Study of the Interphase Exchange Coupling and Magnetocaloric Effect in Co_3Gd_4+Co_7Gd_{12} Nanocomposite Obtained by Mechanical Milling

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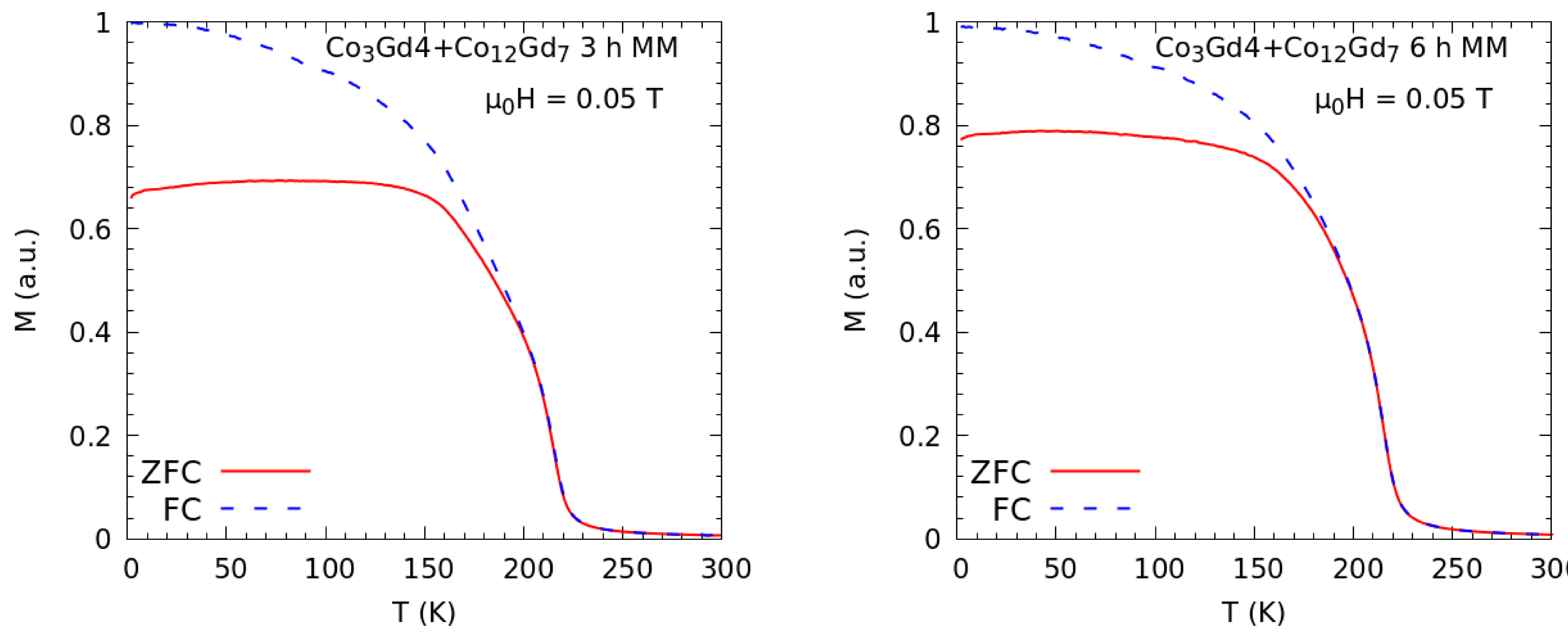
Abstract: The magnetic phases Co_3Gd_4 and Co_7Gd_{12} were obtained by arc melting. The as-cast ingots were annealed to ensure homogeneity. X-Ray diffraction studies have shown that the ingots are single phase with the hexagonal structure (P63/m) and monoclinic structure (P21/c), respectively. Thermomagnetic measurements have shown their Curie temperatures to be 220 K and 163 K, respectively. The magnetic Co_3Gd_4/Co_7Gd_{12} nanocomposite powders were produced by the mechanically milling (MM) of crushed and sieved powders obtained from the alloys. The MM process was followed by annealing to improve the microstructure of the nanocomposite. The relationship between the interphase exchange coupling and the microstructure was investigated by magnetic measurements and X-Ray diffraction. The magnetic entropy change was studied in the nanocomposite materials and the component phases. The magnetic refrigeration efficiency was evaluated by calculating the relative cooling power (RCP) for the investigated nanocomposite..

