Magnetic field influence on magnetomechanical coupling of partially bistable magnetic materials

Papa Gorgui,[1,2*] Pilar Marín [1,2]

[1]Instituto Magnetismo Aplicado IMA ,UCM, Las Rozas (Madrid)

[2] Departamento de Física de Materiales ,UCM, Madrid

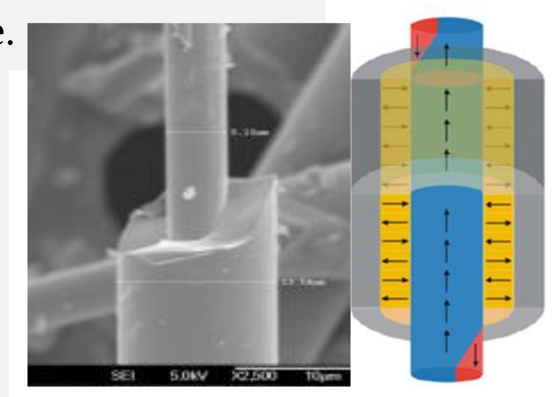
Introduction

The great sensitivity to small fields makes soft magnetic materials excellent for magnetic field sensing.

The magnetic material used in this work are FeSiB based magnetic microwires and ribbon obtained by Taylor's technique and their magnetostriction constant can be positive or negative depending on the Fe/Co percentage.

Amorphous magnetic microwires AWM are continuous filaments with a magnetic core covered by a glassy outer shell. [1]

Generally, the total diameter is less than 100 µm and the diameter of the metallic core is between 4 to 60 µm.



Magnetoelastic sensor

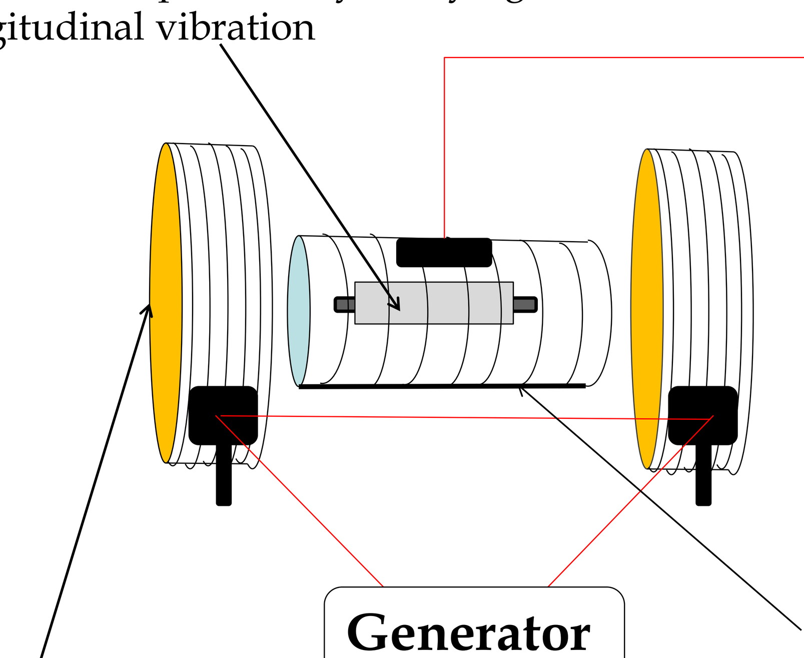
The magnetoelastic resonance is due to the rotation of the magnetization when a material is exposed to AC magnetic field of a certain frequency.[2]

Many applications are done in this way as like as:

- ✓ The detection of salmonella on fresh produce where the frequency change depends on the additional mass added to the sensor surface, which is equivalently the number of bacterial cells bound to the surface sensor.[3]
- ✓ Electronic article surveillance (EAS) alarm systems (anti-theft tags) where an excitation signal is emitted at the resonance frequency of the tag (58 kHz).
- ✓ Magnetic nanodiscs for cancer therapy with a magneto-mechanical actuation. [4]

Experimental set-up

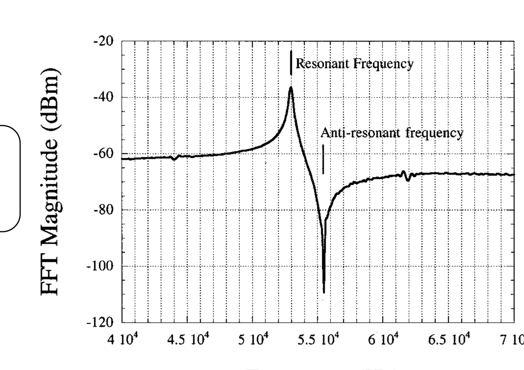
- **The magnetoelastic sensor (sample)** is inserted inside the solenoid (pick up coil) and generate a exponentially decaying sinewave after a longitudinal vibration



