Piezo and Magneto Resistance of Magnetically Oriented Dispersions of Magnetic Particles Covered with Silver in Bulk and Screen-Printed Elastomer Polymers

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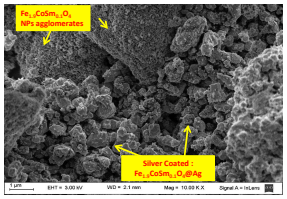
Step 1 Synthesis and characterization of particles, simultaneously magnetic and conductive



Inorganic precursors Fe(III), Fe(II), Co(II) Sm(III)) in acidic solution

coprecipitation of mixed oxides in alkaline solution (Fe_3O_4 and $Fe_{2-x}CoSm_xO_4$)

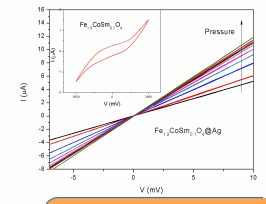
Fe_3O_4 dried in vacuum oven at room temperature for 24h to prevent oxidation

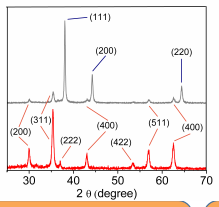
$Fe_{2-x}CoSm_xO_4$ is dried at 60°C for 12h and later calcined at 800 °C for 2h

NPs resuspended in water; Reduction of $Ag(NH_3)_2^+$ with glucose

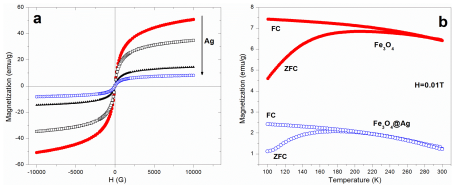
Magnetic and conductive particles

Silver Coating. Left: SEM imaging of $Fe_{1.9}CoSm_{0.1}O_4$ and silver coated particles. The uncoated ferromagnetic nanoparticles tend to aggregate due to magnetic dipole interactions. The formed silver coated particles are micrometrical size aggregates.

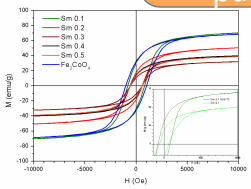




Left: Cyclic voltammetries for ferromagnetic $Fe_{1.9}CoSm_{0.1}O_4$ and for $Fe_{1.9}CoSm_{0.1}O_4$@Ag. The condictivity of the particles increases whet pressure is applied.
Right: XRD patterns for Fe_2CoO_4 (---) and Fe_2CoO_4@Ag ( )



VSM and SQUID (a) Magnetic hysteresis curves at 25 °C of Fe_3O_4 nanoparticles (—•—) and Fe_3O_4@Ag microparticles synthesized in different conditions: $AgNO_3$ at 50°C for 20 hours (—□—), $[Ag(NH_3)_2]^+$ at room temperature for one hour (—▲—) and $[Ag(NH_3)_2]^+$ at 50°C for one hour (—○—) (b) ZFC and FC magnetization vs. Temperature curves (H=0.01T) for the Fe3O4 nanoparticles (—•—) and Fe_3O_4@Ag particles (—•—)



Effect of Sm^{3+} doping and heat treatment: VSM loops, the values of Msat, Mrem and Hc are affected by Sm^{3+} proportion and heat treatment (800 °C for 2 hours).

Step 2 Elaboration of composites: dispersion of partices in organic matrix (PDMS or ethylcelulose + waxes)

Base polymer + cross linker (10:1) + Magnetic and conductive particles (20 % *w/w*)

Air elimination (vacuum)

Curing at 75°C under external uniform magnetic field

Particles alignment

Ethylcellulose + wax + volatile carrier solvent + Magnetic and conductive particles (20 % *w/w*)

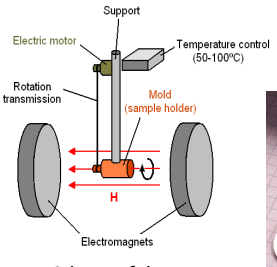
Heat: Solvent evaporation (60°C)

