

58th DAE-Solid State Physics Symposium, Patiala-India, Dec 17-21, 2013

Role of Bimodal Distribution in Tailoring the Inter-particle Interactions in $\text{Cu}_{79}\text{Co}_{21}$ Nanogranular Films

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Abstract

- Nanogranular $\text{Cu}_{79}\text{Co}_{21}$ films magnetotransport properties were investigated as a function of thickness (t)
- The fitting of magnetoresistance (MR) data reveals the presence of bimodal distribution of Co-particles
- Smaller particle (2.5 nm) distribution remains unaffected, the bigger one grows monotonically from 3.3 nm to 4.9 nm for $25 \leq t < 100$ nm and stays same (4.9 nm) for $100 \leq t \leq 200$ nm
- Dependence of MR on ' t ' at low temperature is related to bimodal distribution and its role in tailoring the inter-particle interactions

Scope & Work

Granular magnetic system: Nanometric-sized magnetic particles embedded in a non-magnet matrix

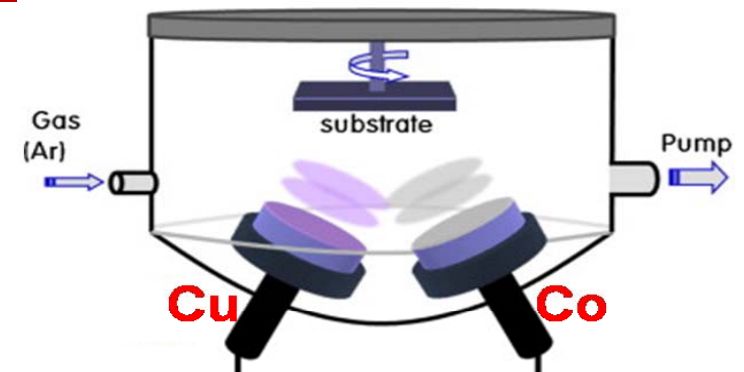
Critical parameters: Particle size, inter-particle separation and intra/inter particle interactions

Applications: High moment soft materials, magnetic sensors, and ultrahigh density bits etc

Experimental Details

Why co-sputtering???

1. Non-equilibrium process
2. Capable of producing otherwise not attainable metastable alloys
3. Wide range compositions can be attained by varying relative sputtering rate



