Universidad del País Vasco / Euskal Herriko Unibertsitatea
ZIENTZIA ETA TEKNOLOGIA FAKULTATEA / FACULTAD DE CIENCIA Y TECNOLOGÍA
BCMATERIALS BASQUE CENTER FOR MATERIALS, APPLICATIONS & NANOSTRUCTURES
Mondragon Unibertsitatea

MAGNETORHEOLOGICAL ELASTOMERS AS MULTIFUCTIONAL MATERIALS FOR BIOMEDICAL DEVICES AND APPLICATIONS

Ander García[1], Carmen Rial Tubio[1], Jon Gutiérrez Etxebarria[1,2], Ainara Gómez[3], Joanes Berasategi[3], M. Mounir Bou-Ali[3], Senentxu Lanceros-Mendez[1,4]

[1] BCMaterials - Basque Center for Materials, Applications and Nanostructures, UPV/EHU Science Park, E-48940 Leioa, Spain;
[2]Faculty of Science and Technology, University of the Basque Country, 48080 Bilbao, Spain;
[3]Mechanical and Industrial Production Department, Faculty of Engineering, Mondragon University, Loramendi 4, 20500 Arrasate-Mondragón, Spain ;
[4] IKERBASQUE, Basque Foundation for Science, 4809, Bilbao, Spain;

Introduction

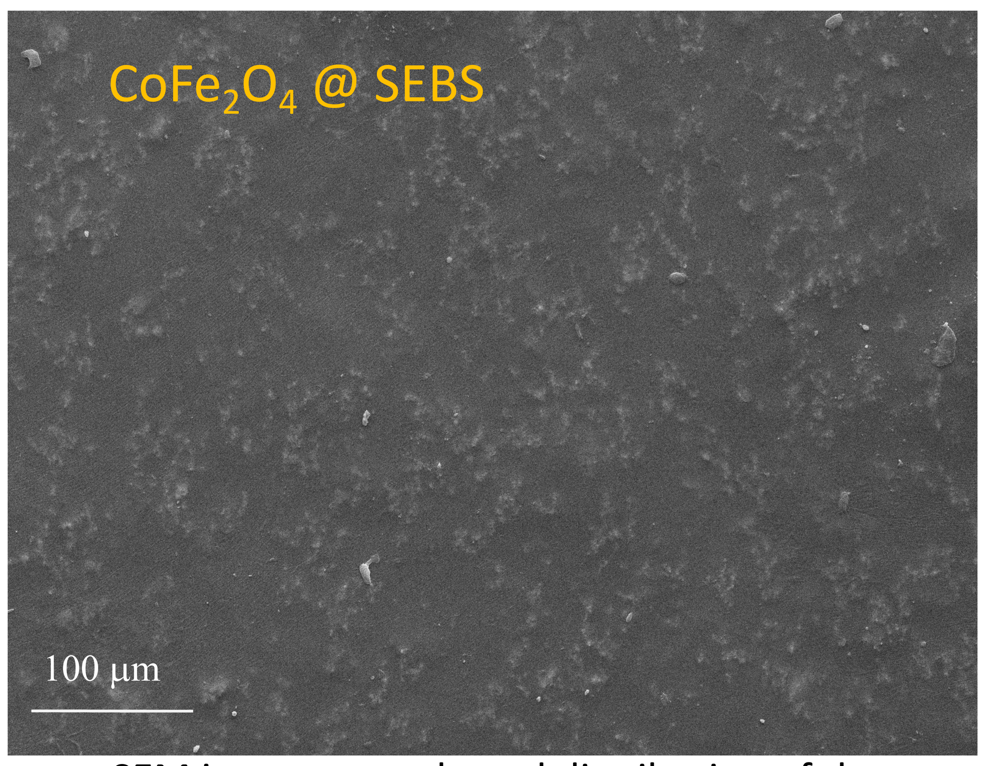
Magnetorheological elastomers (MREs) are active materials composed of a polymeric matrix and an inorganic magnetic filler [1]. Their rheological and mechanical characteristics can be actuated using a magnetic field. Typically, the inorganic component is a soft magnetic material with high saturation, so that switching between rheological states is achieved rapidly [2]. The magnetic particles can be also oriented with an external field during curing, thus getting anisotropic composites with orientation-dependent properties [3]. They are compatible with additive manufacturing [4] techniques and suitable for remotely actuated biomedical devices such as stents and catheters [5], thus offering a promising alternative for next generation to traditional medical tools. Most studies have focused on the use of carbonyl iron microparticles [6] for the fabrication of these elastomers with magnetic nanoparticles, which are more easily functionalized and can be biocompatible, is also highly interesting, based on their tunability.

