Magnetic Structure and Magnetocaloric Properties of $LaMn_2Ge_2$

J.L. Wang[1,2,3], Z.X. Cheng[2], W.Q. Wang[1], C.W. Wang[4], W.D. Hutchison[2] and S.J. Campbell[2]
[1] Institute for Superconducting and Electronic Materials, Innovation Campus, University of Wollongong, NSW 2500
[2] School of Science, The University of New South Wales at the Australian Defence Force Academy, Canberra, ACT 2600
[3] College of Physics, Jilin University, Changchun 130012, People's Republic of China
[4] Neutron Group, National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan

Australian Centre for Neutron

Introduction

- RT_2X_2 series – wide range of interesting physical properties –
  - Superconductivity; heavy fermion behaviour; valence transitions .....
- RMn_2X_2 - Mn magnetic moment; interplay between R-Mn and Mn-Mn exchange interaction
  - Potential for applications - Magnetocaloric effect; magneto-elasticity; magnetostriction [1, 2]
- $LaMn_2Ge_2$ – Ferromagnet – below T_C and Antiferromagnet between T_C and T_N (=413 K) [3, 4]
  - Previous neutron study only to 300 K [5]
  - Magnetic behaviour around T_C?
  - Magnetocaloric effect

AIMS

- Magnetic structure for entire temperature range
- Magnetic behaviours in different format samples:
  - bulk and ribbon
- Magnetic critical behaviour around T_C

Experimental

- Sample Preparation - argon arc melting and spinning
- X-ray, neutron diffraction
  Wombat over T=5 K-460 K with λ= 2.4258 Å
- Magnetic study (5 K- 370 K)

Results; Discussion

Magnetic study

Bulk sample

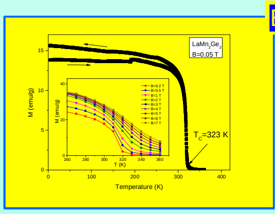


Figure 1 – Magnetization as a function of temperature under various fields for bulk sample

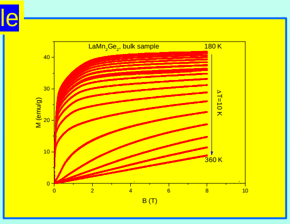


Figure 2 – Magnetization as a function of field at various temperatures

Ribbon sample

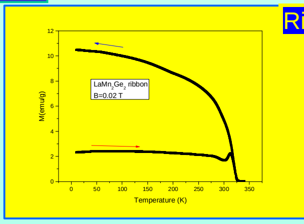


Figure 4 – Magnetization as a function of temperature for ribbon sample

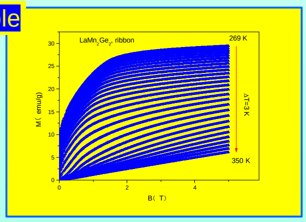


Figure 5 – Magnetization as a function of field at various temperatures

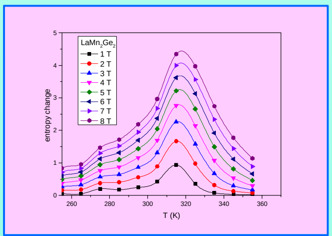


Figure 3 – Magnetic entropy changes

Magnetocaloric Effect

$$\Delta S_M(T,\Delta H)_{\Delta H} = \mu_0 \int_{H_i}^{H_f} \left(\frac{\partial M(T,H)}{\partial T}\right)_H dH$$

- T_C=323 K and T_N=415 K
- Second order magnetic phase transition around T_C
- Magnetic entropy change $-\Delta S_{max}$
  bulk sample: $-\Delta S_{max}$=4.4 J/kg K for Δ B= 8 T
  $-\Delta S_{max}$=3.2 J/kg K for Δ B=5 T
  Ribbon sample: $-\Delta S_{max}$=2.6 J/kg K for for Δ B=5 T