Experimental details:

- The Gd3Gd4 and Co7Co12 alloys were peoduced trough induction melting and subsequent annealing. The homogenity of the phases was investigated by X-Ray diffraction and magnetic measurements.
- The produced alloys were crushed and sieved into a fine powder. The produced powders were mixed in a 50/50 weight ratio and mechanically milled for up to 6 h, in a Fritsch P4 planetary ball mill. The milling media consisted of 80 ml 440C steel vials and 26 10 mm diameter stell balls per vial. The ratio of the planet to main disk speeds was -900/333.
- Magnetic measurements were carried out on a vibrating sample magnetometer (VSM) produced by cryogenics.
- For magnetic measurements, the powders were pressed in a 2.5 mm diameter die at a pressure of 2 tonnes. A small piece of the compact was cut and measured.
- X-Ray diffraction measurements were performed on a Bruker D8 Advance diffractometer equipped with a Cu source,
- All powder handling was done under purified Ar atmosphere.

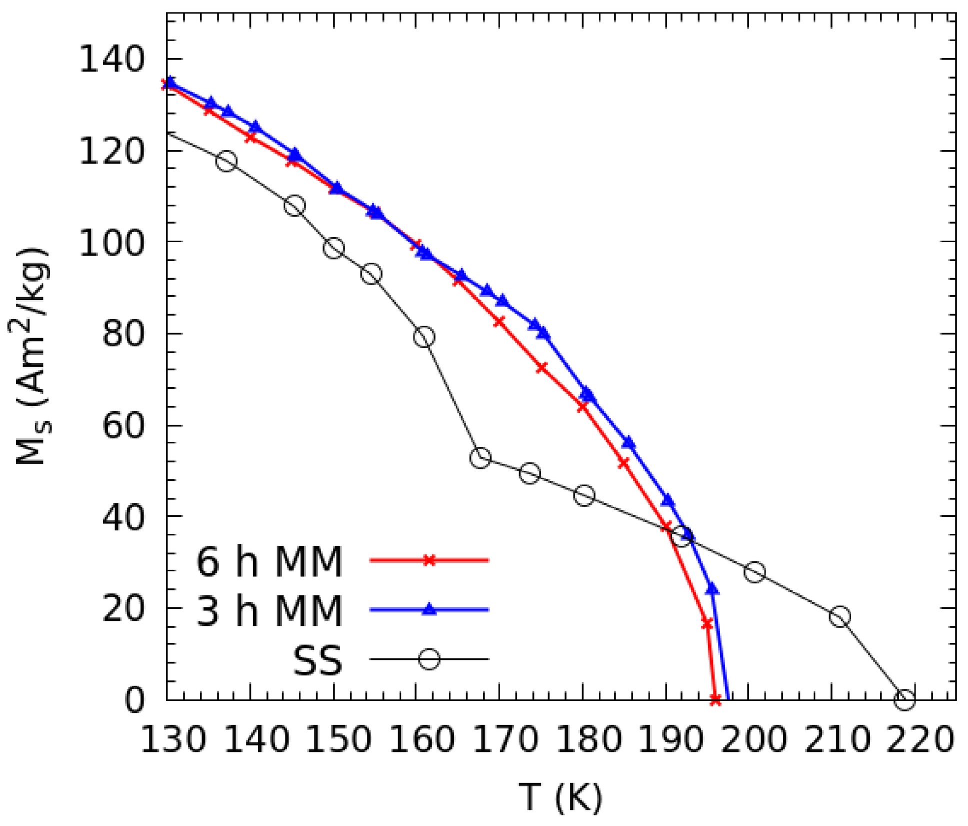
Results and Discussions:



Zero field cooled (ZFC) and field cooled (FC) measurements for the nanocomposites milled for 3 h and 6 h