Goals

- ✓ Evaluate the suitability of different magnetic nanomaterials to develop magnetorheological elastomers, according to their magnetic properties.
- ✓ Evaluate the structural, magnetic, mechanical, thermal and magnetorheological characteristics of the composites.
- ✓ Investigate the effect of shape, size and orientation of the fillers in the magnetorheological properties of the composites.
- ✓ Incorporate additional effects onto the MREs to create multi-responsive materials.
- ✓ Demonstrate their compatibility with additive manufacturing techniques to improve device integration and to develop free-form devices.

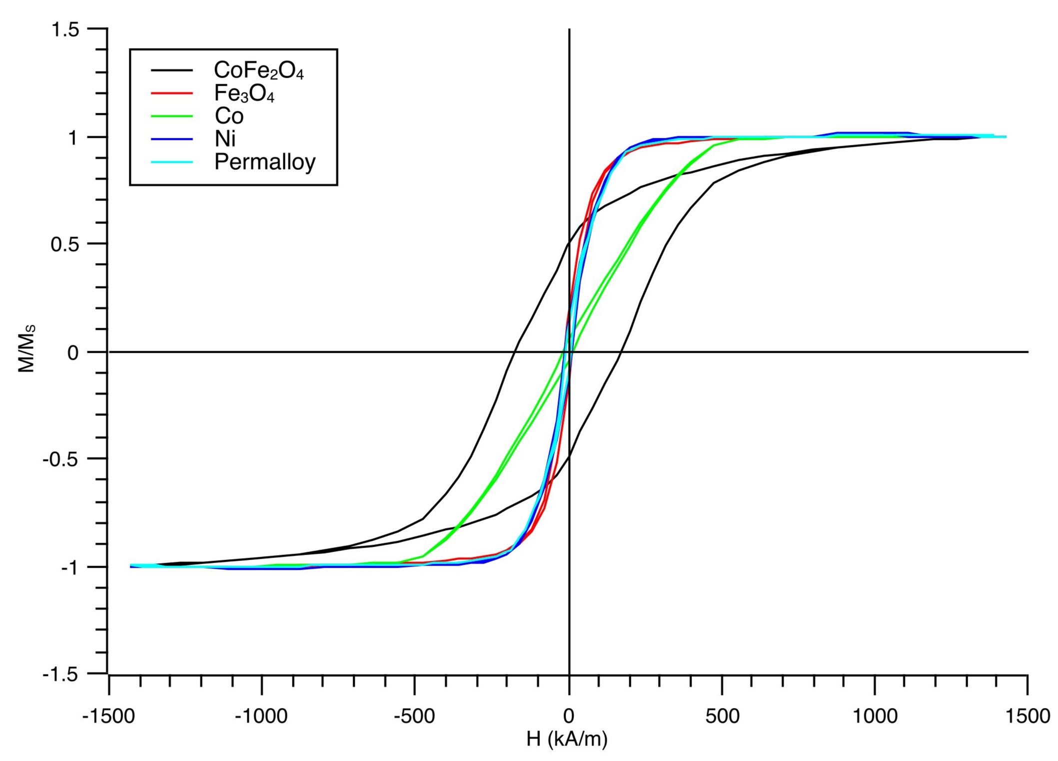
Results

Morphology (SEM images)



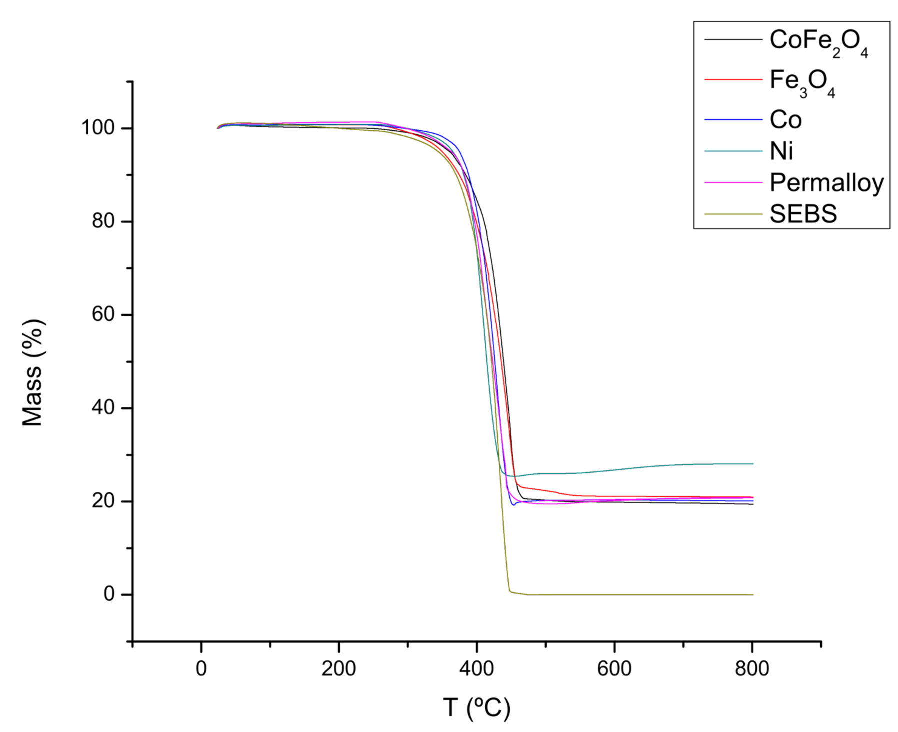
SEM images reveal good distribution of the nanoparticles across the films.

