Reversibility of Magnetic Behavior in High Entropy Oxides

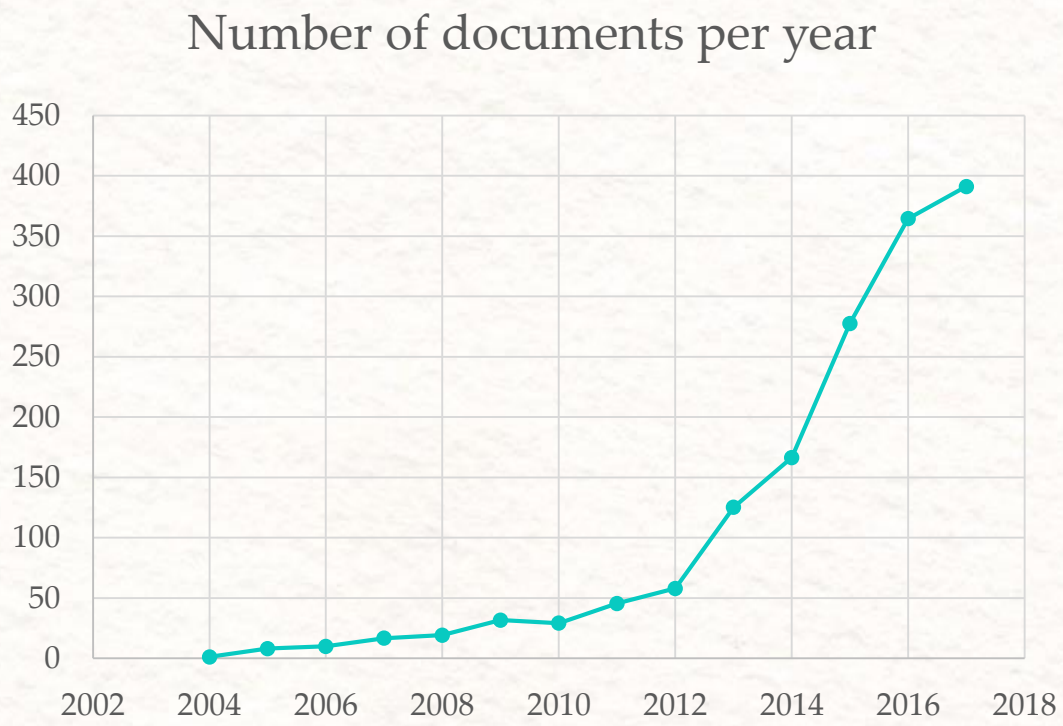
Tahereh Afsharvosoughi
Prof. David Crandles
Physics Department
Brock University

Outline

- Introduction
- Objective
- Methodology
- Results
- Conclusion

Hot topic!

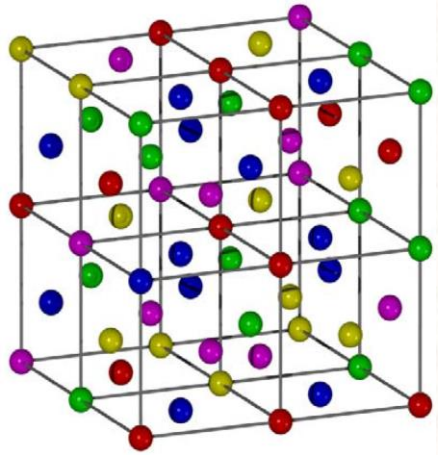
Year wise publications in the research area of HEAs (Based on the Scopus analyze search results for "High Entropy Alloys" as on Sep 12, 2017)[1].



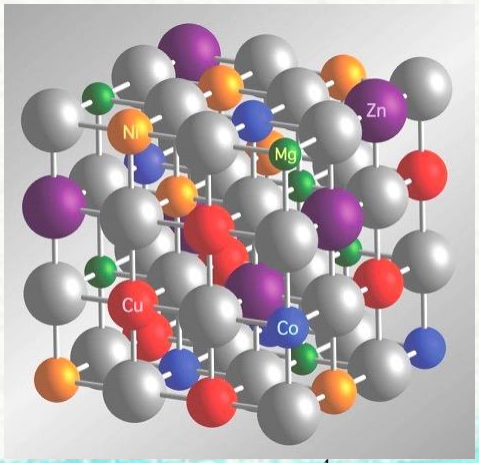
[1]Kim et al. Adv. Eng. Mater. 20: 1700645 (2018)

What are High Entropy Materials?