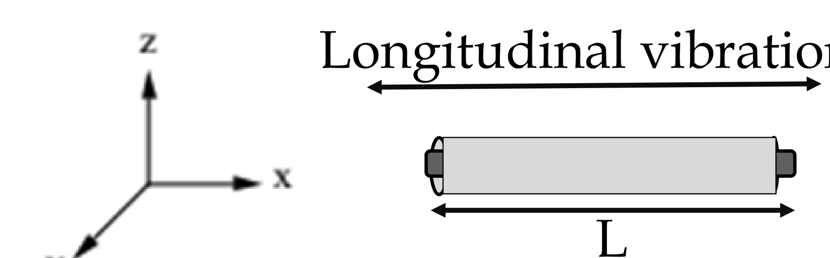
- **Impedance Analyzer**

The time-domain response of the sensor is converted into frequency-domain

- **Computer**



- **An excitation coil** (Helmholtz coils) are connected to a generator and produce a magnetic field as a sinusoidal signal.
- **pick up coil** receive the information from the deformation of the sensor.



Theory:

$$\frac{\partial^2 u_x}{\partial t^2} = \frac{E_S}{\rho_S(1-\sigma^2)}\frac{\partial^2 u_x}{\partial x^2} \quad (1)$$

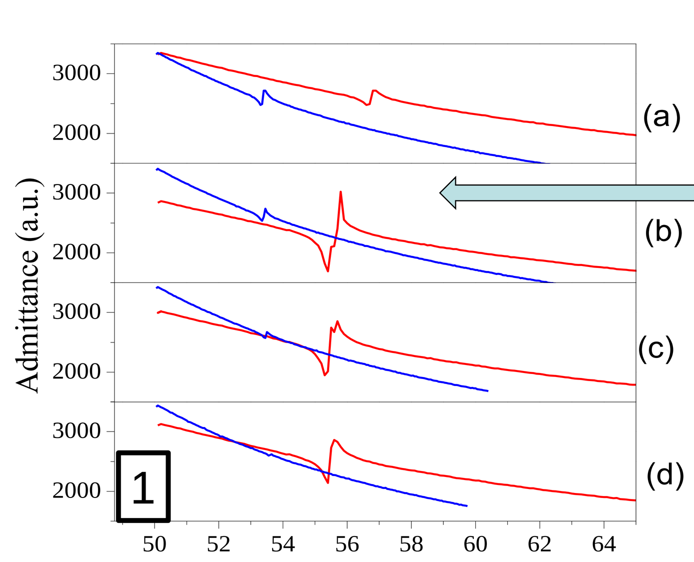
Motion equation

$$f_n = \frac{n\pi}{L}\sqrt{\frac{E_S}{\rho_S(1-\sigma^2)}} \quad (2)$$

Where E is Young's modulus of elasticity, σ is the Poisson ratio, ρ is the density of the sample.

Our system measures the impedance of the solenoid as a function of frequency. Since the permeability of the sensor increases significantly at resonance, a sharp peak will occur in the solenoid's impedance spectrum at the resonant frequency of the sensor.

Results



Optimal applied field

Maximal Permeability of the sensor

Maximal conversion of magnetic energy into elastic energy and vice versa

High coupling factor k

$$k = \sqrt{\frac{\pi^2}{8}\left[1-\left(\frac{\vartheta_r}{\vartheta_a}\right)^2\right]}$$

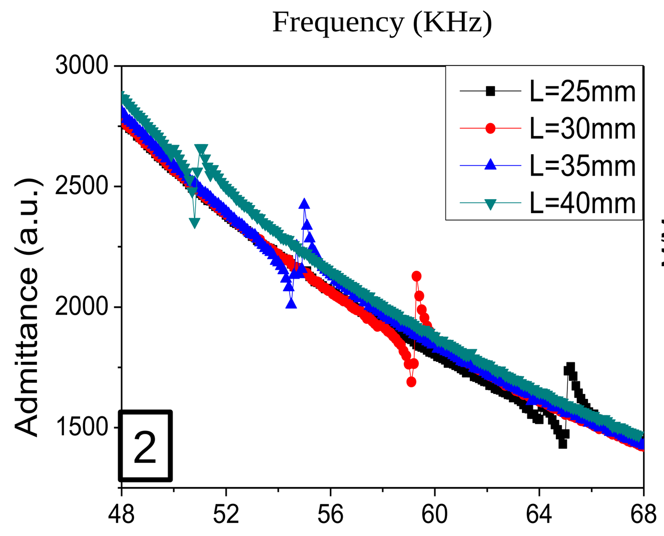


Fig.1: **(1)** Spectrum resonance of (■) wire, (■) ribbon, for different value of applied AC field. (a) H=0,5 Oe, (b) H=1 Oe, (c) H=3 Oe, (d) H=9 Oe **(2)** Influence of the length in Mws at H= 00 Oe of applied field.

