

Structural and Magneto transport Study of Mixed Phase MnGa Alloy

Thin Films for Spintronics Applications

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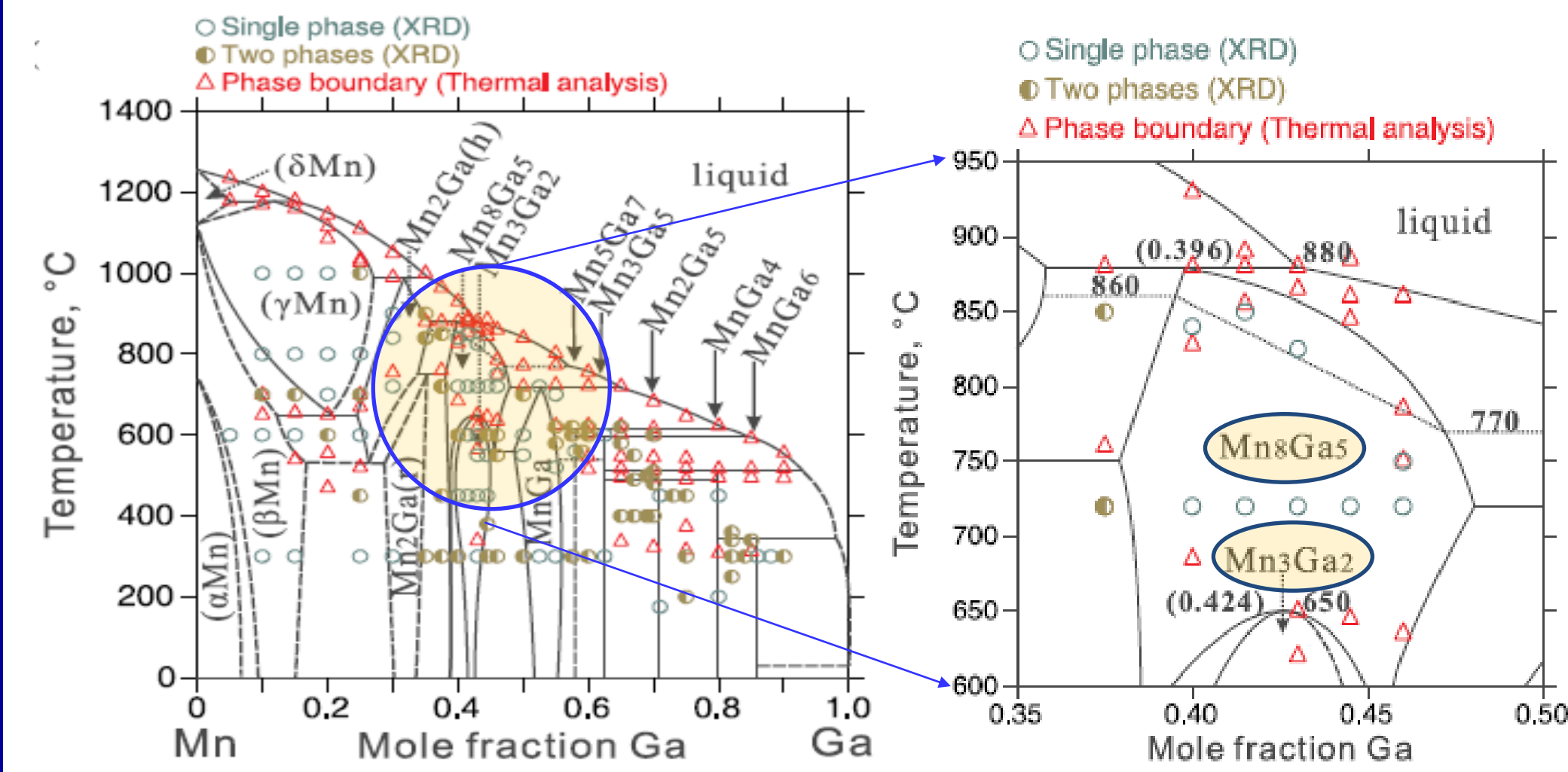
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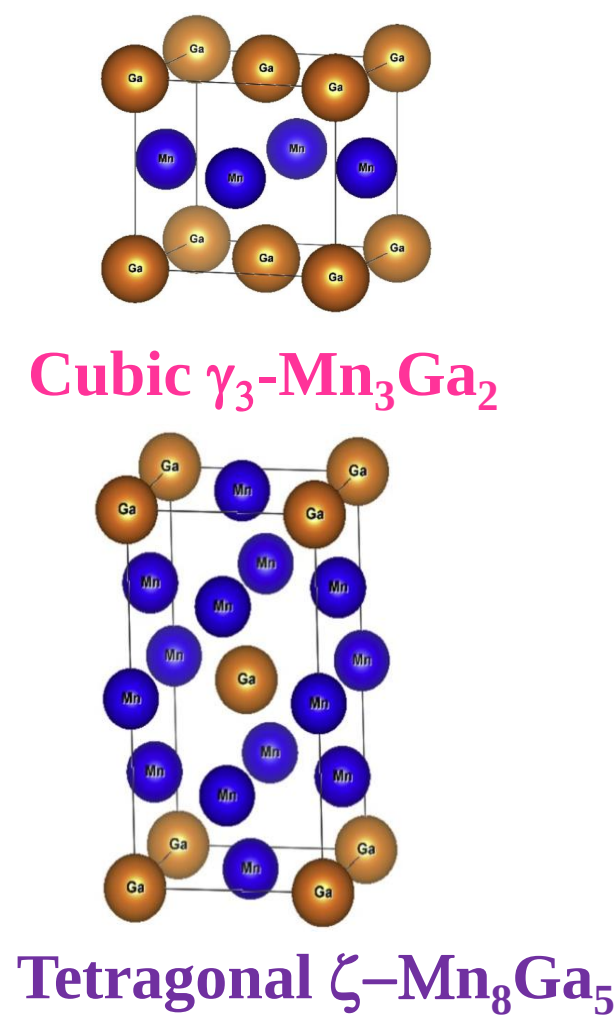
Abstract: The influence of substrate temperature (T_s) and deposition power (P) in the mixed-phase MnGa (i.e., ζ -Mn₈Ga₅ and γ_3 -Mn₃Ga₂) thin films are investigated. Structural and magneto-transport properties of thin films are explored in terms of potential spintronic applications such as magnetic recording, permanent magnets, magnetic sensors, memories, and logics.

