Chemical Synthesis of FePt Nanoparticles

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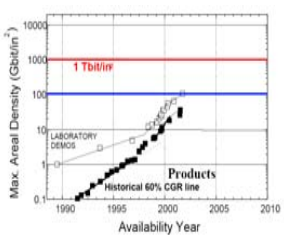
ABSTRACT

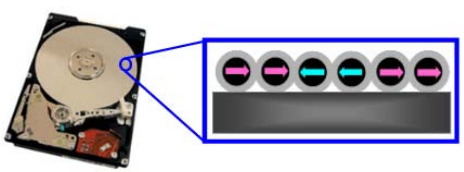
Monodisperse FePt nanoparticles have been made from thermal decomposition of iron pentacarbonyl in octyl ether in the presence of oleic acid and oleyl amine. The size of the nanoparticles can be controlled by amount of surfactant, solvent, heating rate and other reaction parameters. The as-synthesized particles have chemically disordered FCC structure and can be transformed into the chemically ordered FCT structure after proper thermal treatments. The FCT structured thin film FePt nanoparticle assemblies exhibit hard magnetic properties with coercivity as high as 2.7 T. These hard magnetic nanoparticles can be used in many technological applications.

MOTIVATION

Nano-scaled magnetic materials have tremendous potential for following applications.

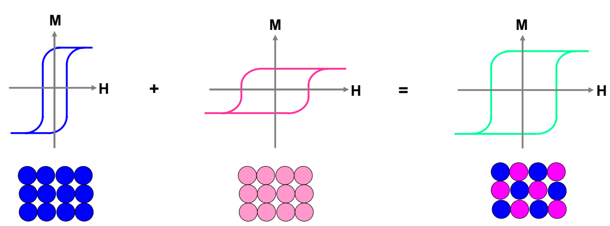
Multi terabit/in^2 data storage systems





A Magnetic hard disk and the schematic illustration of the recorded bits supported by an array of ferromagnetic dots.

Stronger permanent magnets

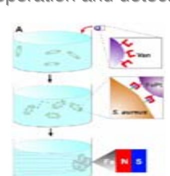


Soft Particles

Hard Particles

Exchange Coupled Nanocomposite

Bio-seperation and detection



Other Applications

- Ferrofluids
- Magnetic refrigeration systems
- Enhanced magnetic resonance imaging
- Catalysis
- Targeted drug delivery

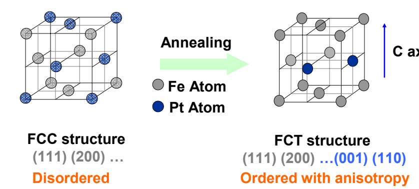


Fig. 1 Structural Transition of FePt

Alloy systems	material	K_u (10^7erg/cc)	Ms (emu/cc)	H_c (kOe)	T_c (K)	Δ_w (A)	γ (erg/cc)	D_c (µm)	D_p (nm)
	CoPtCr	0.20	298	13.7	-	222	5.7	0.89	10.4
Co-alloys	Co	0.45	1400	6.4	1404	148	8.5	0.06	8.0
	Co_3Pt	2.0	1100	36	-	70	18	0.21	4.8
	FePd	1.8	1100	33	760	75	17	0.20	5.0
$L1_0$ alloys	FePt	6.6-10	1140	116	750	39	32	0.34	3.3-2.8
	CoPt	4.9	800	123	840	45	28	0.61	3.6
	MnAl	1.7	560	69	650	77	16	0.71	5.1
Rare earth	$Fe_{14}Nd_2B$	4.6	1270	73	585	46	27	0.23	3.7
Tran.metals	$SmCo_5$	11-20	910	240-400	1000	22-30	42-57	0.71-0.96	2.7-2.2

EXPERIMENTAL

FePt nanoparticles are synthesized as follows: 0.5 mmol Pt(acac)$_2$ is charged to 125 ml flask containing a magnetic stir bar and 20 ml of octyl ether. Argon gas was flowed throughout the whole experiment. After purging with Argon for 30 minutes at room temperature, the flask was heated up to 100°C and 1.1 mmol of Fe(Co)$_5$, 0.5 mmol each of oleic acid and oleyl amine were added and the temperature is kept constant for 30 minutes. Then the flask is heated up to 295 °C and refluxed for 30 minutes before cooling to room temperature under the Argon blanket. A heating rate of 5°C per minute was maintained during the experiment. The resulting black product was precipitated by adding ethanol and the precipitate was redispersed in hexane and stored under refrigeration. Samples for magnetic characterization were prepared by depositing 2 to 3 layers of the dispersion onto 3x3 mm silicon substrate, which led to the formation of FePt 4 nm nanoparticle assemblies. Different size of the nanoparticles can be synthesized by changing amount of surfactant, solvent, heating rate and other reaction parameters

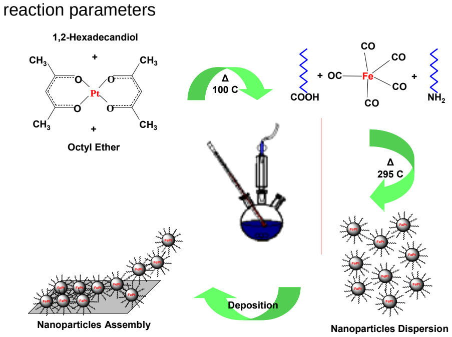


Fig. 2 Schematic showing the chemical synthesis of the FePt nanoparticles.

RESULTS

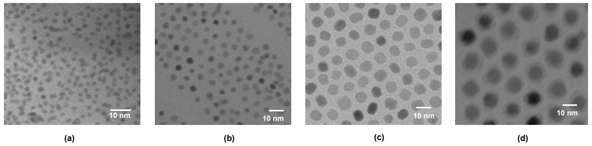


Fig 3 TEM image of as synthesized FePt nanoparticles of (a) 2 (b) 4 (c) 8 and (d) 16 nm

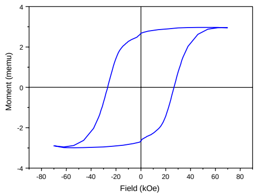


Fig. 4 Magnetic hysteresis loop of nanoparticle assembly

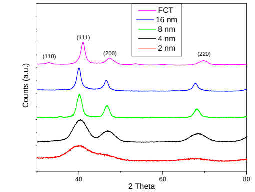


Fig. 5 X ray diffraction patterns of the as-synthesized particles

As-synthesized particles have FCC structure and completely isotropic. To transform into anisotropic FCT structure, these particles has to be annealed at higher temperatures (above 500° C). So, after annealing in forming gas (Ar + 7% H$_2$) atmosphere for 1 hour at 650°C, these hard particles show very high coercivity up to 2.7 T (see Fig. 4, magnetization not normalized). The high coercivity of annealed particles clearly proves beyond doubt that these particles are transformed into the FCT phase with high magnetocrystalline anisotropy after annealing.

CONCLUSIONS

Monodisperse FePt particles have been successfully synthesized by wet chemical methods. Meanwhile, composition control has been realized which resulted in correct stoichiometry of the hard magnetic FePt FCT phase. After annealing, the nanoparticles assemblies give high coercivity. In the future we will use the hard magnetic particles as building blocks to produce advanced nanostructured thin film and bulk magnets.

REFERENCES

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3. D. Weller et al. IEEE. *Trans. Magn.*, 36(1), 2000, 10.

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