Magnetic measurements (VSM)



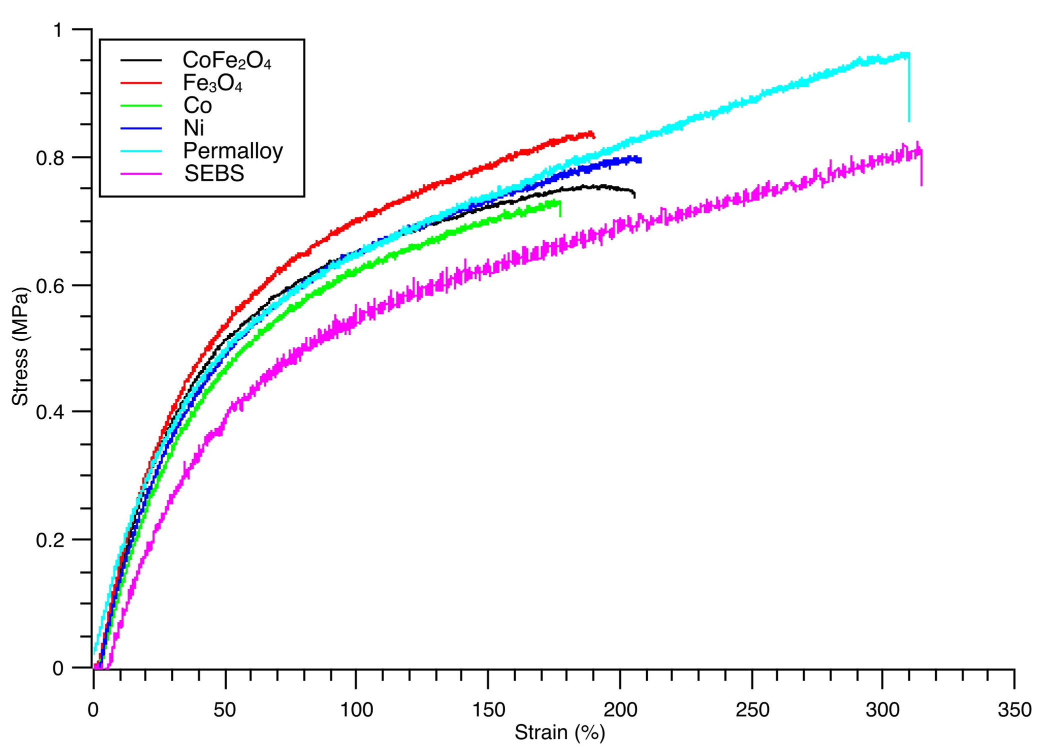
Composites retain the magnetic properties of the fillers.