- Mixtures of alloys (e.g: Cr, Mn, Fe, Co, Ni)[2]



- Mixtures of oxides (e.g: NiO, CuO, MgO, CoO, ZnO)[3]

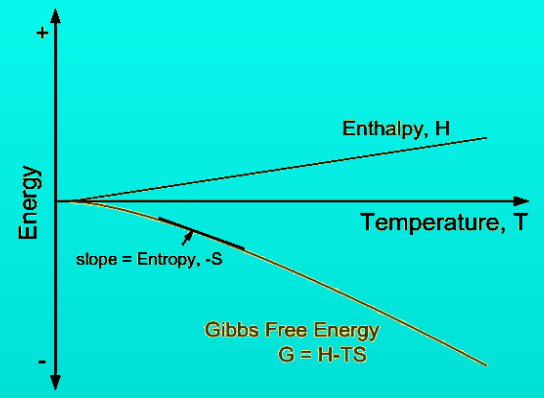


[2] S. Wang. *Entropy 15*(12): 5536-5548(2013).
[3] Rost et al. Nat. Commun.6:8485 (2015).
Image 1 credit: Shaoqing Wang.
Image 2 credit: Jon-Paul Maria

Why they are called high entropy materials?

High configurational entropy

($\Delta G = \Delta H - T\Delta S_{conf}$)



- Maximum achieve when equimolar mixtures ($x_i = \frac{1}{N}$ $in\ S_{conf} = -k_B \sum_{i=1}^{N} x_i \log(x_i)$)[4]
- Facilitate formation of single phase solid solution[5]

[4]Tsai et al, *Mater. Res. Lett.*,Vol. 2, No. 3, 107–123(2014).
[5]Meisenheimer et al, Nat. Commun.7: 13344(2017):

Fascinating properties

HEAs	HEOs
great hardness	colossal dielectric constant[6]
toughness	Superionic conductivity [7]
Corrosion resistance[5]	Enhanced exchange bias[4]

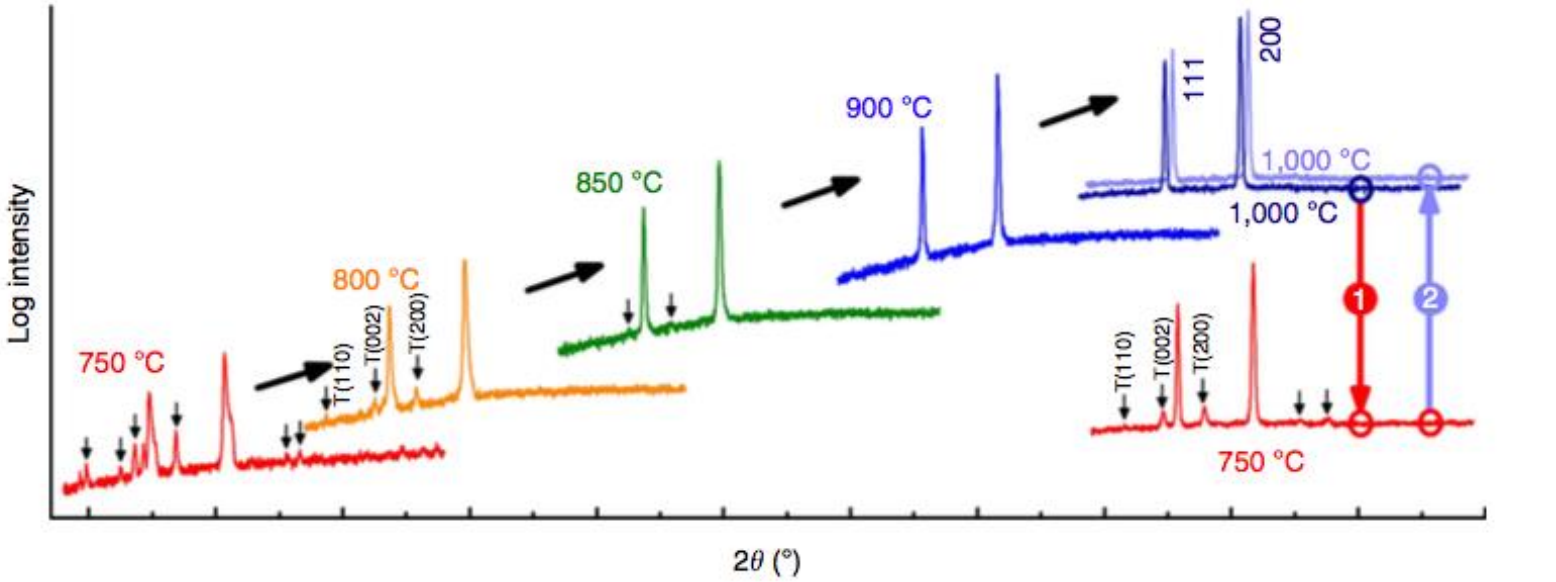
[4]Tsai et al, *Mater. Res. Lett.*,Vol. 2, No. 3, 107–123(2014).
[5]Meisenheimer et al, Nat. Commun.7: 13344(2017)
[6]Berardan et al, *Phys. Status Solidi - Rapid Res. Lett.* **10**, 328–333 (2016).
[7] Berardan et al, *J Mater Chem A* 9536–9541 (2016).

