3D-printable reconfigurable magnets based on wax/cobalt ferrite composite

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Introduction:

Conventional magnets are based on heavy rare-earths such as dysprosium (Dy) and terbium (Tb). The magnets based on rare-earth are costly and, in applications where modest magnetic properties are required, it is not necessary to employ them.

$CoFe_2O_4$ (CFO) based nanocomposites can provide sufficient magnet response for such application and, additionally, the magnets can be produced by means of 3D-printing in any desired shapes. Wax-based composites allow facile processing and reconfiguration of the already printed magnets to new shapes by simple dissolution in ethanol. The effect of cobalt ferrite concentration on the evolution of printed magnets has been studied and discussed [1].

References:

[1] R. Brito-Pereira et al., J. Mater. Chem. C, **8** 952-958 (2020).

Experimental:

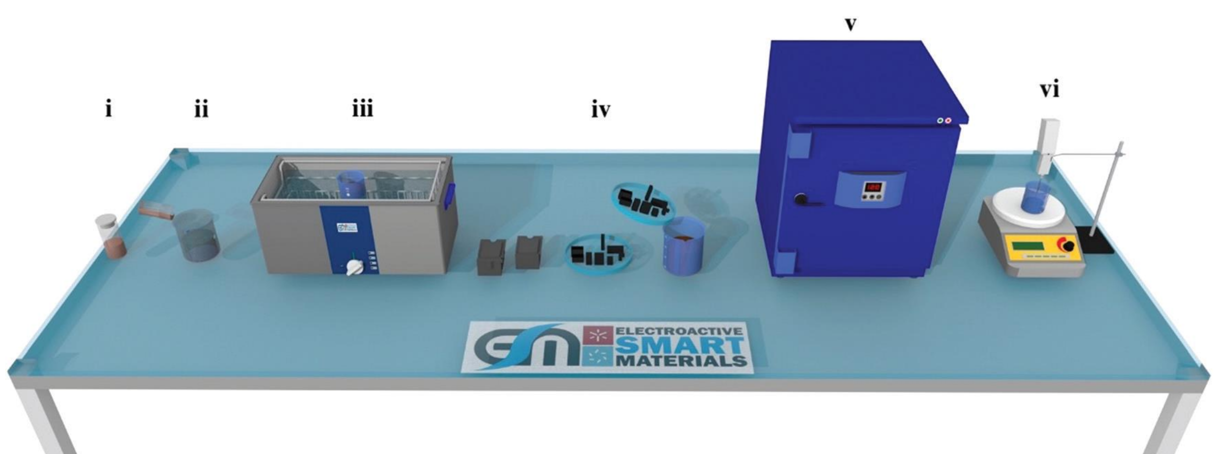
Preparation of the Wax/CFO ink

CFO nanoparticles (35 to 55 nm particle size) (i) were initially added (in 3 weight percentages – 30 wt%, 75 wt% and 90 wt%) to 5 mL pure ethanol (ii) and the solution was dispersed in an ultrasonic bath (iii) for 3 h to ensure good dispersion and to prevent nanoparticle agglomeration Afterwards, the previously cut Wax (1.5 g) was added (iv) to the solution and it was placed inside an oven (JP Selecta, Model 2000208) for 30 min (v) at a temperature of 120 °C for polymer melting and the complete removal of the solvent. Thereafter, the solution was removed from the oven, placed on a hot plate with a temperature of 120 °C and was mixed for 1 h with the help of a mechanical Teflon stirrer (vi) to ensure complete dissolution of the polymer and homogeneity of the mixture