MnGa Phase-Diagram:

There are several intermetallic compounds in the Mn–Ga system. Their magnetic properties can be tuned by varying the alloy composition and processing.



Introduction/Motivation



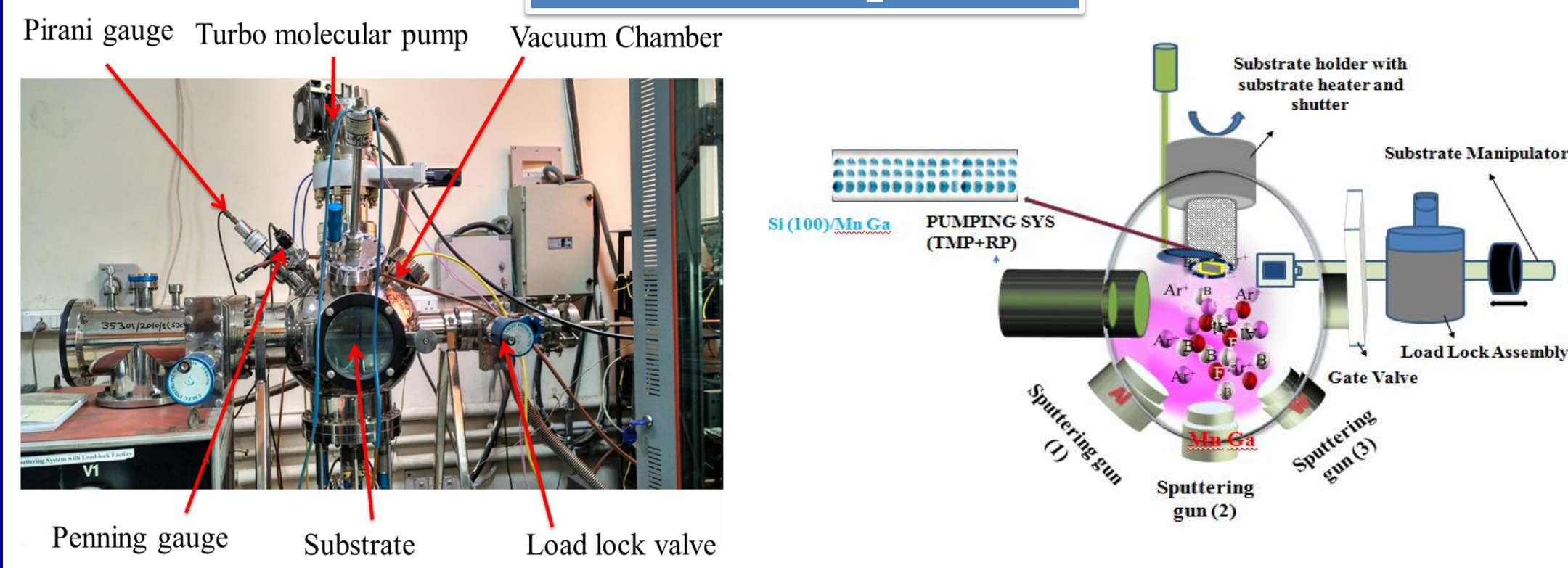
Why MnGa binary alloy?