What are we looking for ?

- Whether the magnetic behavior just like structural behavior is reversible by sintering or not?

Reversibility of structural phase transition by sintering in HEOs

In 2015 ☛Rost et al showed reversible transition from multiphase to single phase by sintering at intermediate and high temperature and vice versa[3]



[3]Rost et al. Nat. Commun.6:8485 (2015).
Image credit: Rost et al

Methodology

- Sample Preparation

Mixing MgO, CuO, NiO, ZnO, CoO in ball mill for 2 hours

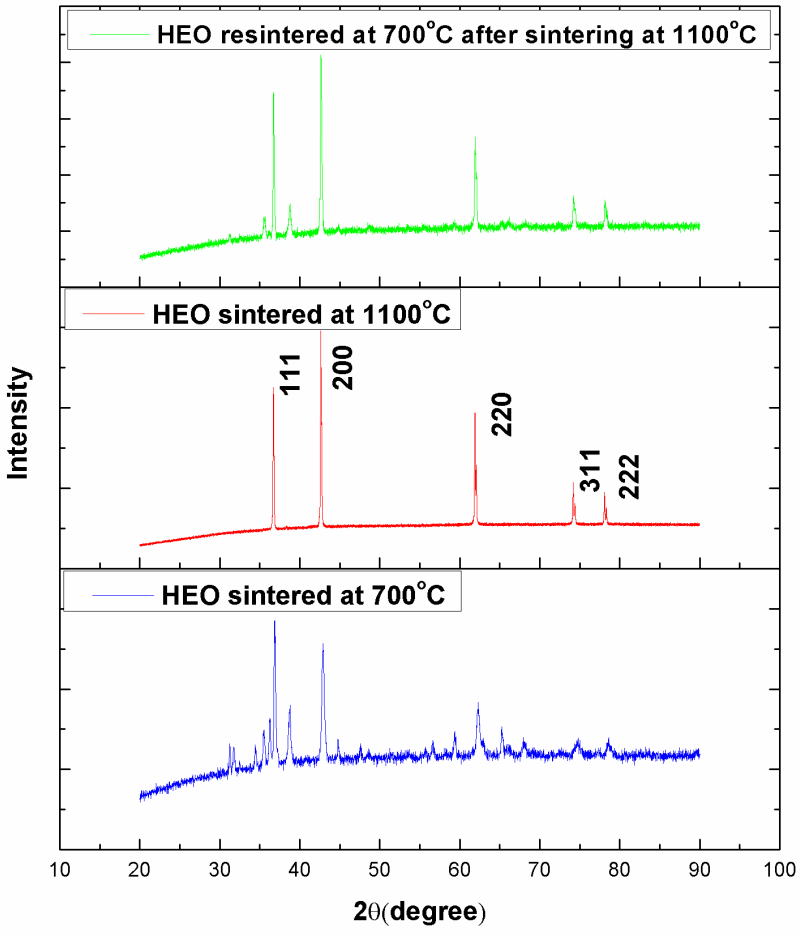
- Structural property measurement

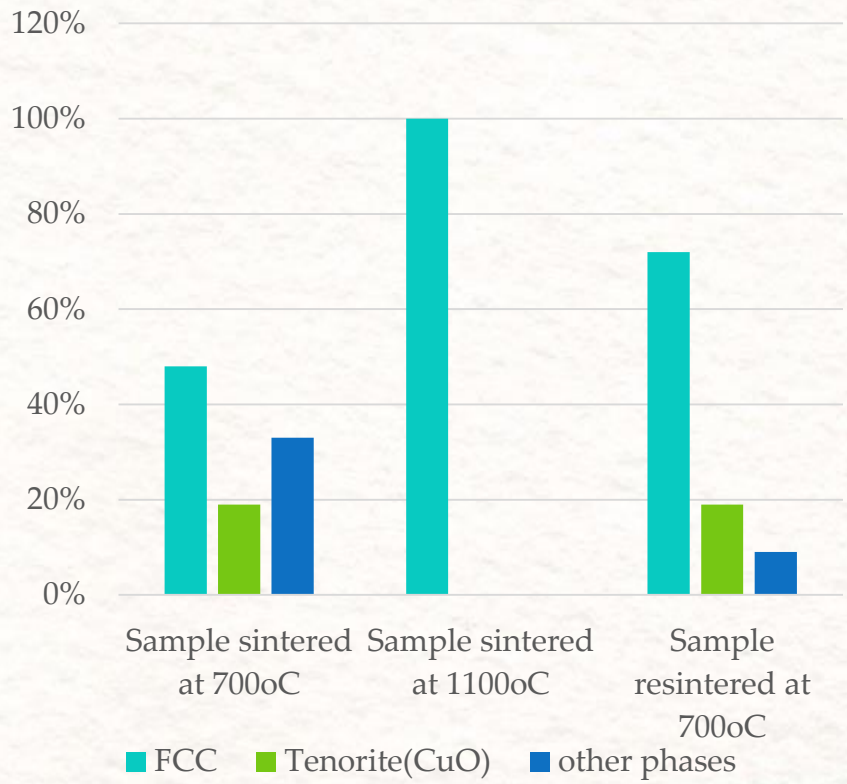
Rigaku X-ray diffractometer with Cu-Ka radiation

- Magnetic property measurement

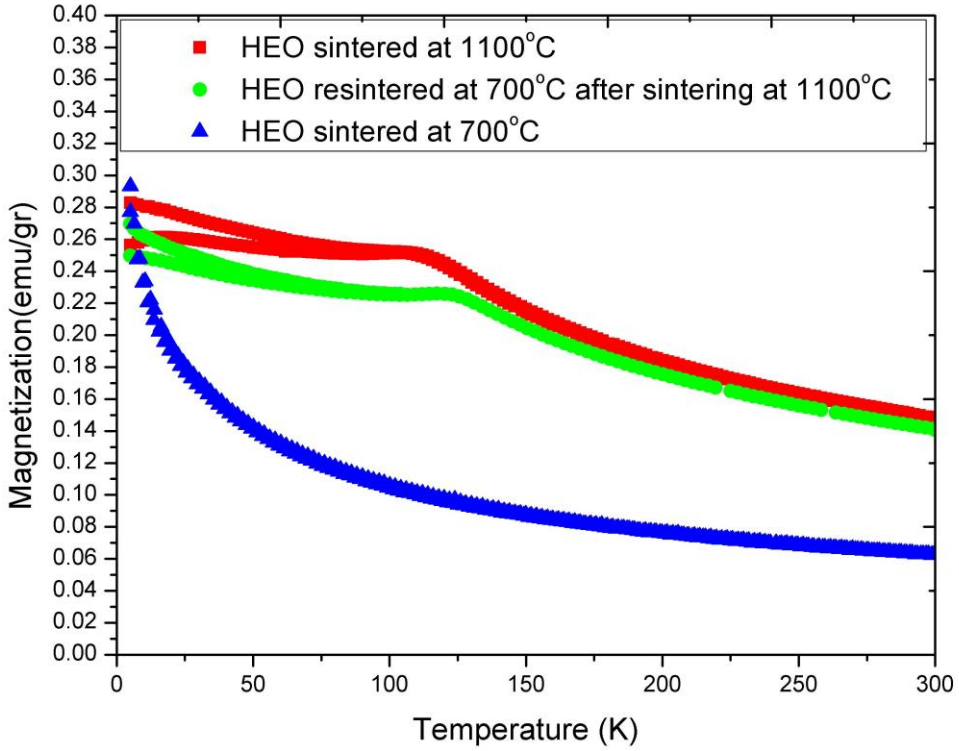
Quantum Design Magnetic Properties Measurement System (MPMS)

