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Novel Multifunctional Magnetic Inorganic Composites: Synthesis and Characterization

G. Marangoni[1], R. Bertani[1], L. Del Bianco[2], M. Natali[3], D. Pavarin[1], P. Sgarbossa[1], F. Spizzo[2], S. Tamburini[3]

[1]Department of Industrial Engineering, University of Padova, Via Marzolo 9, 35131 Padova Italy;
[2]Department of Physics and Earth Sciences, University of Ferrara, Via Saragat 1, 44122 Ferrara Italy; [3] National Research Council - CNR ICMATE, Corso Stati Uniti 4, 35127 Padova Italy

INTRODUCTION

A series of new inorganic magnetic composites (IMCs) has been prepared to obtain magnetic materials with tunable thermal and mechanical resistance properties. Indeed, in the field of power inductive components, inductive heating and cooking, they may transfer energy with high robustness and excellent performance. Moreover, these materials may mitigate electromagnetic interference (EMI) at frequencies in the LF and MF band.

K - WORDS

- Magnetic nanoparticles
- Inorganic polymers
- Composite Materials
- Magnetic characterisation

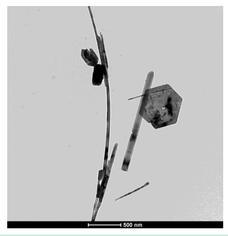
MAGNETIC NANOCOMPOSITES

A series of new inorganic magnetic composites has been prepared by using an alcaline or acidic activation process carried out in the presence of commercial nanoparticles (isotropic and anisotropic Sr-ferrite). Three different matrices have been prepared, varying the kind of activator, slag addition, water content and aggregates. Alkaline geopolymer matrices and an acidic one were prepared for the purpose of investigating electrical conductivity which is known to be lower for acidic than for alkaline geopolymers as no mobile alkali ions are present in the latter.

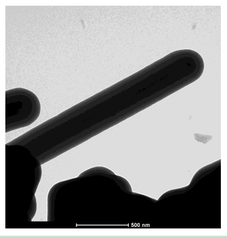
OTHER MNPs

Other Magnetic Nanoparticles with high aspect ratio were synthesized to be further embedded in an inorganic matrix. Magnetite Nanoparticles were synthetsided through co-precipitation, and futher embedded in a Silica layer to prevent them from agglomeration and oxidation.

Naked nanospindle

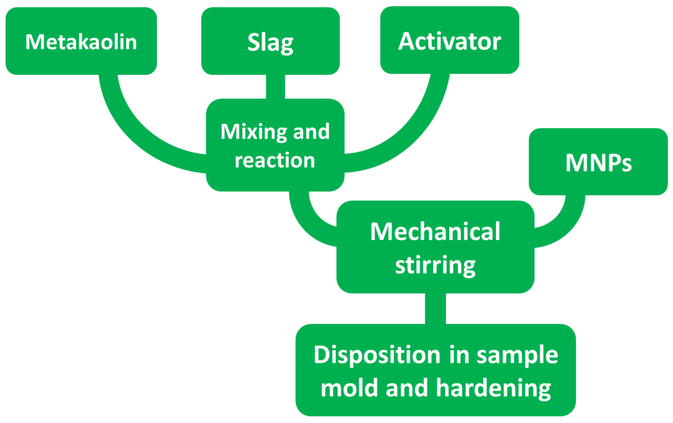


Coated nanospindle



RESULTS

Metakaolin (MK), slag, activator and H_2O were mixed by hand in a beaker using a spatula, assisted by pneumatic vibration, to start reaction of MK and slag reagents with the activator solution. Then inert aggregates and eventually magnetic particles were added and further mixed under vibration, forming a highly tixiotropic paste. The paste was dispensed into an appropriate sample mold and further hardened by curing at 60 °C in an oven for 12 hours. The process was then repeated applying an external magnetic field during hardening.



Tab. 1: Inorganic matrices and their composition.

Sample	MK	Slag	Activator	Aggregates	Water (%W on total wet amount)	Curing
G1	C39/750	C47	K-silicate	None	9.8%	60 °C
Ratio	1	1	1.33			
G2	C39/750	C47	K-silicate	I84	5.9-6.4%	60 °C
Ratio	1	1	1,33	3.2		
G3	C46	None	H_3PO_4	I85	15.6-16.6%	60 °C
Ratio	1		0,33	1.1-1.2		

- K-silicate pH:14
- K/Si ratio: 1.26
- I84: Ventilated quartz, <160 µm
- I85: Ventilated quartz, <75 µm

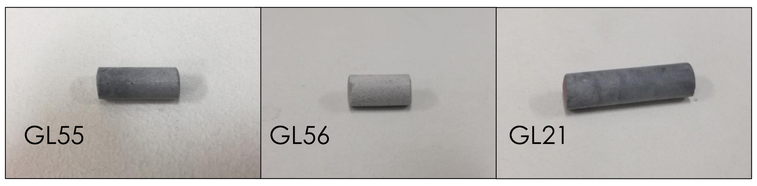


Fig.1: Samples obtained from different matrix and nanoparticles concentration.