Liquid mixture of ethylcellulose + wax + particles

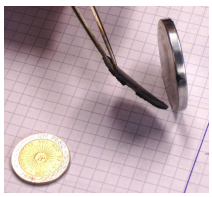
external uniform magnetic field

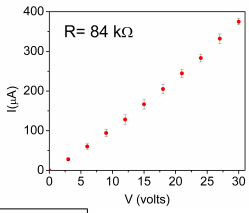
Particles alignment

Anisotropic structured magneto rheological composites

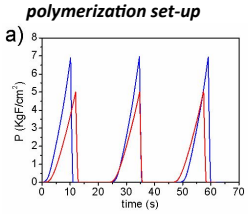


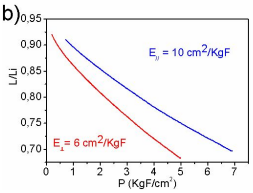
Scheme of the polymerization set-up



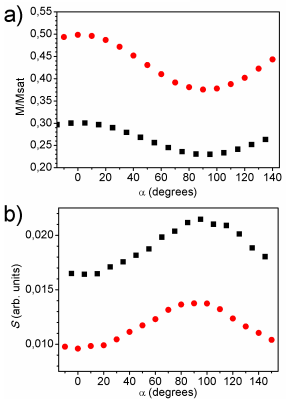


I vs. V plot of Fe_2CoO_4@Ag-PDMS (20 % *w/w*) film (shown at the left) for a pressure of 0.5 KgF/cm²



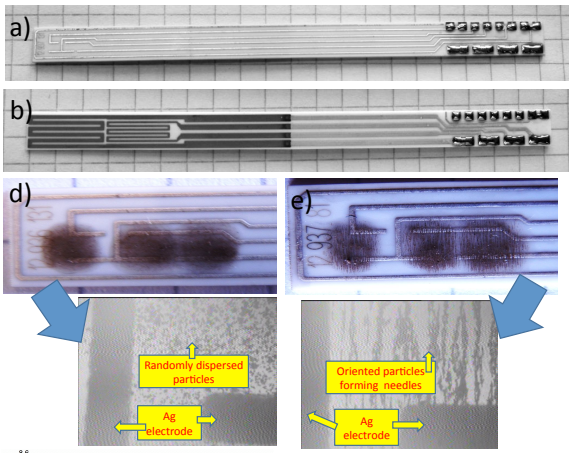


Texture analysis of PDMS-NPs composites. a) slow compression, fast decompression (strain 30%) on PDMS-NPs (10% w/w, x =0.2, not calcined) composite. b) Relative thickness (L/Li) vs. applied pressure (P) for PDMS-NPs (10% w/w, x =0.2, not calcined) composite. (---) pressure applied parallel to the needles. (---) pressure applied perpendicular to the needles.

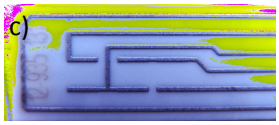


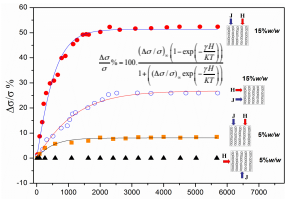
a) Remanence magnetization (normalized to Ms,α) vs angle respect H (α) for PDMS-Fe1.9CoSm0.1O4 composites (10% w/w) using particles with and without heat treatment. b) Magnetic viscosity as a function of α for PDMS-Fe1.9CoSm0.1O4 composites. (•) Composite prepared with calcined particles. (•) Composite prepared with particles before heat treatment.

Step 3 Screen printing on alumina substrate with the fluid mixture

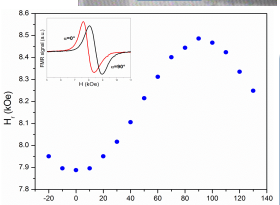


Screen Printing on alumina substrate:
a) top view of the alumina substrate with silver traks and ohmic contacts.
b)rear view of alumina substrate with Pt and Pt-Pd tracks as thermistors and ohmic contacts.
c) Magnified image of a)
d) PDMS-Fe_3O_4@Ag printed on substrate, cured in absence of magnetic field.
e) PDMS-Fe_3O_4@Ag printed on substrate, cured in presence of external uniform magnetic field. The particles get aligned forming needles visible at naked eye.





Magnetoresistivity Correlation between Δσ/σ% and H at room temperature for different percentages of Fe3O4@Ag in MRE elastomer. The field H was applied in collinear and all perpendicular combinations with respect to the electrical flux, J. It is worth to note that for H⊥J no changes in the current were detected. The solid lines represent the model.



Magnetic behavior (FMR): Hr(α) curves for PDMS-Fe3O4 5%w/w measured at 24.13 GHz. The inserted graph shows FMR curves for PDMS-Fe3O4 15%w/w measured at 24.13 GHz with the external field applied parallel (α=0°) or perpendicular (α=90°) to the needles.

The total resistance of the composite is considered as two resistors in series: $R_t=R_i+R_H$. The first resistance R_i is an intrinsic inter-grain resistance which is an activated process present in any polycrystalline material (dependent on temperature but not on H). R_H is an activated process (with an associated conductivity $\mathbf{R_H} \approx 1/\sigma_H$) that accounts the effect of matching partially the spin polarizability of both grains by spin-alignment through the presence of H.

Fe_3O_4@Ag-PDMS composites present magneto resistant properties. Magneto resistant studies of Fe_2CoO_4@Ag-PDMS composites are currently in progrerss.