Synthesis and Characterization of Ferromagnetic FeScGe and MnScGe having the Fe_2P Crystal Structure

J.K. Hebert, D.P. Young, J.F. DiTusa

Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803

LA-SiGMA
Louisiana Alliance for Simulation-Guided Materials Applications

NSF

Abstract

Interesting magnetic phenomena can occur in magnetic materials that lack a center of inversion in their crystal structure (noncentrosymmetric), such as helimagnetism. Helimagnetism is characterized by a spiral arrangement of magnetic moments. Recently, the Skyrmion lattice state has been discovered in helimagnets when exposed to small external magnetic fields. Magnetic Skyrmions are thought to have potential applications in spintronics. The Skyrmion lattice state is an hexagonal lattice of vortices consisting of magnetic moments.

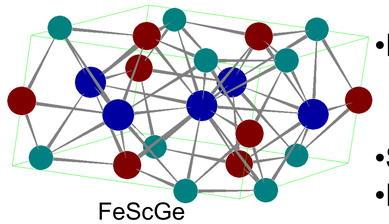
For this project, we are exploring several materials having the Fe_2P crystal structure in order to determine their magnetic properties and their potential for hosting a Skyrmion lattice state. The materials under investigation are FeScGe and MnScGe. Synthesis was performed by arc melting and or by melting in an RF furnace followed by annealing in vacuum in a tube furnace. The crystal structure was determined by powder X-Ray diffraction (XRD), and the magnetization was characterized in a Quantum Design Superconducting Quantum Interference Device (SQUID).

Acknowledgements

Special thanks to Drew Rebar and Mojammel A. Khan for their technical assistance with this project. This material is based upon work supported by the National Science Foundation under the NSF EPSCoR Cooperative Agreement No. EPS-1003897 with additional support from the Louisiana Board of Regents.

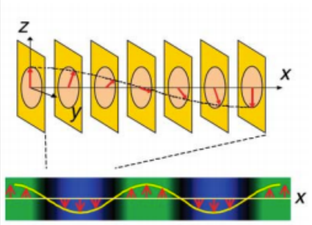
LSU

Background

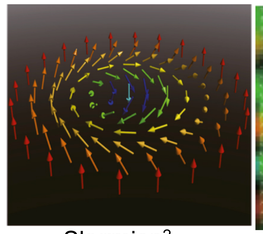


FeScGe

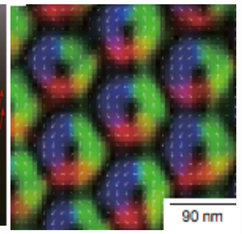
- Fe_2P type compounds:
  - MnScGe
  - FeScGe
- Space group $P\bar{6}2m$, $C22^3$
- Helimagnetism, skyrmions?



Helimagnetic Ordering[1]



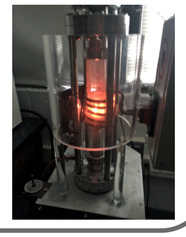
Skyrmion[2]



Skyrmion Lattice[2]

Synthesis

- Reaction
  - Arc melted at about 2500 °C in Argon atmosphere
  - RF furnace: induction heating at over 1500°C
- Annealing
  - Tube furnace at 1000°C for 7 days



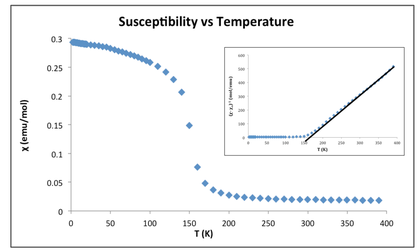
Conclusions

- Metallic
- Soft, itinerant ferromagnet
- Phase transition of unknown origin in resistivity

References

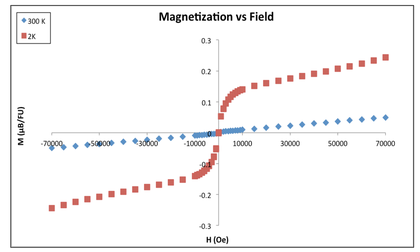
[1]Masaya, et al. Science. v311. 2006
[2]Yu, et al. *Nature*. v465. 2010
[3]Kotur, et al. *DOPOVIDI AKADEMII NAUK UKRAINSKOI RSR SERIYA B-GEOLOGICHNI KHIMICHNI TA BIOLOGICHNI NAUKI*. 1984

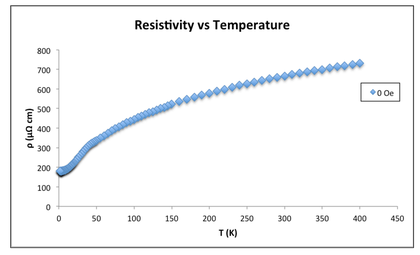
Results



The susceptibility shows ferromagnetic ordering below Curie temperature of about 150K. The Curie-Weiss fit gives Weiss constant of 160 K.

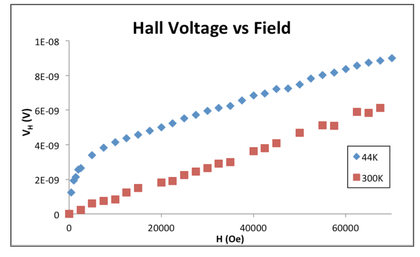
A relatively small magnetization and lack of hysteresis means material is likely a soft, itinerant ferromagnet.





The resistivity data displays a behavior consistent with a that of a metallic material and a phase transition near 40K of unknown character.

The non-linearity of the Hall voltage indicates an anomalous Hall effect contribution known to occur in ferromagnetic materials.



Future Work

Improve sample quality, grow single crystals, measure specific heat, and neutron scattering