Understanding and Controlling Magnetic Coupling and Diffusion of FePt Nanocrystals in 1-Dimensional Channels

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Introduction

At the nanosize regime, the energy barrier to spin flip is lowered, so the magnetic spin is free fluctuate between its easy axes. Because of the spin fluctuations, it makes magnetic applications difficult. It has been shown that dipole coupling of nanocrystals in a 1-D stack creates a harder magnetic system, preventing spin fluctuations.[1] To create the dipole coupling of nanocrystals, we will be incorporating these nanocrystals into these nanosized channels via 1-D diffusion.

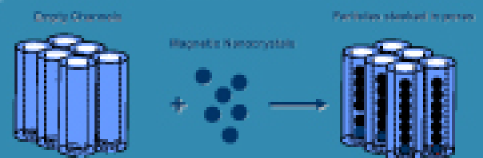

Figure 1: Coupled particles in channels create harder magnetic systems.

Methods

The material used is mesoporous silica that have nice 1-D linear channels. They are made from amphiphilic organic surfactants or block co-polymers that co-assembled with inorganic oligomers to produce periodic inorganic/organic composites.[1]

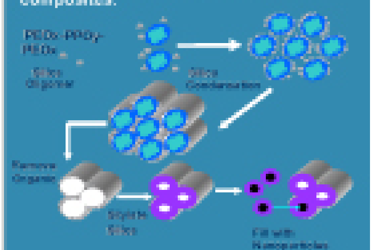

Figure 2: Block co-polymers are co-assembled with inorganic oligomer, organic template is removed by heat treatment. Then silica walls are silylated to facilitate incorporation.

The magnetic system consists of FePt nanocrystals synthesized as two different crystal structures. A FCT FePt structure should produce a hard magnetic system where as a FCC FePt structure should produce a soft magnetic system.[3,4]

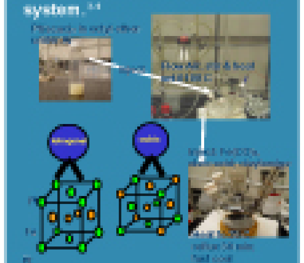
Figure 3: FePt synthesis to produce two different crystal structures.

Incorporation was carried out in a mixture of heptane, mesoporous silica powder, and FePt nanoparticles. The solution was then placed in two separate oil baths with the same varying concentrations so that we can compare how temperature and concentration affects incorporation amount.

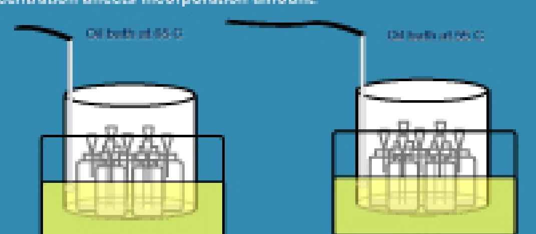

Figure 4: Two oil baths with different temperature setup for particle incorporation.

Results

XRD shows that particles stack inside 1-D nanochannels

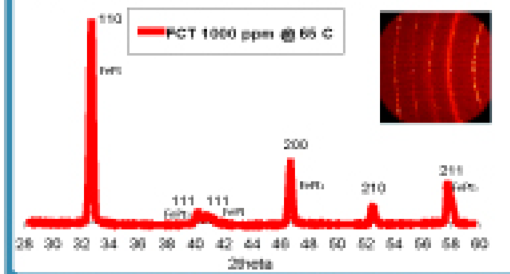

Figure 5: Spot patterns from XRD show that particles stack as a single crystalline domain. Also, the data suggests that there may be FePt as well as FePt₃ incorporated in the channels.

Increasing incorporation concentration gives larger coercivity in hard magnets

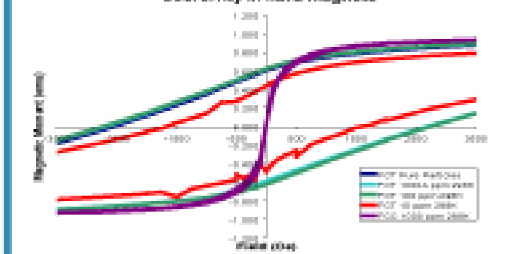
Figure 6: SQUID data shows that 1000A and 100 ppm measurements were fairly similar, but 10 ppm measurement was smaller. From the data with similar coercivity, this may suggest that we have a higher density of chains as opposed to longer chains.

Increasing incorporation concentration gives larger coercivity in soft magnets

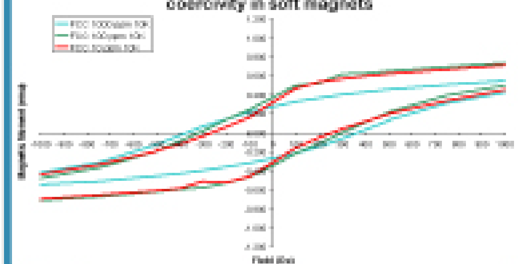
Figure 7: From the SQUID data at 10K we can see that as we increase the incorporation concentration, the coercivity increases which supports stacking of particles in 1-D channels.

ICP-AES suggests magnetic particles have higher filling fraction relative to non-magnetic ones

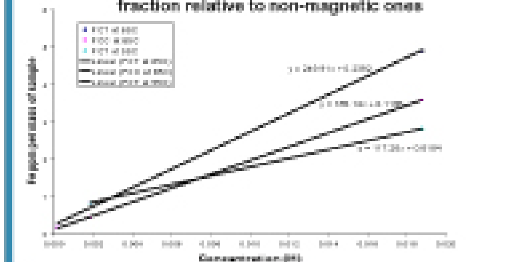

Figure 8: Comparing the slope of the FCT line and FCC line, we can see that at a given concentration magnetic particles fill more than non-magnetic particles.

Conclusions

Our XRD data shows that the particles stack as a single crystalline domain and that there is a mixture of FePt₃ and FePt particles in the channels, which is supported by our ICP-AES measurements. SQUID magnetometry results show us that FCT hard magnets do incorporate better resulting in better magnetic properties than FCC soft magnets. Also, the data supports that with increasing concentrations of nanoparticles result in a higher concentration of incorporated particles. The SQUID data also shows a trend that suggests that concentration affects the coercive width until a certain point, at which the particles stack in new chains rather than longer chains inside the channels.

Acknowledgments

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References

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[2] Sun, S.H et al Science. 287. 1989.
[3] Zhao D.Y. et al Science. 279. 1998.
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