X-ray diffraction measurement results

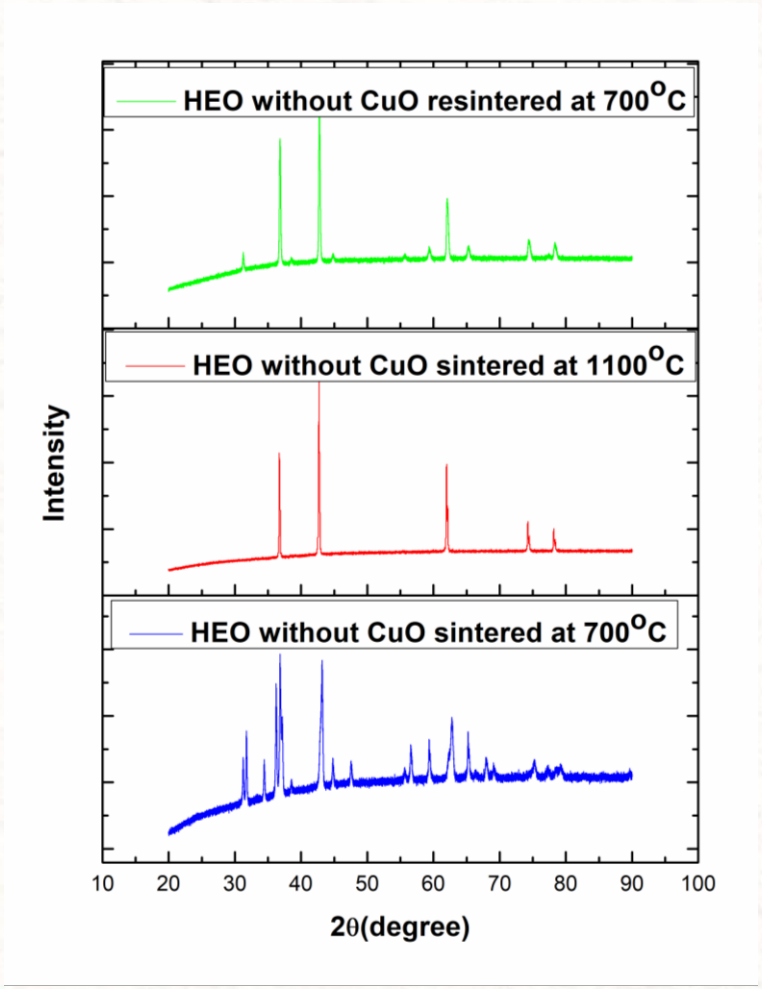


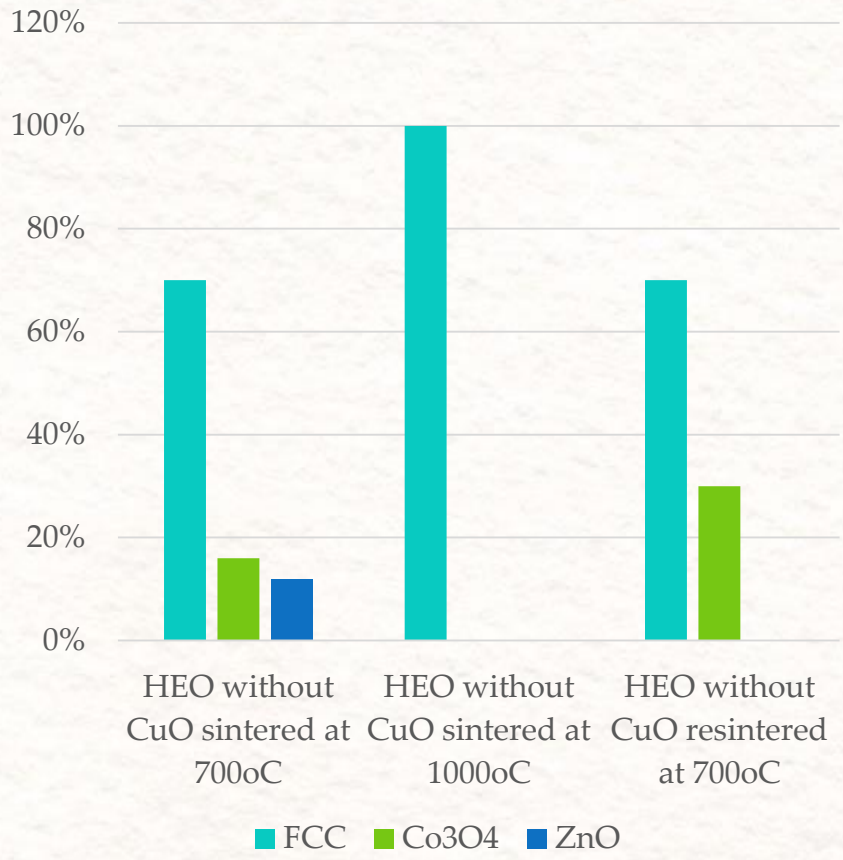


Magnetization measurement result

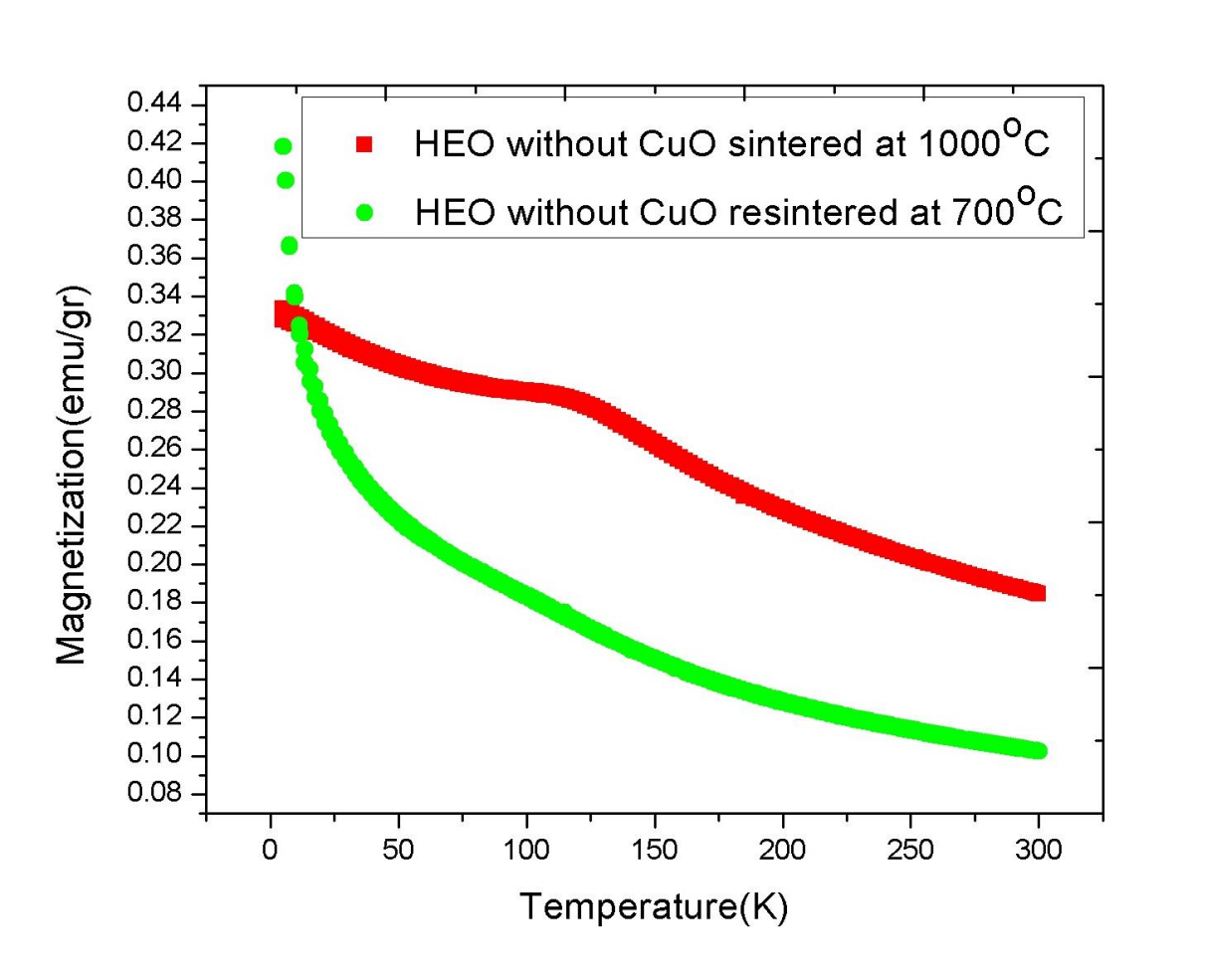


Four mixtures without CuO

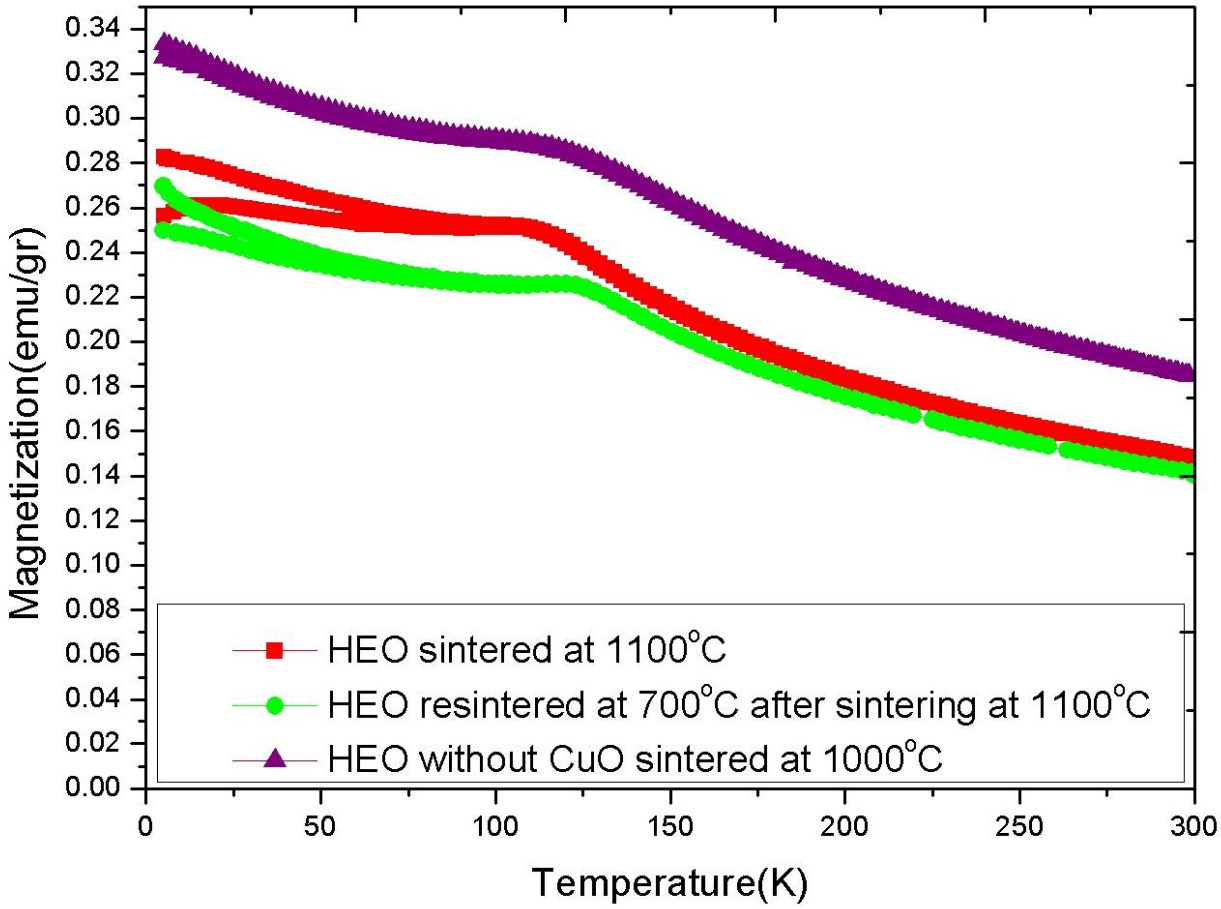




