Porous polymer sponge and magnetic nanoparticles: a magneto-elastic energy harvester

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The growing use of sensors and devices demands increased energy consumption, making the adoption of renewable energy sources and the development of smart energy harvesters capable of recovering wasted energy crucial. This study proposes the fabrication and characterisation of an innovative energy store composed of a porous polymer matrix loaded with magnetic nanoparticles that relies on the magnetoelastic effect to recover energy from ubiquitous vibrations.

Keywords: magneto-elastic harverster, nanocomposite magnetic sponge, magnetic nanoparticles

1. Introduction

Industry 5.0 and Smart City projects aim to create sustainable and technologically advanced smart factories and services that respect the planet's production limits and citizens' health [1]. This is leading to an increase in the use of sensors and devices.

This ambitious revolution requires an increase in energy consumption, which must be addressed sustainably by minimizing greenhouse gas emissions to mitigate climate change. The use of renewable energy sources along with the development of smart devices capable of recovering wasted energy (i.e., energy harvesters), will be essential.

Cutting-edge scientific research explores efficient energy harvesters based on composite materials exploiting the unique and distinctive properties of nanomaterials. As an example, magnetostrictive 2D layers on piezoelectric substrates constitute devices capable of simultaneously harvesting energy from both mechanical vibrations and ac magnetic fields [3] or nanostructured surfaces in triboelectric harvesters convert mechanical energy into electricity [4].

This study aims to support the energy transition by developing an innovative energy harvester based on composite materials exploiting the magnetoelastic effect capable of recovering energy from the ubiquitous vibrations.

2. Results and discussion

A porous and soft sponge was fabricated by the low-cost sacrificial pattern technique, using sugar or salt crystals as sacrificial material and polydimethylsiloxane (PDMS) as polymer matrix. The latter was loaded with magnetically hard MNPs such as NdFeB and hexagonal Ba-ferrite.

An optical image of the magnetic polymer sponge is shown in the left panel of Figure 1. The sponge is characterised by a homogeneous porosity throughout its volume. The brown color is given by the homogeneously dispersion of the MNPs within it. The morphological details of the porous structure are analysed using SEM images, see right panel of Figure 1. The pores appear irregular in shape with dimensions of hundreds of micrometres.

The porosity of the magneto-polymer sponge was finely optimized to control mechanical properties and to improve its deformability under mechanical vibrations. Meanwhile, the composition and concentration of MNPs were tuned to maximise the electrical induced signal.

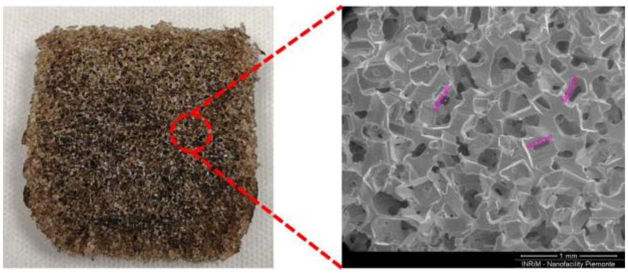

Figure 1: left panel: optical image of magnetic polymer sponge. Right panel: SEM image of pores.

The hard magnetic properties of the NdFeB and hexagonal Ba-ferrite were investigated using an ultra-sensitive magnetometer. Specifically, the coercive field (H_c) is around 5.25 kOe and 2.71 kOe, respectively.

Controlled mechanical vibrations were applied to the harvester by means of a custom agitator, which operates in the frequency range of 5 - 40 Hz and amplitude range of 0.5 - 5 mm. The proposed energy harvester combines the unique properties of a porous and soft polymer sponge and magnetic nanoparticles (MNPs), which are appropriately aligned by an intense magnetic field. Under mechanical vibration, the flexible sponge compresses, altering the net magnetic moment generated by the MNPs. This change is then converted into electrical energy by electromagnetic induction and finally stored in a supercapacitor

1. References

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