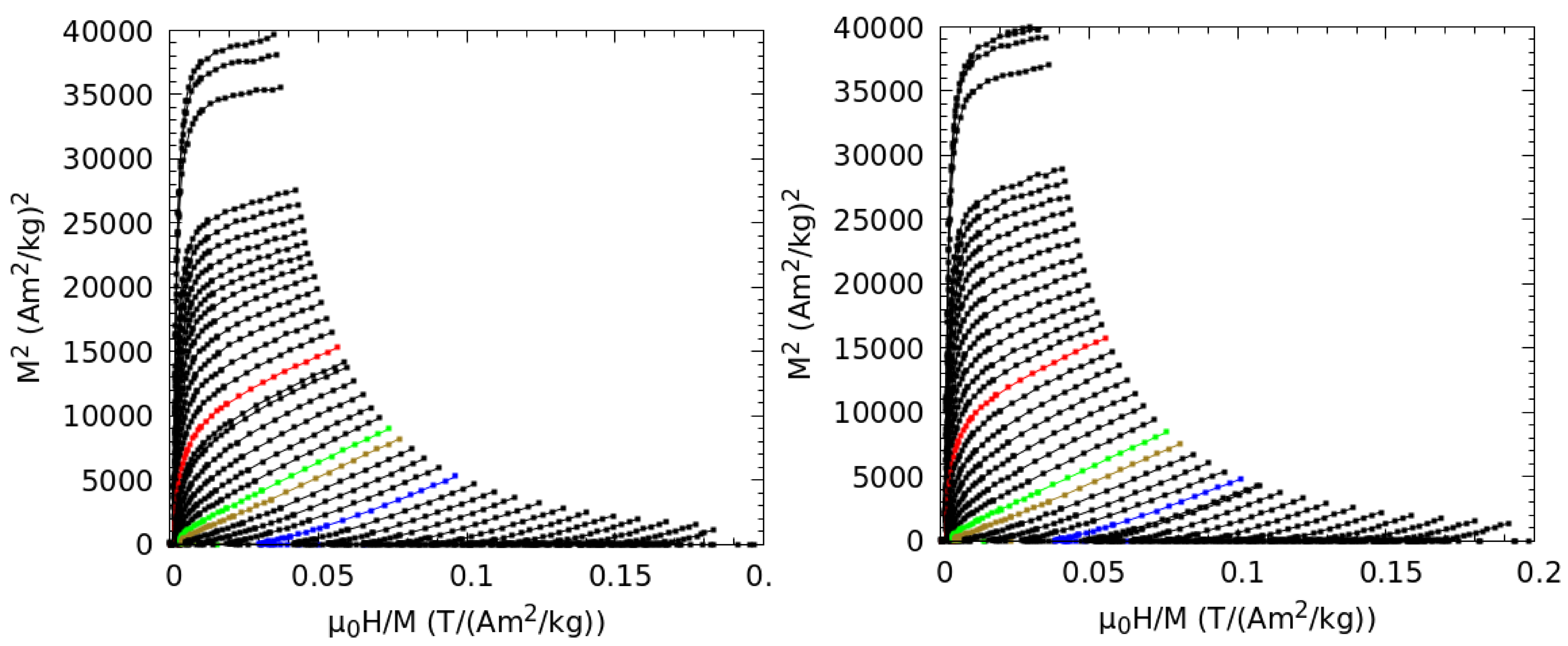
The ZFC and FC measurements on the nanocomposite powders show a relatively smooth curve for the 3 h MM sample. The smothness of the curve increases when milling time is increased. The magnitude difference between the ZFC and FC curves shows that the anisotropy of the samples also decreases with milling time, as the difference between the two curves becomes smaller.
The estimated Curie temperature for the two curves is 220 K.

The dependence of the magnetic moment as a function of temperature was also investigated trough Arrott plots. These plots show that the Curie temperature of the two nanocomposites is around 197 K. A very slight curvature of the plots a low values of H/M may be indicative of a small ammount of decoupled magnetic phase. The decoupled phase is most likely also responsible for the higher Curie temperature seen in the ZFC FC plots.