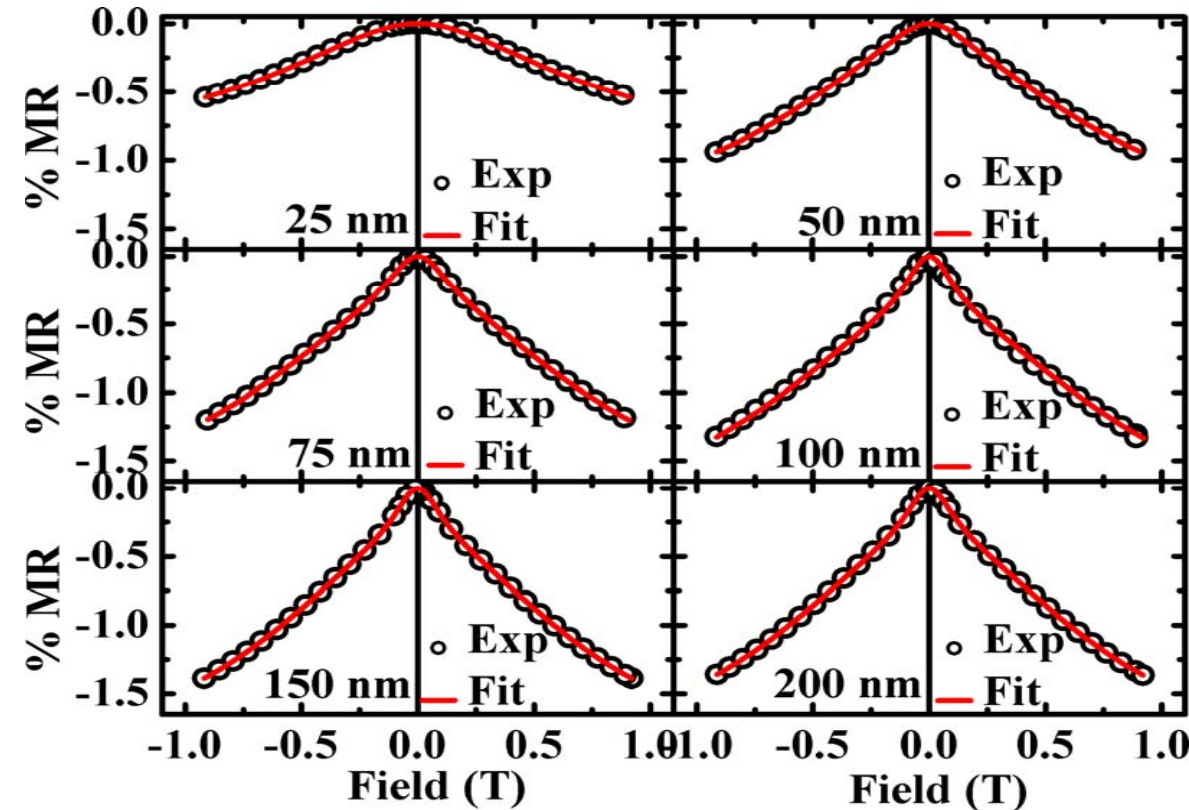
Deposition Details

Base pressure= 1.5×10^{-6} Torr

Working pressure= 5×10^{-3} Torr

Thickness of films= $25-200$ nm

MR at Room Temperature



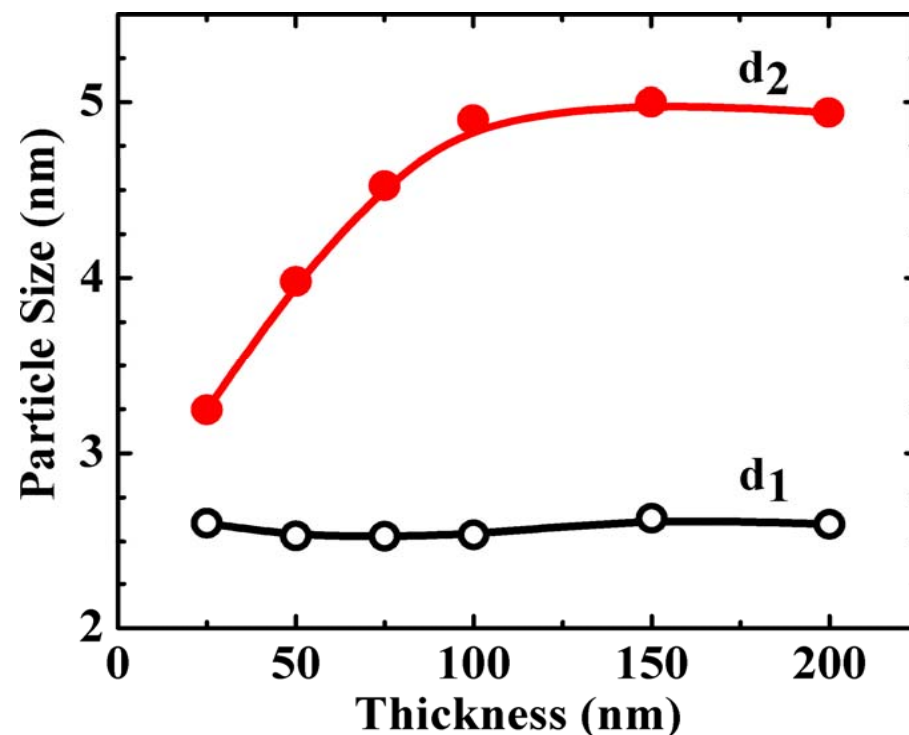
- *MR* increases monotonically with the increase of thickness for $t \leq 100 \text{ nm}$
- *MR* is independent of thickness for $t > 100 \text{ nm}$
- *MR* is non-saturating, -ve, isotropic and non-hysteretic
- *MR* suggests the presence of SPM particles in these films

$$MR(H) = -A \sum_{i=1}^n W_i L^2(x_i), \quad x_i = \frac{\mu_i H}{k_B T} \quad (i = 1, n), \quad \sum_{i=1}^n W_i = 1$$