- ✓ Very high perpendicular magnetic anisotropy energy ($K_U \sim 2 \times 10^7$ erg/cc)
- ✓ Ultra-low damping constant ($\alpha \sim 0.0003$)
- ✓ High spin polarization ($\sim 71\%$ at Fermi level)
- ✓ High curie temperature (~ 630 K)

Applications

- ❖ Spin Valve (high spin polarization)
- ❖ MTJ (exchange biasing, free layer)
- ❖ MRAM (high storage)
- ❖ Permanent magnets (high H_C, T_C)
- ❖ Other spintronics devices

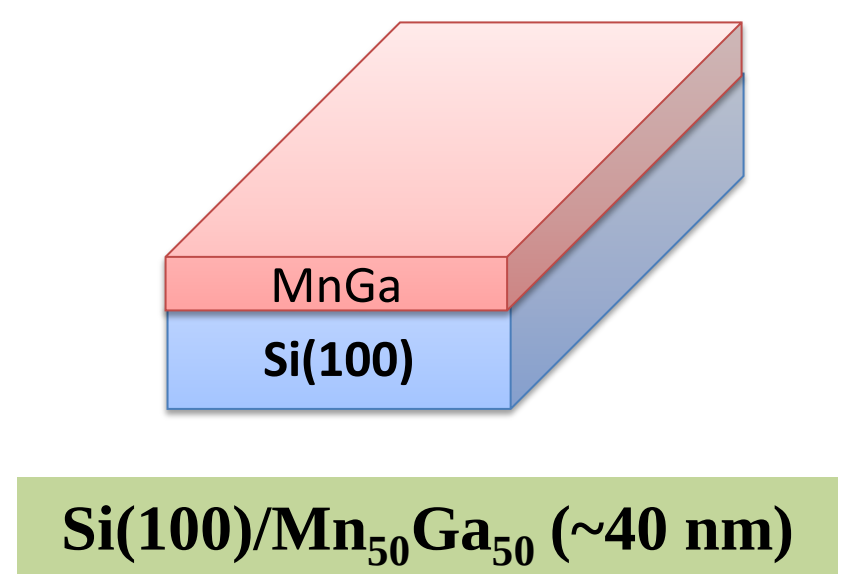
Fabrication process



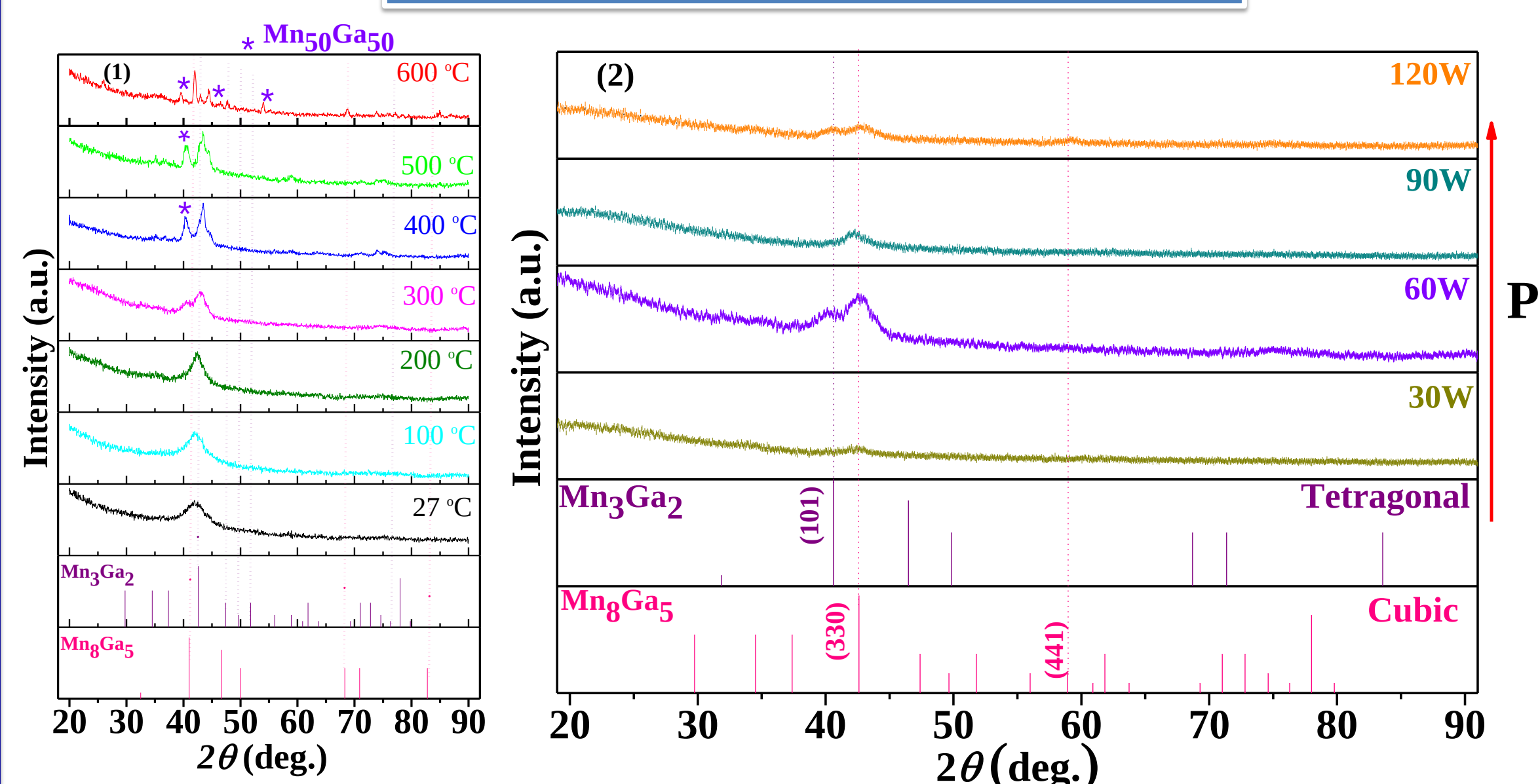
Schematic: Pulsed DC magnetron Sputtering

Deposition conditions:

Base pressure	: $\sim 2.0 \times 10^{-7}$ Torr
Working pressure	: $\sim 3.1 \times 10^{-3}$ Torr
Target-substrate gap	: 12 cm
Power	: 30, 60, 90 & 120 W
Ar gas flow rate	: 12 sccm
Substrate Temperature	: RT- 600° C