Thermogravimetric analysis



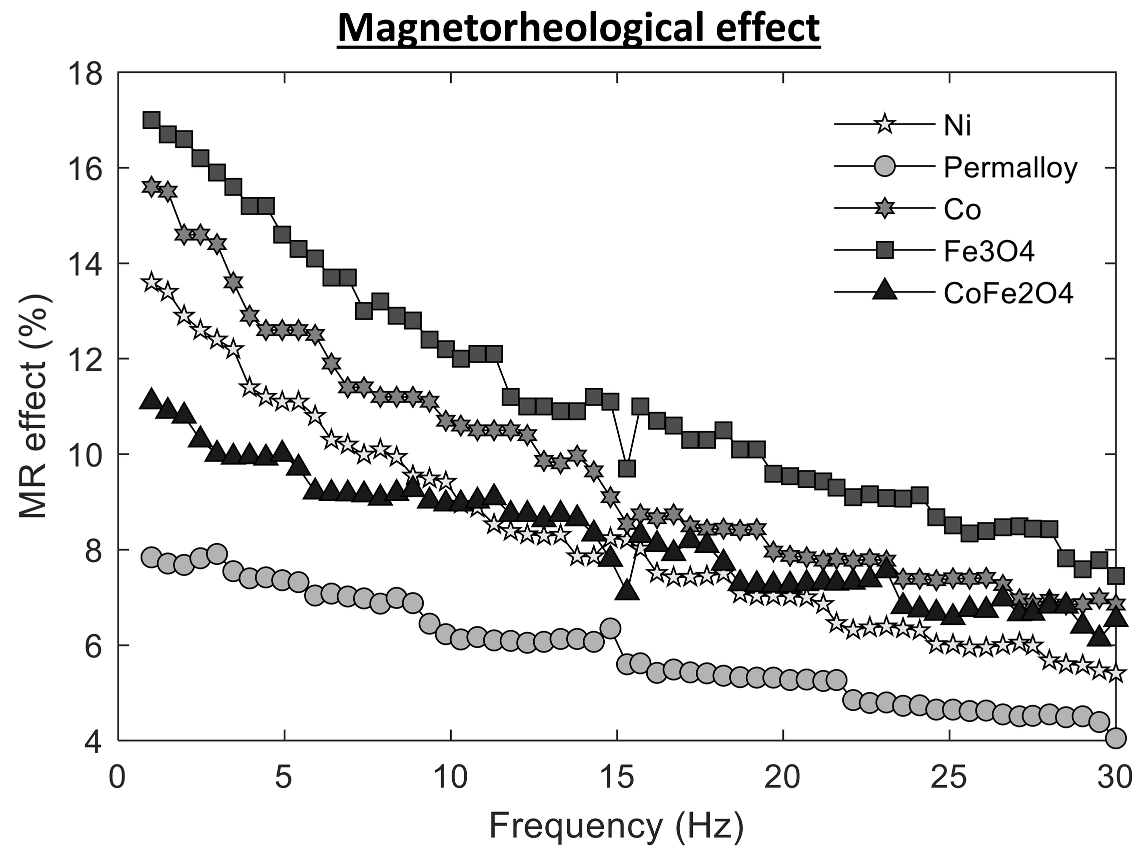
The magnetic fillers slightly improve the thermal stability of the composites.

Mechanical properties



The addition of the magnetic nanoparticles decreases the maximum elongation of the polymer but also enhances the elastic modulus.