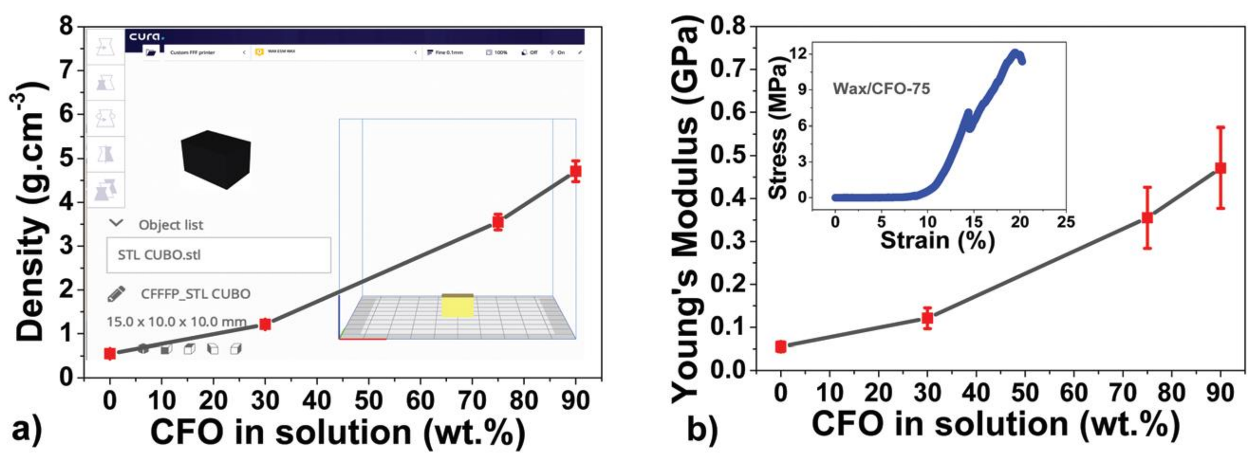
Printing of the Wax/CFO composites

The polymer mixture was placed in a commercial glass syringe. Then, it was fixed to the 3D Printer (3D Cultures, Philadelphia, USA) with a predefined temperature of 120 °C to ensure the optimum viscosity (3–10 mPa s) of the solution in order to be uniformly printed. The syringe distance was 0.1 mm. Each printed layer corresponds to 200 mm of printed magnet. The parallelepiped samples were designed in SolidWorks 2017 (Dassault Systems Cedex – France) and then converted to STF files using Swift Converter. The process starts with a 3D dataset that is sliced by a computer to generate the printing matrix of each layer. Printed patterns were dried at room temperature. Thermal annealing was performed inside an oven (JP Selecta, Model 2000208) for 1 hour at a temperature of 80 °C.

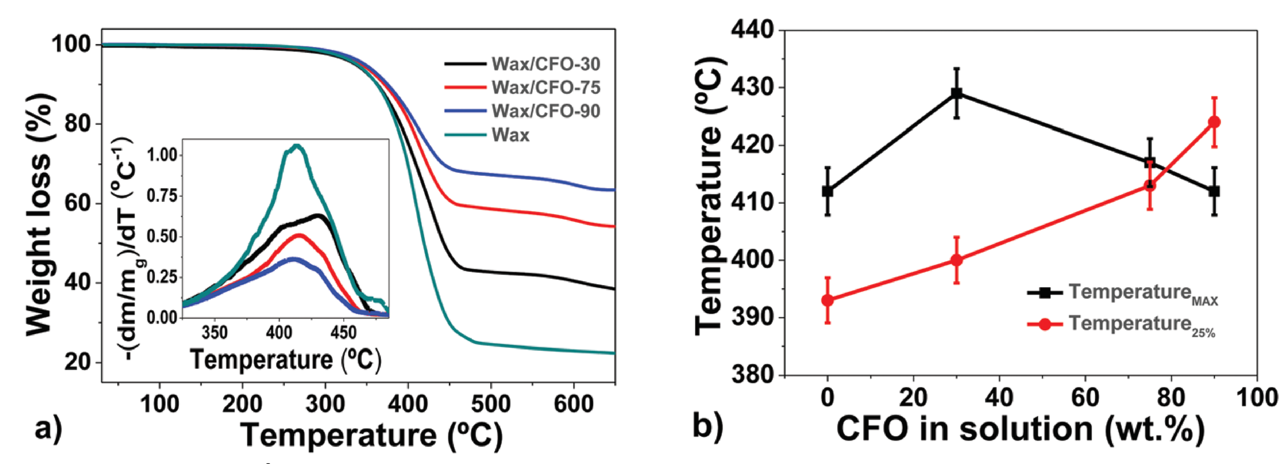
Results:



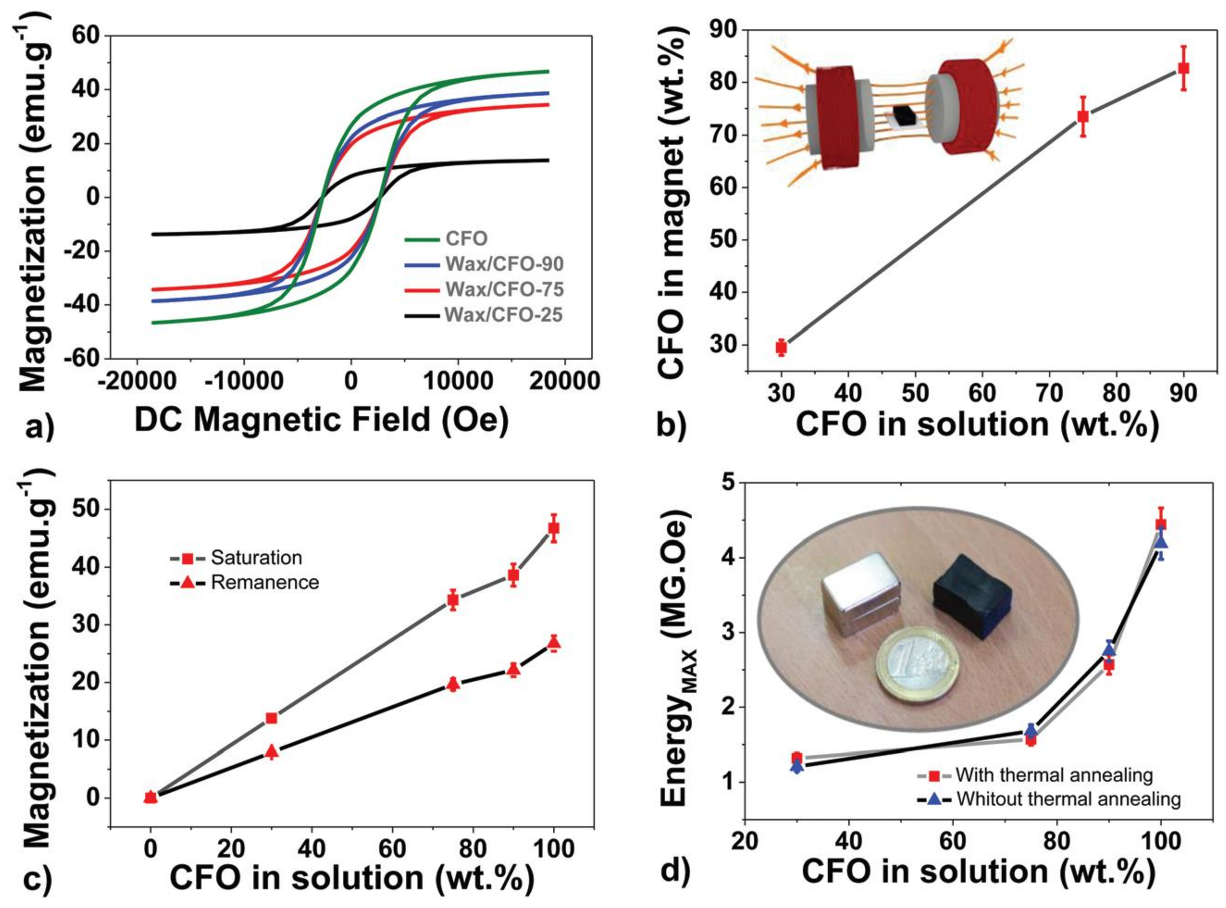
Ink preparation process



Density and Young's Modulus of the Wax/CFO composite increases with CF concentration.