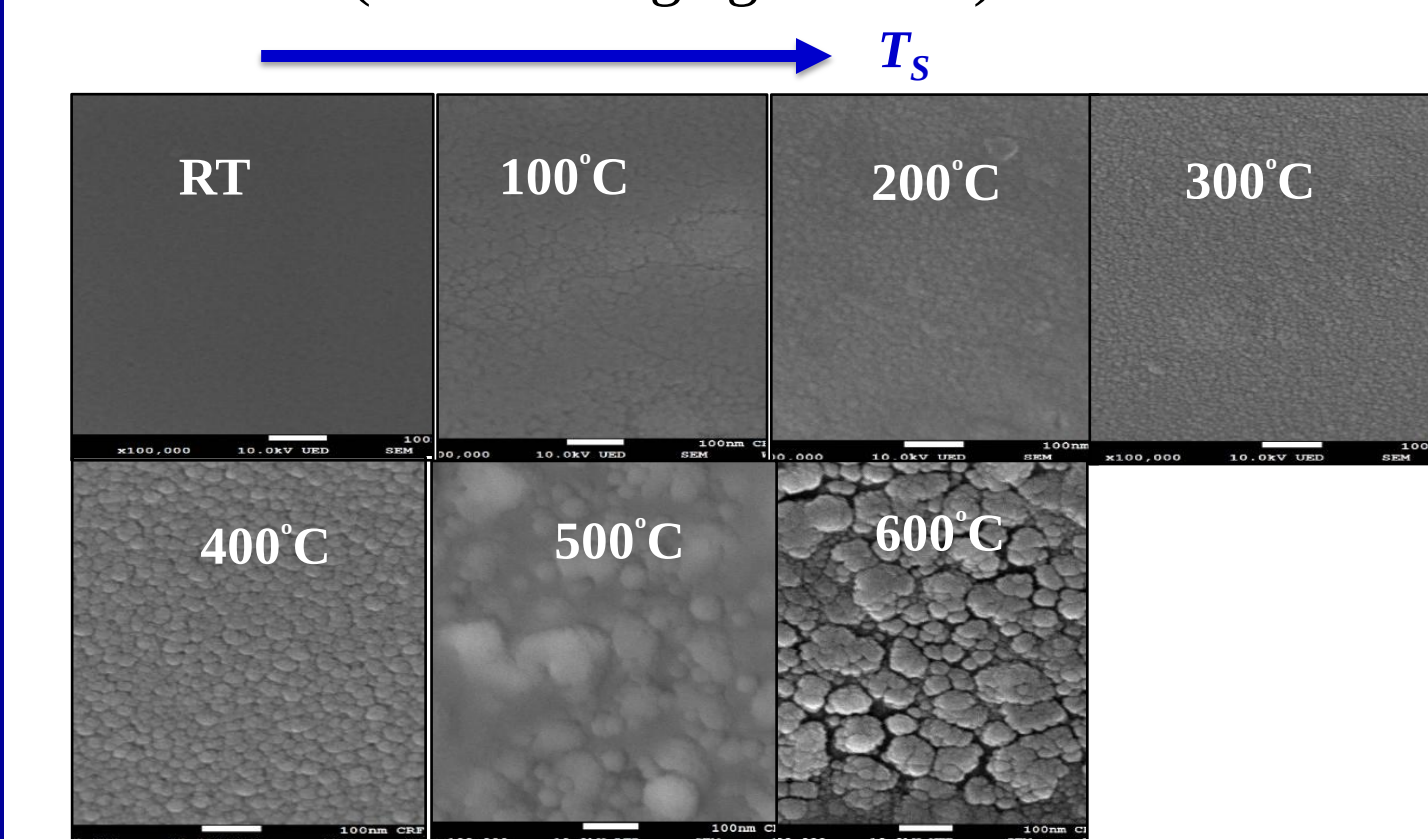
X-Ray Diffraction (XRD)



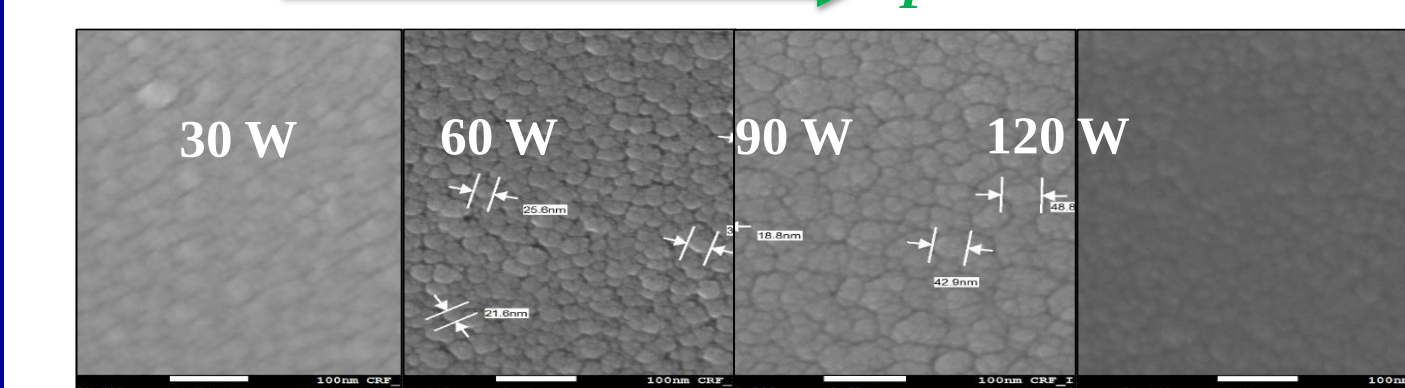
- XRD studies reveal the co-existence of cubic- ζ Mn₈Ga₅ and tetragonal- γ_3 Mn₃Ga₂ phases at $T_s=300^\circ\text{C}$ at 60W Sputtering power. (Fig.1)
- No significant change was found when the sputtering power is tuned in 30-120 W range. (Fig.2)

