Exploring the Effects of Indium in a Four Element Magnetic Alloy

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Why? To make magnets CHEER. Cheaper, Helpful, Efficient, Environment-Friendly, Reliable

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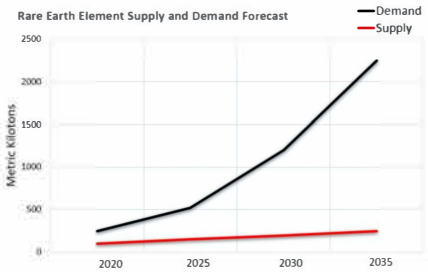
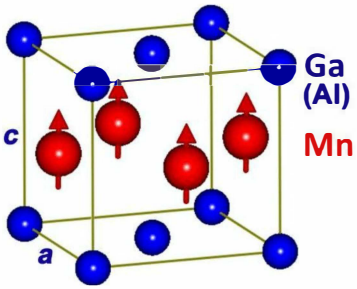
Abstract

This study addresses the growing concern with the difficulty of obtaining Nd for NdFeB magnets. Mn-Al has the potential to be a substitute but it lacks the high coercivity and ferromagnetic phase stability. Indium and gallium help with coercivity and phase stability, respectively. Through a two-step heat annealing process, the quaternary alloy showed an increase in coercivity although a greater decrease in magnetization when compared to a sample of the same composition without indium.

Background



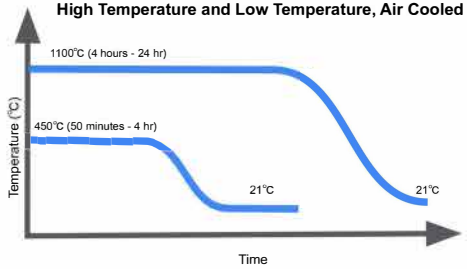
The CuAu (L10) Structure



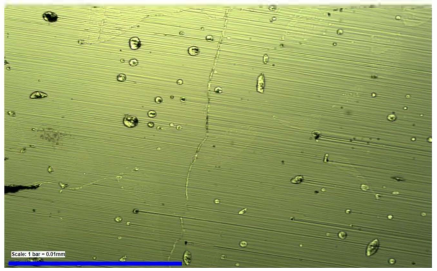
- NdFeB demand will greatly increase; non rare-earth elements can be used to create novel magnets
- The magnetization depends on Mn atom magnetic moments being aligned - found only in this crystal structure
- Ga and In can substitute for Al because of their

Processing and Results

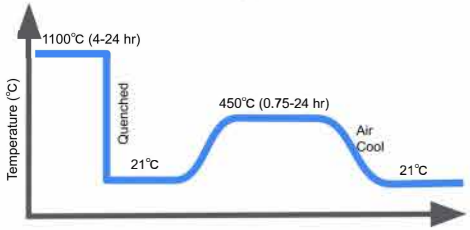
High Temperature and Low Temperature, Air Cooled



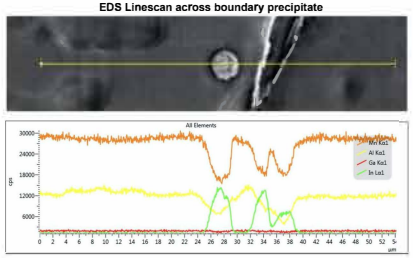
Sample AR 300E, a Mn-Al-Ga-In alloy (55-36-6-3 at%) micrograph taken at 10X zoom.



High Temperature, Quenched, then Low Temperature, Air Cooled

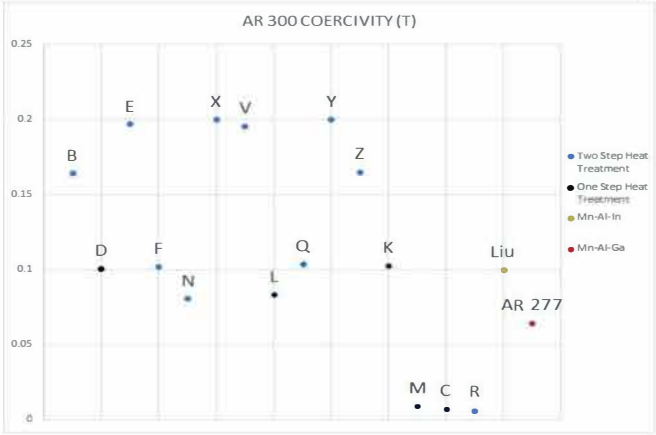


EDS Linescan across boundary precipitate



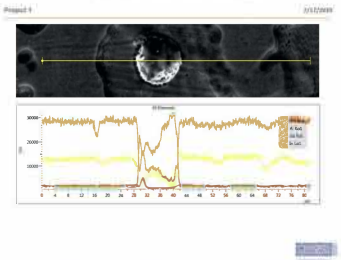
Coercivity Plot

- The best order of heat treatments along with cooling methods is 1100℃ quenched then 450 ℃ air
- cooled. Two heat treatments need to be done to achieve the highest coercivity
- Time plays a role as a 4 hour heat treatment starts to show ferromagnetism while a 24 hour treatment decreases the coercivity.



Scanning Electron Microscope

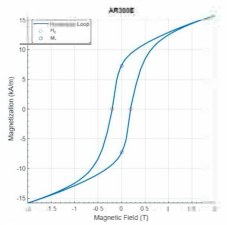
EDS Line Scan Across Precipitate



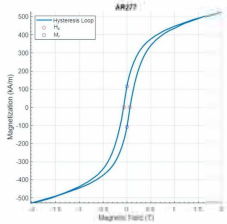
Through EDS analysis, the circular precipitate has a very high concentration of indium. This suggests that these precipitates act as a pin in the alloy thus increasing the coercivity of the alloy.

Magnetization Comparisons

Mn-Al-Ga-In
(55-36-6-3 at%)
Coercivity: 0.2 T
Saturation Magnetization:
15 kA/m



Mn-Al-Ga
(55-39-6 at%)
Coercivity: 0.06 T
Saturation Magnetization:
500 kA/m



Conclusion:

- Indium increases the coercivity of the alloy 0.2 T to 0.06T in a non-indium alloy sample. However the magnetization is very low.
- 2 Heat treatments need to be done in a specific order in order to maximize the coercivity and the magnetization of the alloy

Future Works

- If the composition is the same then test different temperatures with different times
- If composition changes then repeat the best heat treatment course from here and compare

References

Liu, et al. Microstructures and Magnetic Properties of Rapidly Solidified MnAl Alloys Modified with Indium. J Supercond Nov Magn 36, 217–222 (2023).
Jianliang Wang, Meiyu Guo, Mingming Liu, Xinqiang Wei, Long-term outlook for global rare earth production, Resources Policy, Volume 65, 2020, 101569, ISSN 0301-4207,
Electrical Transport of perpendicularly magnetized L10-MnGa and MnAl films - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/The-lattice-structure-of-L10-ordered-MnGa-and-MnAl_fig1_312016849 [accessed 4 Jul. 2023]

Acknowledgement: This work was supported by the NSF via the REU Site: Materials for Society (Award No. 1950305)