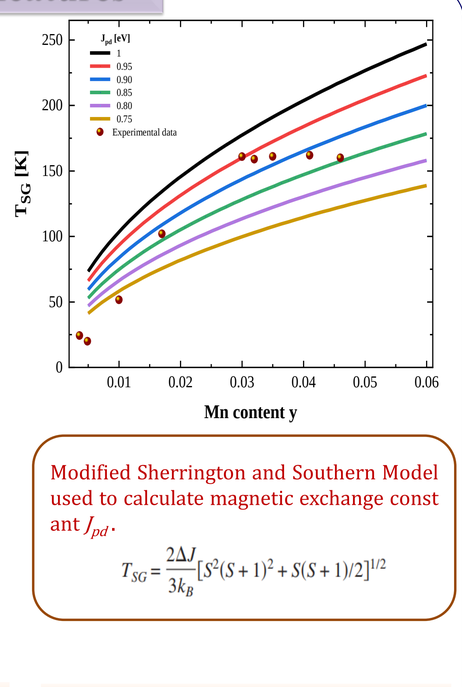


(a) Magnetization as a function of magnetic field at temperature 4.5 K, (b) Magnetization curves at T = 50 K and T = 99 K for different x and y, and (c) Ramanant Magnetization and Coersivity as a function of Mn concentration

Spin-glass like features







Mydosh Parameter $R = \dfrac{\Delta T_f}{T_f(\log \Delta f)}$

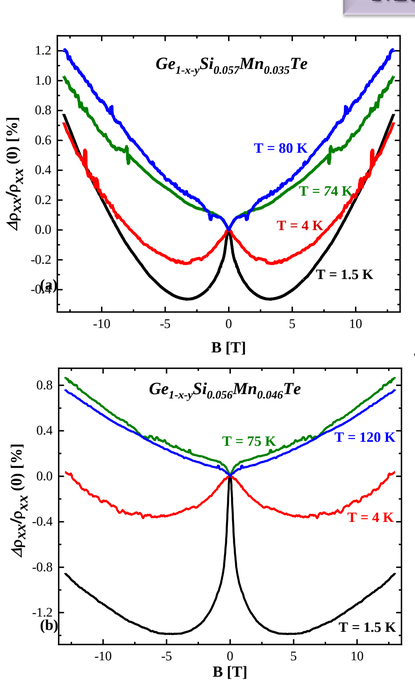
Modified Sherrington and Southern Model used to calculate magnetic exchange const ant J_{pd}.

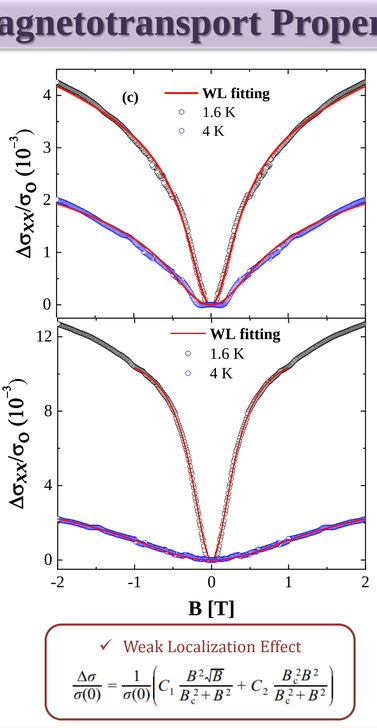
$$T_{SG} = \frac{2\Delta J}{3k_B}[S^2(S+1)^2 + S(S+1)/2]^{1/2}$$

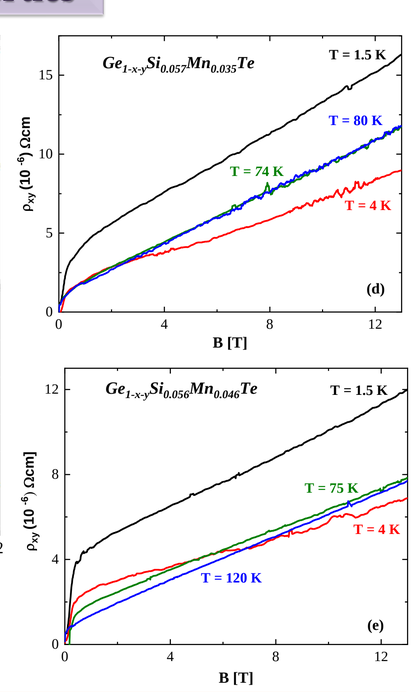
Magnetic susceptibility with temperature measured for different ac magnetic field frequencies and freezing te mperature T_F for different frequencies

Spin glass transition temperature for different J_{pd} values as a func tion of Mn content

Magnetotransport Properties







✓ Weak Localization Effect

$$\frac{\Delta\sigma}{\sigma(0)} = \frac{1}{\sigma(0)}\left(C_1 \frac{B^2\sqrt{B}}{B_c^2 + B^2} + C_2 \frac{B_c^2 B^2}{B_c^2 + B^2}\right)$$

(a) and (b) Magnetoresistance curves for y = 0.035 and y = 0.046 Mn content different temperatures, (c) weak localization fitting at T = 1.5 K and T = 4.5 K at low field region and (d) and (e) Hall effect measurements at different temperatures and anomalous hall effect observed at low temperature and low field regime

Conclusion

In conclusion, we have investigated the magnetic properties of a bulk $Ge_{1-x-y}Si_xMn_yTe$ crystal with a different chemical composition of Mn and Si. The crystal has been exa mined by temperature dependent magnetic susceptibility and magnetization measurements. Obtained results reveal the transition from paramagnet to ferromagnetic like ordering. The modified Curie-Weiss fitting done in paramagnetic region for analyzing the magnetic ordering and calculate Curie constant and Curie-Weiss temperature. . The transition sta te has further been analyzed by frequency dependent susceptibility measurements. Also, the *M(H)* curves having a well defined hysteresis attributes the existence of ferromagneti c state and spin glass transition for different J_{pd} values were calculated by using Modified Sherrington and Southern model. The magnetotransport measurements were performed at different temperatures and observe weak localization effect and anomalous hall effect at low field and low.