FESEM Analysis

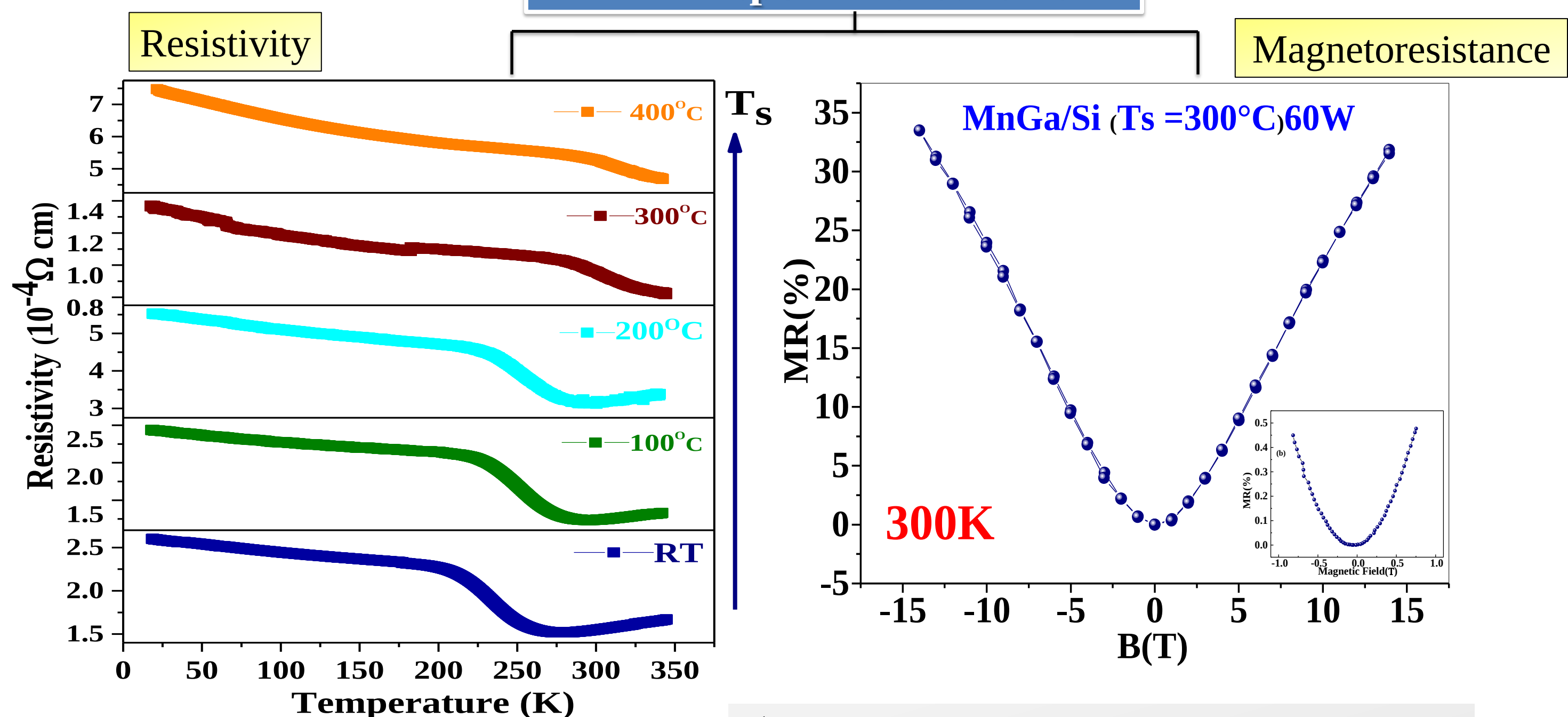
- ✓ Particle size increases with the increase in T_s .
- ✓ High T_s provides higher surface mobility of adatoms (leads to large grain size)