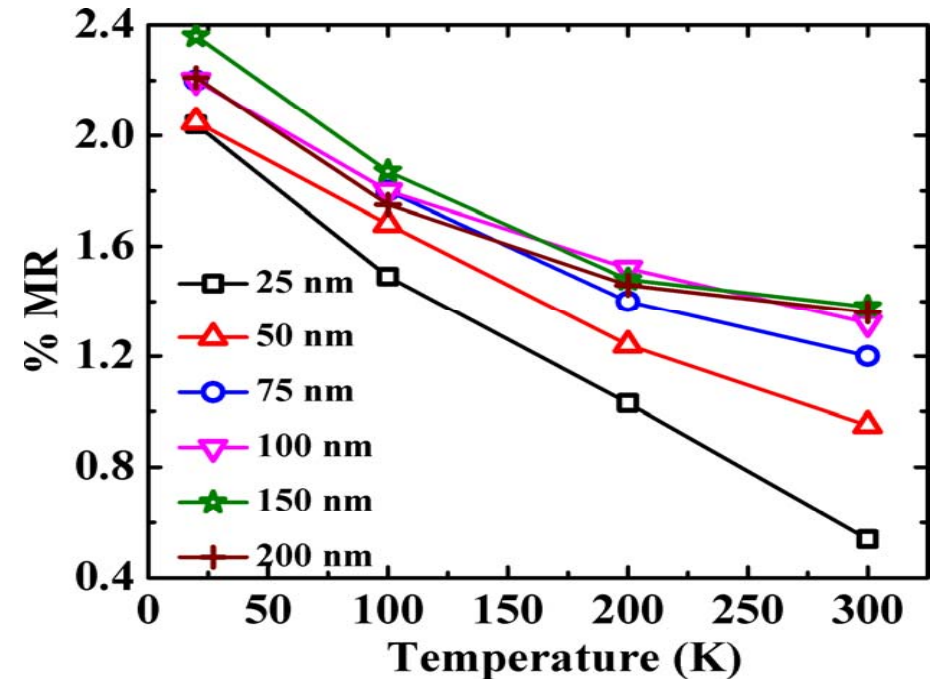
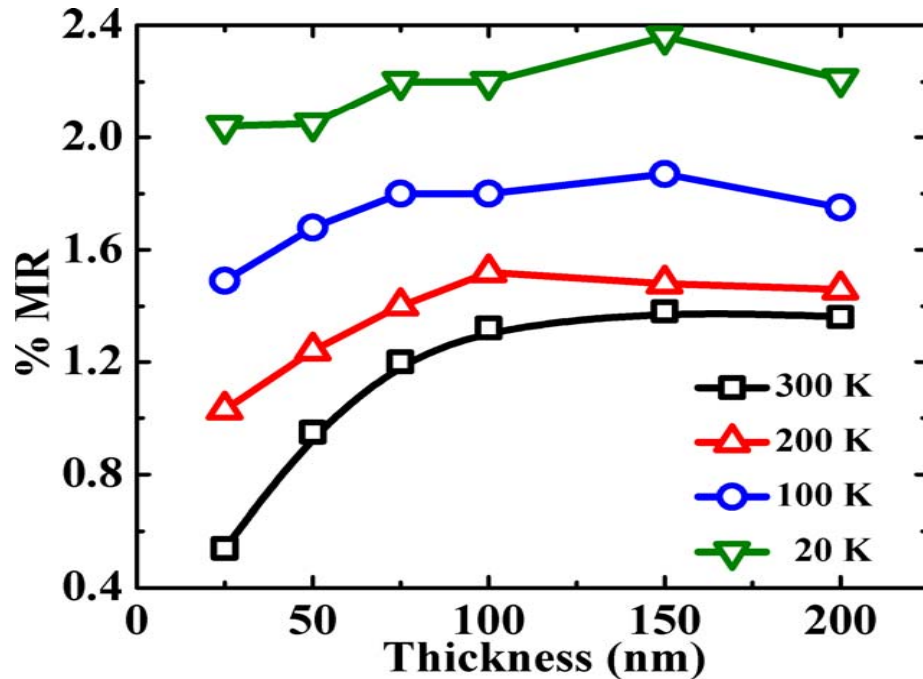
- *MR* curves fits quite well for all the films for $n=2$, such that $w_1 + w_2 = 1$
- Fittings with $n=3$ or higher revealed unphysical errors

t (nm)	A	x_1	x_2	w_1	w_2	d_1 (nm)	d_2 (nm)
25	1.11	3076±7	1585±9	0.85	0.15	2.60	3.25
50	1.92	3345±33	861±11	0.82	0.18	2.53	3.98
75	2.36	3352±17	586±3	0.80	0.20	2.53	4.52
100	2.51	3323±112	461±14	0.78	0.22	2.50	4.90
150	2.50	2975±152	434±17	0.79	0.21	2.63	4.95
200	2.51	3094±67	450±11	0.78	0.22	2.59	4.94

- It is observed that there are two values of mean particle size with diameter d_1 and d_2 in films of all thicknesses
- Cobalt particles with continuously varying size in the form of a bimodal distribution
- d_1 stays same at ~2.5 nm and independent of thickness
- d_2 increases progressively with increase in t up to 100 nm, but almost same for $t=100, 150, 200$ nm



MR at Low Temperature



- The value of MR_{20} is found to be 3.8, 2.1, 1.8, 1.7, 1.7, and 1.7 for films with $t=25, 50, 75, 100, 150$ and 200 nm, respectively
- Temperature is reduced the influence of interactions is enhanced as the ferromagnetic ordering is enhanced at lower temperature
- For $t \leq 100$ nm the number and size of d_2 increases with ' t ', hence the interactions
- For $t > 100$ nm the d_2 particle's size and fraction stays constant, thus MR dependence on t is well explained on the basis of evolution of bimodal distribution

Conclusions

- **The ability of tailoring the interparticle interactions is demonstrated as a function of thickness**
- **It is found that increasing fraction and size of bigger particle d_2 with the increase of film thickness is playing a critical role for controlling the interparticle interactions**
- **100 nm is threshold thickness above which interparticle interactions become thickness independent for $\text{Cu}_{79}\text{Co}_{21}$ films**

References:

1. Dinesh Kumar, Sujeet Chaudhary, and Dinesh K. Pandya, J. Appl. Phys. 112, 083924 (2012).
2. Dinesh Kumar, Sujeet Chaudhary, and Dinesh K. Pandya, J. Appl. Phys. 114, 023908 (2013).
3. Dinesh Kumar, Sujeet Chaudhary, and Dinesh K. Pandya, AIP Conf. Proc. 1512, 1126 (2013).
4. L. Peter, Z. Rolik, L. F. Kiss, J. Toth, V. Weihnacht, C. M. Schneider, and I. Bakonyi, Phys. Rev. B 70, 174410 (2006).

Acknowledgement: One of the authors D. K. acknowledges MHRD-Government of India for the SRF Fellowship