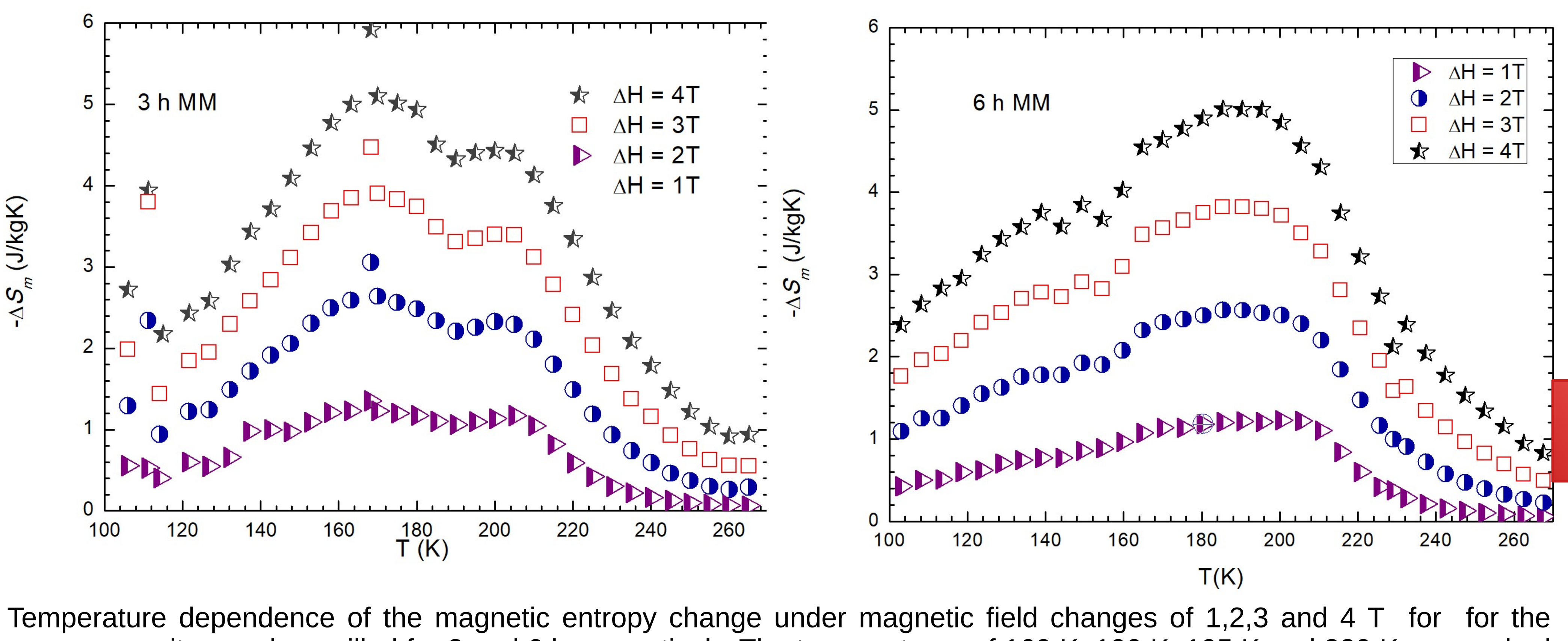
The dependence of the spontaneous magnetization as a function of temperature was deduced from the Arrott plots. The two materials act like a single material. For the 3 h MM sample, there is a small maximum around 160 K 9the Curie temperature of Co_7Gd_{12}), however it dissapears after additional 3 h of milling time. Both sampless shpw a Tc of 197 K.

Spontaneous magnetization as a function of temperature for the starting sample, 3 h MM and 6 h MM samples.



Arrott plots for the nanocomposite powders milled for 3 and 6 h respectively. The temperatures of 160 K, 190 K, 195 K and 220 K are marked in red, green, olive and blue.

Milling time	T_{max} (K)	$\lvert\Delta S_M\rvert$ (J/KgK)				δT_{FWHM} (K)				RCP(S) (J/kg)			
h		ΔH=1T	ΔH=2T	ΔH=3T	ΔH=4	ΔH=1T	ΔH=2	ΔH=3T	ΔH=4	ΔH=1T	ΔH=2T	ΔH=3	ΔH=4T
3	**170**	1.37	2.68	3.85	5.1	83	95	100	105	113.71	254.6	385	535.5
6	**190**	1.21	2.56	3.82	5	97	110	116	124	117.37	281.6	443.12	620



The plots of the variation of the magnetic entropy evidenciate the two ohase behaviour of the nanocomposites milled for 3 h. On the other hand additional milling leasd to a smooth curve with a single maximum, i.e. interogase exchange is improved.
The relative cooling power of the materials was evaluated and was also found to increase with milling time. THe best result was obtained for the 6 h MM curve, 620 J/kg, nearly 150% higher than that of the sample milled for 3 h.

Temperature dependence of the magnetic entropy change under magnetic field changes of 1,2,3 and 4 T for for the nanocomposite powders milled for 3 and 6 h respectively. The temperatures of 160 K, 190 K, 195 K and 220 K are marked in red, green, olive and blue.

Exchange coupled Co_3Gd_4+Co_7Gd_{12} nanocomposites were obtained. The microstructure of the samples remains to be checked mre thorougly trough microscopy.

- All measurements show that at 6 h MM the samples begin to behave as a single phase, with a smooth curve and a single Curie temperature
- It may be possible that by increasing milling times, the particles size could be reduced.

Acknowledgment

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