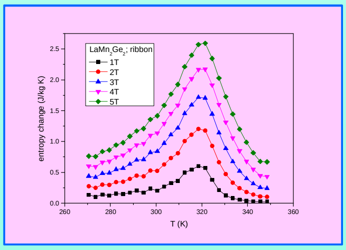
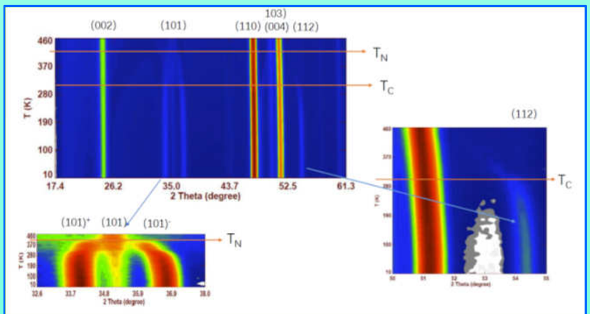


Figure 6 – Magnetic entropy changes

Neutron Diffraction



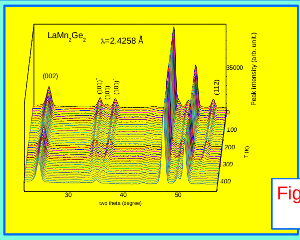


Figure 10 – Neutron diffraction patterns

- Magnetic structures determined
  Fmi below T_C
  AFfs between T_C and T_N
- No pronounced magneto-volume effect around T_C and T_N
- Clear change of - magnetic moment, k_z and z_{Ge} around T_C

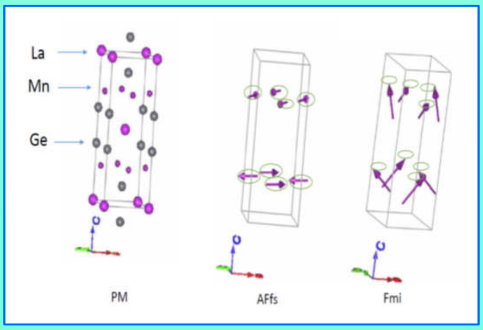


Figure 11 – Crystal and magnetic structures

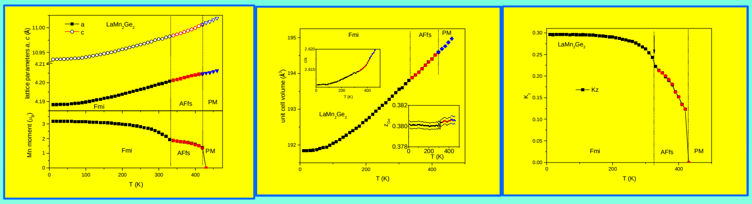


Figure 12 – Refinement results over 5 K - 460 K:
lattice parameters, magnetic moment, unit cell volume and k_z

Analyse Magnetic Results:

- Kouvel-Fisher method –
- Plot $M_s(dM_s/dT)^{-1}$ and $\chi_0(d\chi_0/dT)^{-1}$ versus T
- Critical isotherm analysis at T_C

The exponents can be expressed by the following equations:

$$M_S(T) = M_0\left|(T-T_C)/T_C\right|^{-\beta}, \quad \text{for } T<T_C \quad (1)$$

$$\chi_0^{-1}(T) = (h_0/M_0)(T-T_C/T_C)^{\gamma}, \quad \text{for } T>T_C \quad (2)$$

$$M = DH^{1/\delta}, \quad \text{for } T=T_C \quad (3)$$

- Critical exponents for ribbon sample: β=0.41, γ=1.14 and δ=3.10
- magnetic interactions are long range

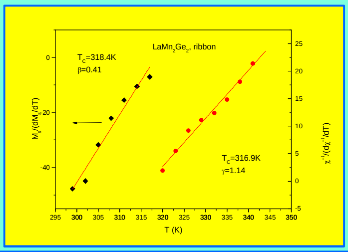


Figure 7 – Critical exponent analysis: Kouvel-Fisher plot for the spontaneous magnetization *MS(T)* and the inverse initial susceptibility χ^{-1}

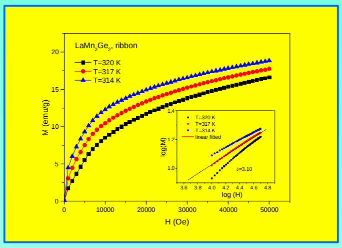


Figure 8 – Critical isotherm of *M* vs *H* close to the Curie temperature *Tc* = 335 K. Inset shows the same on log-log scale and the straight line is the linear fit

References

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Acknowledgements

We acknowledge access to the Wombat Diffractometer, OPAL Reactor, ANSTO