High Field Magnetic Response of Solid Solution Titanomagnetites ($Fe_{3-x}Ti_xO_4$, $1 \geq x \geq 0$)

W. Schoenthal, S. Lan, K. Groschner, M.E. McHenry (CMU, Materials Science & Engineering), Marina Diaz-Michelena (INTA)

Introduction

Titanomagnetites (TMs) are common magnetic minerals, the solid solution series between magnetite (Fe_3O_4) and ulvöspinel (Fe_2TiO_4). "TMX" refers to X% ulvöspinel. TMs, except ulvöspinel, are ferrimagnetic. Their remnant magnetization is believed to contribute to planetary field anomalies on Earth, the moon, and Mars [1]. They can provide insight to the geomagnetic evolution of planetary bodies [2]. Further understanding the complex interactions of exchange energies in the inverse spinel structure of TMs is important to predicting their magnetic behavior and the circumstances under which the minerals were formed.

When a high magnetic field is applied to a ferrimagnet, the Zeeman energy can overcome the exchange energy and rotate the magnetic moment that is aligned antiparallel against exchange and into alignment with the field and other moments. This is known as spin flop. The applied field at which this occurs will give quantitative data on the exchange energy.

Experimental

Using a capacitor driven pulsed magnet at NHMFL, a 55 Tesla field was applied to a variety of powdered TM compositions (TM80, 85, 95, and100) at low temperatures (2-4Kelvin) and M vs H curves were recorded. The TMs were synthesized at CMU.

Results and Discussion

Prior experiments performed on the samples up to 9T displayed a linear magnetic response in the rotation against exchange region, after initial saturation. Extrapolations of this data lead us to believe high titanium concentration TMs could reach spin flop magnetizations at fields near the capabilities of the pulsed magnets at the NHMFL. Results from the 55 Tesla pulse did not reach spin flop magnetization in our TM80-100 samples.

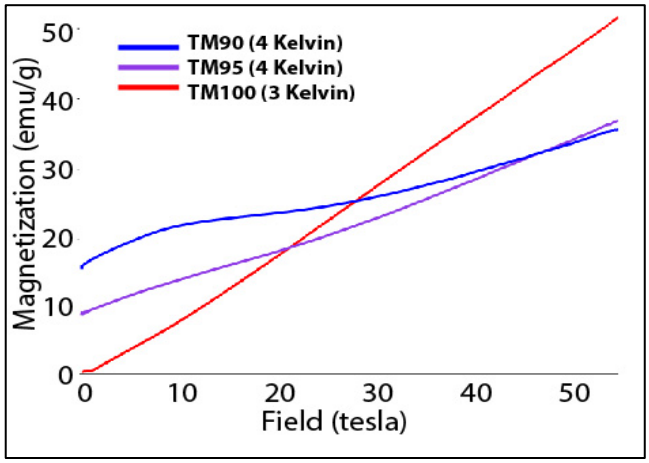

Fig.1: Magnetization vs Applied Field (TM90-100)

The magnetic response was non-linear. This is an indicator of magnetic frustration. Magnetic frustration is normally discussed in the context of a spin liquid, ice, or glass, where the magnetic ground state is frustrated. In our case the frustration is induced at a high applied field. The cause of this frustration is the subject of further research.

Ulvöspinel, an antiferromagnet, does not display the frustration, however with increasing Fe content two slope changes become more apparent in the M vs H curve. The final slope of the curves decreases with increasing Fe content, indicating greater exchange energies that need to be overcome to induce spin flop. Extrapolating from these slopes suggests that the spin flop magnetization may be attainable with the NHMFL's more powerful motor-generator and capacitor driven pulse magnet.

Conclusions

We have shown a magnetically frustrated state is created at high applied fields (>10Tesla) in Titanomagnetites. The frustration is composition dependent. Applied field required for spin flop in titanomagnetites is also composition dependent, increasing with decreasing Ti content. This is not only due to a higher spin flop magnetization, but a lower rotation against exchange susceptibility.

Acknowledgements

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References

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