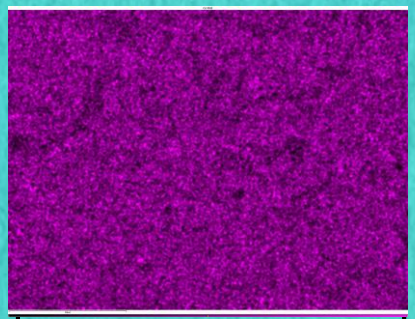
Magnetization measurement result



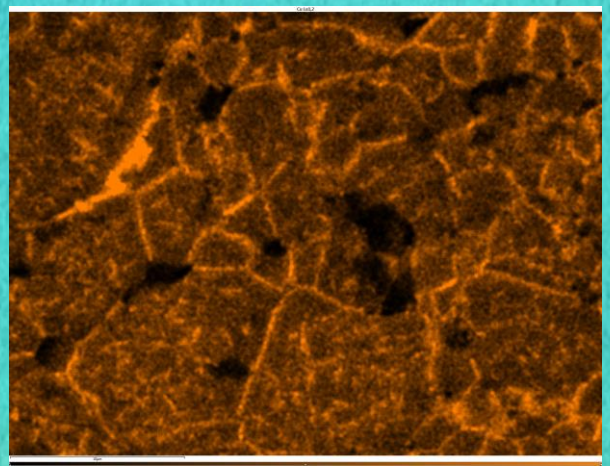
Comparison of five and four mixtures without CuO



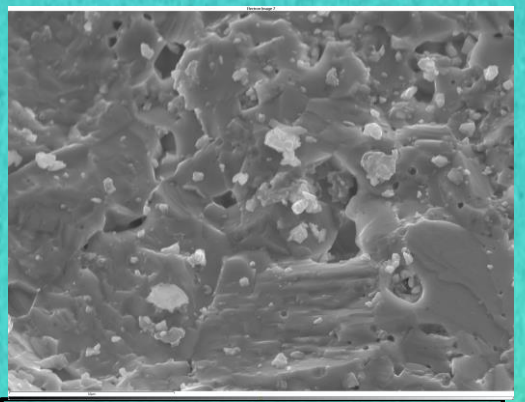
SEM result for five mixture resintered at 700°C