Thermal stability of Wax/CFO composites increases with increasing CFO concentration.



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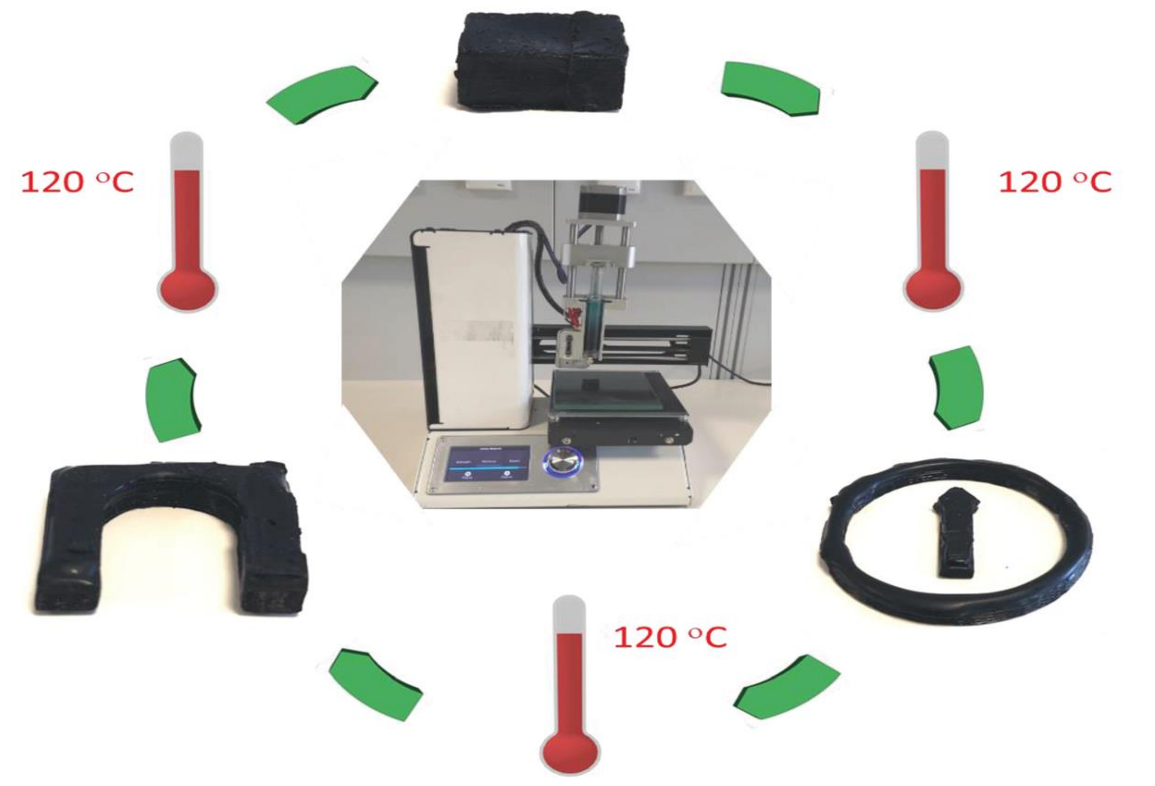

Magnetization and maximum energy product of Wax/CFO composites increases with increasing CFO concentration.

Conclusion:

It was demonstrated that the saturation and remnant magnetization increase monotonously with ferrite content, reaching maximum values of 38.6 emu g^{-1} and 22.1 emu g^{-1}, respectively. The coercive field (≈2500 Oe) was kept constant for all samples. The presence of ferrite nanoparticles increase also the Young's modulus (from 0.06 GPa to 0.47 GPa) and improves the thermal stability of the composites, as well. In addition, the measured (coercive field) × (remanence field) maximum energy product $(H_C \times B_C)_{MAX}$ was the highest reported in the literature for $CoFe_2O_4$-based magnets (*i.e.*, 4.44 MG Oe for sample of 90 wt% of ferrite content).

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