Tab. 2: Comparison between the nominal relative concentration of magnetic particles and the relative concentration values obtained from magnetization measurements carried out at 300 K, both on magnetized samples (M) and non-magnetized ones (NM).

Sample	GL55	GL55B	GL56	GL21F	GL21G
Matrix	G1		G2	G3	
Magnetic Nanoparticles (MNPs)	Sr-Ferrite anisotropic	Sr-Ferrite isotropic	Sr-Ferrite isotropic	Sr-Ferrite isotropic	Sr-Ferrite anisotropic
Nominal concentration	11.2	10.2	8.9	5.9	5.9
Concentration (M)	10.5	10.6	9.0	6.2	5.9
Concentration (NM)	10.0	10.0	9.1	6.3	5.8
Uncertainty	± 0.2	± 0.2	± 0.2	± 0.1	± 0.1

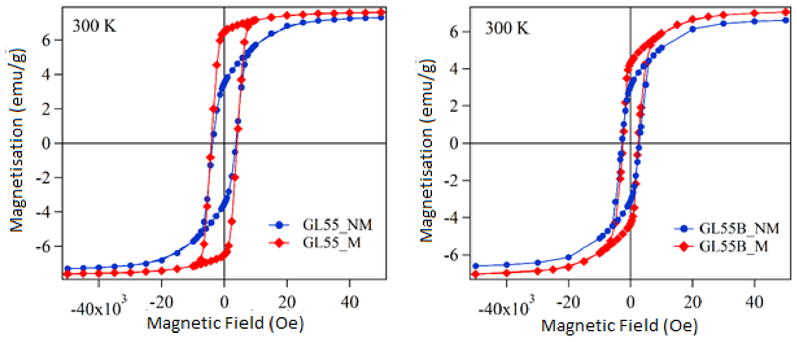


Fig. 2: The effect of the magnetization process during the solidification of the samples. Comparison of the magnetization cycles on M and NM samples with nominal concentration of particles ~ 10%.

Tab. 3: Evaluation of the residual magnetisation after a further magnetisation process and comparison with initial magnetisation.

Sample	GL55	GL55B	GL56	GL21F	GL21G
NM initial magnetisation ($M_{NM,in}$) [emu/g]	4.9 10^{-1}	8.5 10^{-1}	5.5 10^{-1}	1.6 10^{-2}	4.4 10^{-2}
M initial magnetisation ($M_{M,in}$) [emu/g]	8.6	4.6	3.4	2.4	2.8
Residual magnetization (M_R)[emu/g]	9.2	5.9	4.9	3.5	3.6
$M_{M,in}/M_R$ Ratio	0.93	0.78	0.70	0.69	0.78

The initial value of magnetization is lower than that of the residual magnetization, due both to the viscosity of the matrix and to the fact that the intensity of the magnetic field applied in the solidification phase is lower than the value of the irreversibility field.The irreversibility field varies, for both the M and NM samples, between 8000 and 9000 Oe (data collected at 300 K).

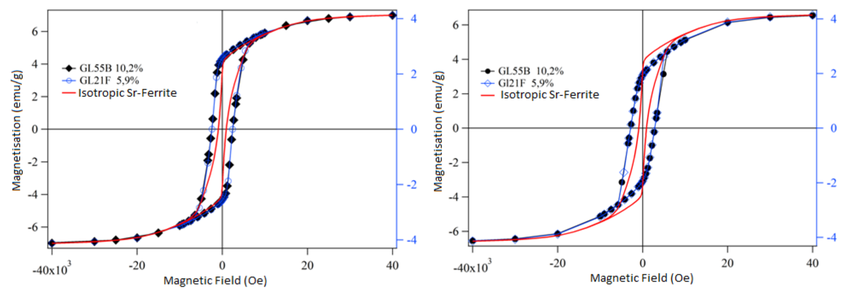
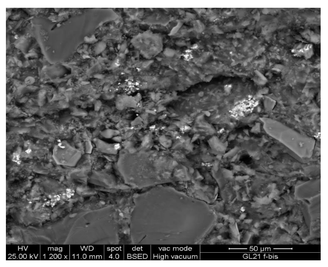


Fig. 3: Comparison between samples M (left) and NM (right) having different concentration of isotropic Sr-Ferrite particles (GL55B with 10.2% and GL21F with 5.9%)

Fig. 4: The particles of the magnetic powder in the back-scattered electron SEM images appear lighter than the matrix. SEM images show that there is a noticeable tendency for magnetic particles to aggregate. Isolated single magnetic particles are rare.



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FUTURE WORKS

- Extension of the series of magnetic nanoparticles used.
- Sinthesys of nanocomposites with silica-coated nanoparticles.
- Study of the mechanical, electrical and thermal properties of the obtained nanocomposites.

AKNOWLADGMENTS

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