- ✓ Homogeneous coverage at all power
- ✓ Compactness remain intact



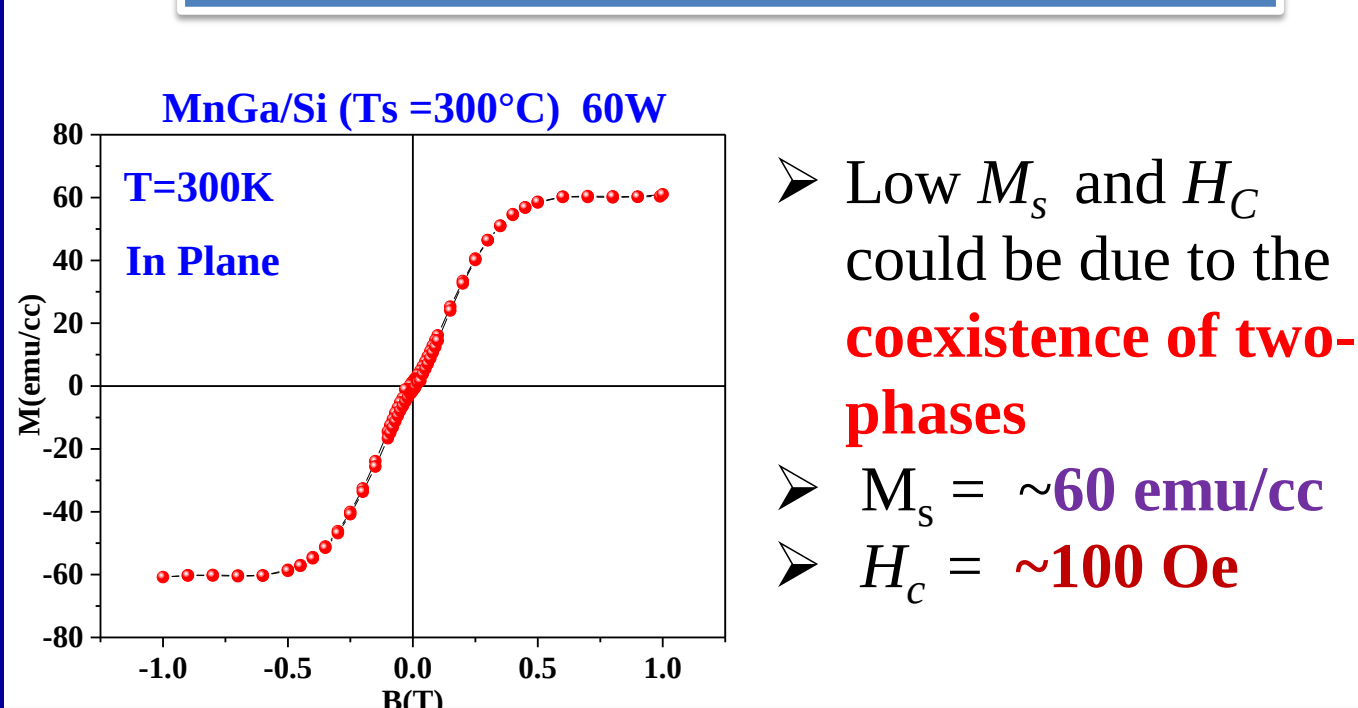
Transport Measurement



- ✓ 20-300 K: Semiconductor behavior
- ✓ 300-350 K: Metallic behavior
- ✓ Resistivity range = ~ 100 -700 $\mu\Omega$

- ✓ The longitudinal magnetoresistance (LMR) shows the large positive LMR of $\sim 31\%$
- ✓ Quadratic LMR at low field and quasi-linear at high field.
- ✓ High LMR attributed to carrier compensation

Magnetic Characterization



- Low M_s and H_C could be due to the coexistence of two-phases
- $M_s = \sim 60$ emu/cc
- $H_C = \sim 100$ Oe

Conclusions

- ❖ Coexistence of ζ -Mn₈Ga₅ and γ_3 -Mn₃Ga₂ phases is a manifestation of the deposition parameter.
- ❖ FESEM analysis shows a gradual change in the morphology and composition with the change in growth parameters.
- ❖ 60W MnGa ($T_s=300^\circ\text{C}$) film shows the ferromagnetic nature with positive and non-saturating MR behavior upto high field of 14T, suggests that the carrier compensation effects.

References

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