Nanocomposite materials for applications in future inductor cores

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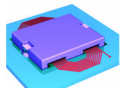
Introduction

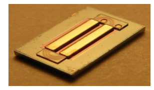
- Package or chip integrated inductors will be needed to enable the efficient point of load supply of power in future miniaturised electronic devices.
- Circuit operation at increased frequencies will be needed to minimise the size of the passive components.
- Integration of inductive components requires new low loss, high frequency magnetic core materials which are compatible with CMOS processing temperatures.
- The features of such materials must include low losses, high saturation flux densities and a high anisotropy field.
- To meet these future requirements new nanocomposite magnetic materials are being investigated for their suitability to this role

Background – Passive Magnetics Development

Discrete Inductors



PCB integrated inductors

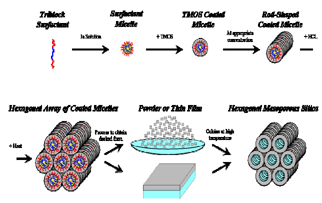


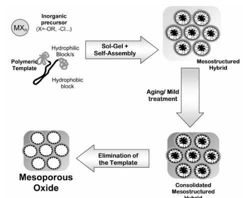
Magnetics on silicon

Methodology

- Approaches to synthesis include employing sol-gel self assembly techniques.
- This incorporates nanometre sized ferromagnetic transition metals grains into mesoporous silica thin films.
- This approach aims to exploit the unique property of nanocrystalline magnetic materials which exhibit a decrease in coercivity as the average grain size decreases to below approximately the domain wall width.
- The silica matrix will provide electrical isolation between the individual ferromagnetic particles.
- A composite material of Ni, Fe or Co with silica is hence created.
- Other approaches to synthesis include doping microporous silica spheres, to create both nanoparticle impregnated and nanoparticle coated silica sphere composites.
- These doped porous silica spheres are suitable for spin coating into suitable thin films.

Doped Mesoporous Thin Film (MTF) Sample Preparation





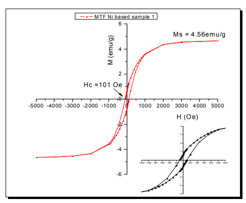
MTF synthesis flow diagrams

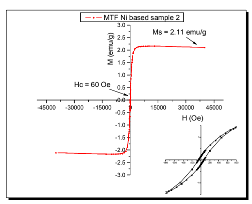
Doped Silica Sphere Sample Preparation

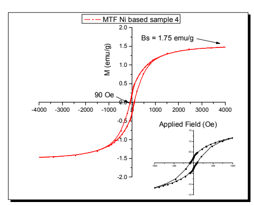
- Method: CTAB was dissolved in a mixture of methanol and water. NH_4OH was then added to the solution followed by TEOS.
- To produce Nickel-doping: Solutions of $NiCl_2$ in ethanol were prepared and added to silica spheres.
- The uncalcined metal-doped spheres were then placed in the middle of a quartz tube in a furnace and heated to 450° C, under a flow of 10% H_2 in Argon to calcine the samples.

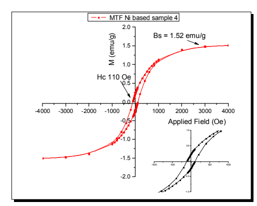
Doped Mesoporous Thin Film Sample Results

Sample Name	Coercivity Hc (Oe)	Saturation Induction (emu/g)	Pore Size (nm)Wall Thickness (nm)	Pore Size (nm)Wall Thickness (nm)
Ni based sample – 1	100	4.56	2.54	1.78
Ni based sample - 2	60	2.11	2.31	1.84
Ni based sample - 3	110	1.52	2.04	1.91
Ni based sample - 4	90	1.75	--	--

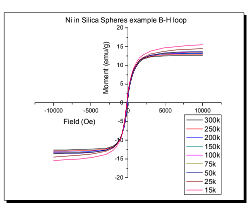




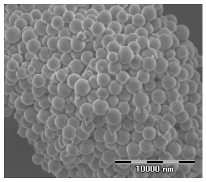


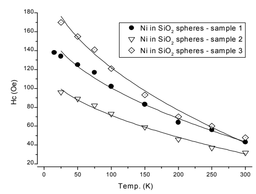


Doped Silica Sphere Sample Results



Sample	Saturation Magnetisation (emu/g)	Room Temperature Coercivity (Hc)
Ni in silica spheres sample 1	11.8	43
Ni in silica spheres sample 2	21	49
Ni in silica spheres sample 3	32.2	34





$$T_B = \frac{KV}{25k} \text{.......}eq2$$

$$H_c = H_{co}\left[1 - \left(\frac{T}{T_B}\right)^{0.5}\right] \text{........} eq.1$$

Specimen	H_{co} (Oe)	T_B (K)	K (ergs/cm^3)
Ni-SiO_2 spheres, 0.1M	179	523	1.05E+05
Ni-SiO_2 spheres, 0.3M	127	519	1.04E+05
Ni-SiO_2 spheres, 0.4M	231	450	9.05E+04

Conclusions

- Results to date have shown that the doping of mesoporous materials with ferromagnetic elements holds potential for applications in the soft magnetic cores of inductors.
- These materials can be easily spin coated onto substrates.
- Increased loading of the templates will produce saturation inductions values comparable to those of bulk Ni, Fe & Co.
- These nanocomposite materials may provide a way to limit the effects of the high frequency losses which dominate in soft magnetic materials in the GHz frequency range.

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