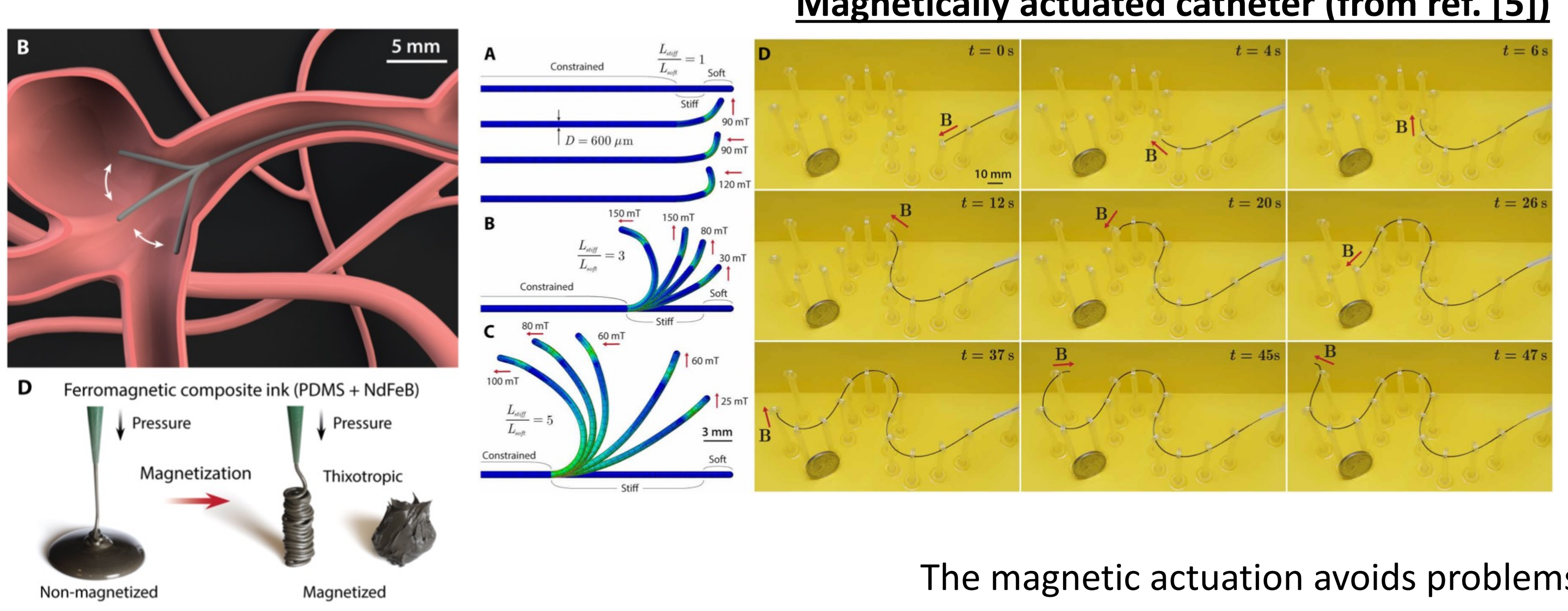
Magnetorheological effect



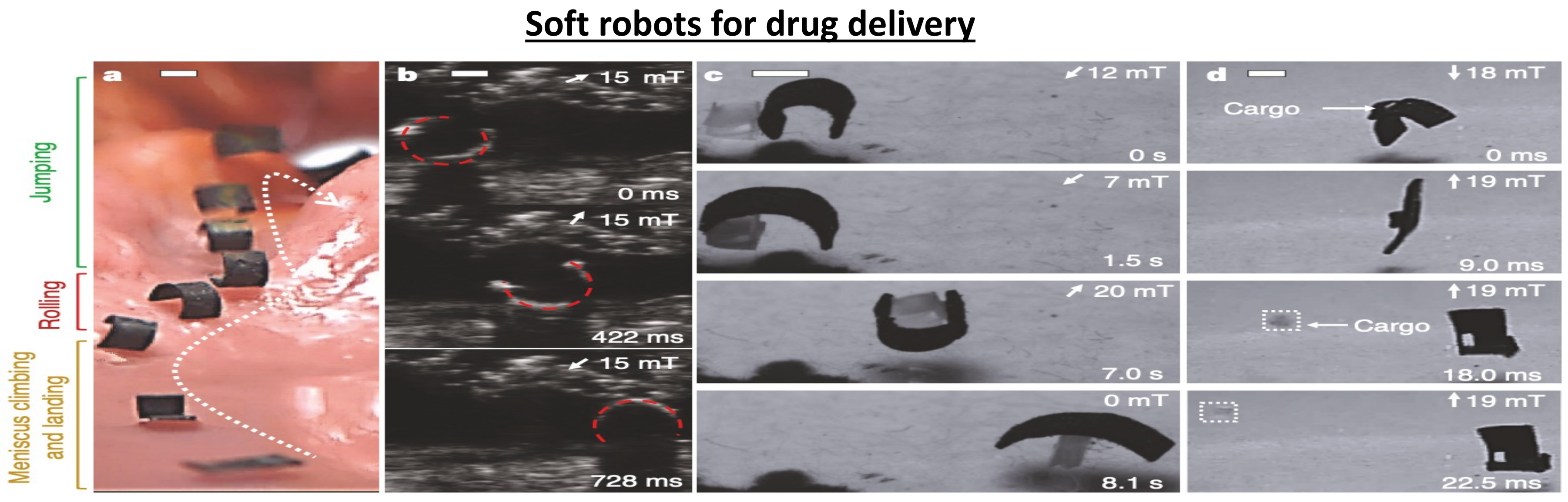
Overall, particles with higher saturation magnetization and lower coercivity yield better magnetorheological effect (such as magnetite), while those with higher coercivity seem to have lower magnetorheological effect.

Potential Applications

Magnetically actuated catheter (from ref. [5])



Soft robots for drug delivery



The magnetic actuation avoids problems with power supply of the soft robots

Conclusions

- ✓ Nanoparticles with different magnetic properties are suitable for fabrication of MREs, improving mechanical, rheological and thermal characteristic while retaining magnetic activity.
- ✓ Filler type, concentration and orientation allow to tune magnetorheological properties.
- ✓ Potential applications include medical devices printable by 3D printing or soft robots actuated by magnetic fields, among others.

Acknowledgments

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