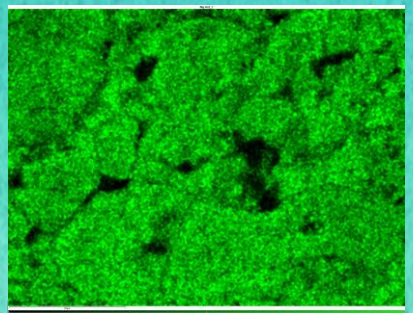
Co-Kα1



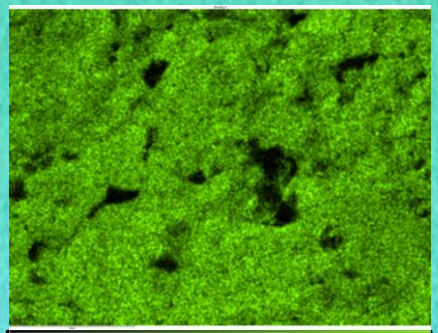
Cu-Kα1



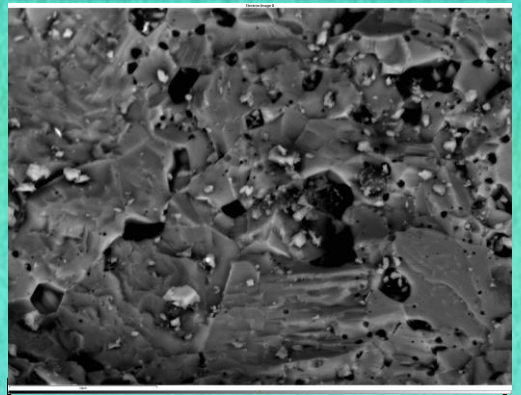
Secondary electron image(SE)



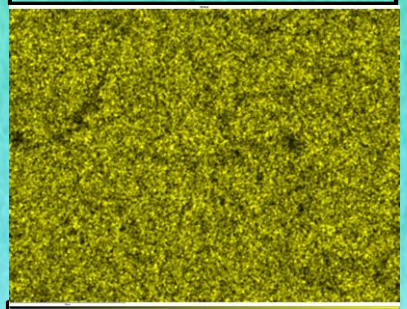
Mg-Kα1



Zn-Kα1



Backscattered electron image(BSE)



Ni-Kα1

Conclusion

- The SEM, XRD and magnetization data all indicate segregation of CuO when resintering single phase FCC material at 700°C.
- There is an interplay between structural and magnetic behavior.

Thanks for Your Attention