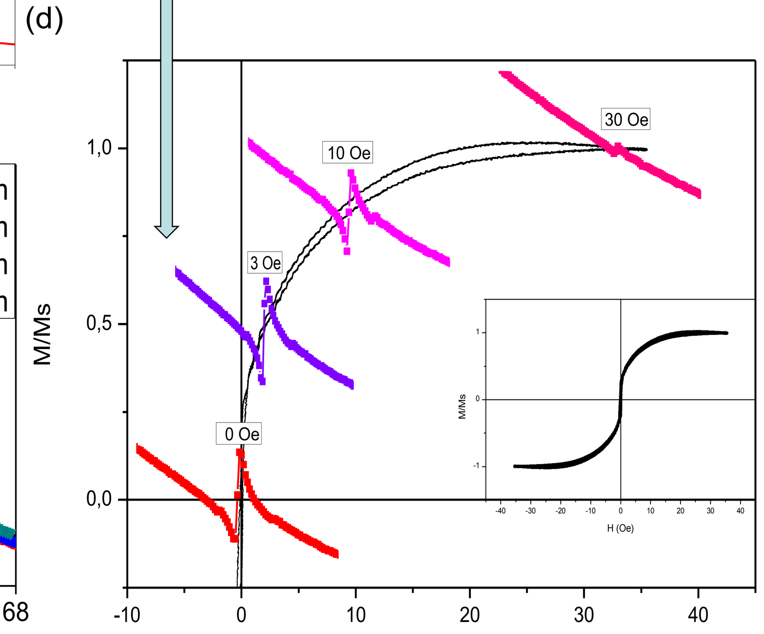
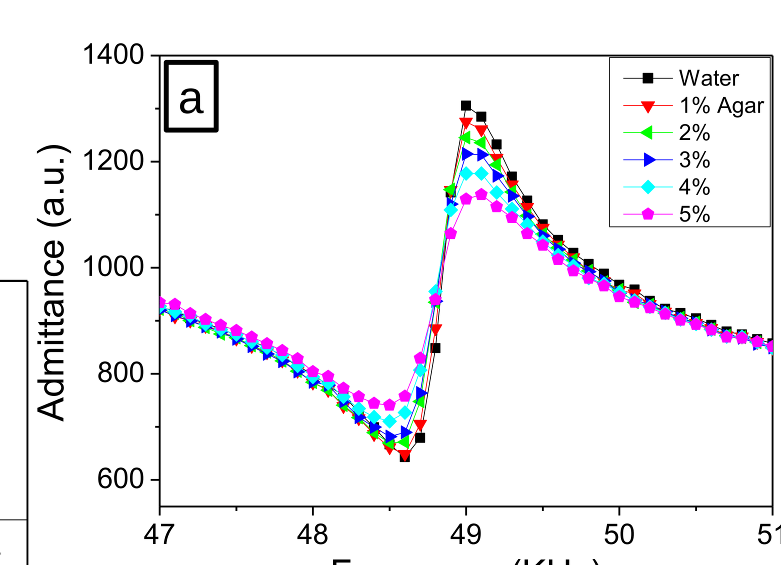
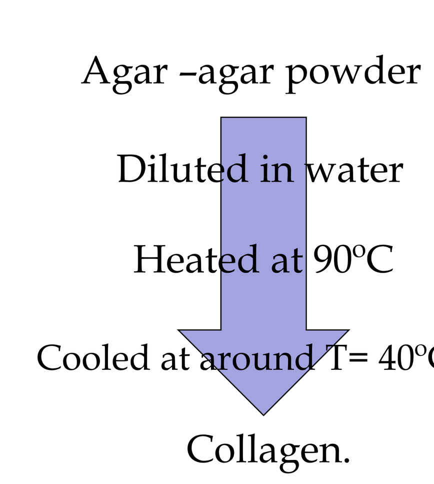
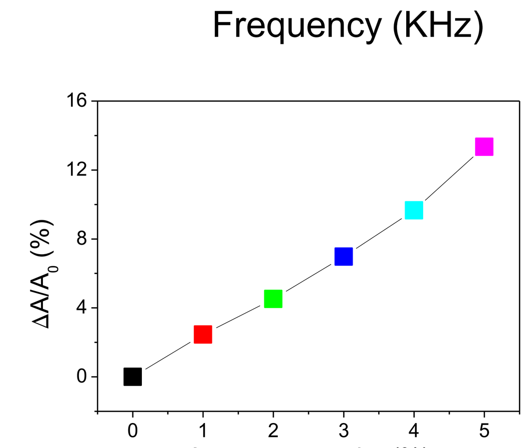


Fig 2: Hysteresis loops of a 3.5 cm length of glass coated microwire (dm=60 µm, Dgl= 100 µm) and resonance frequency evolution.







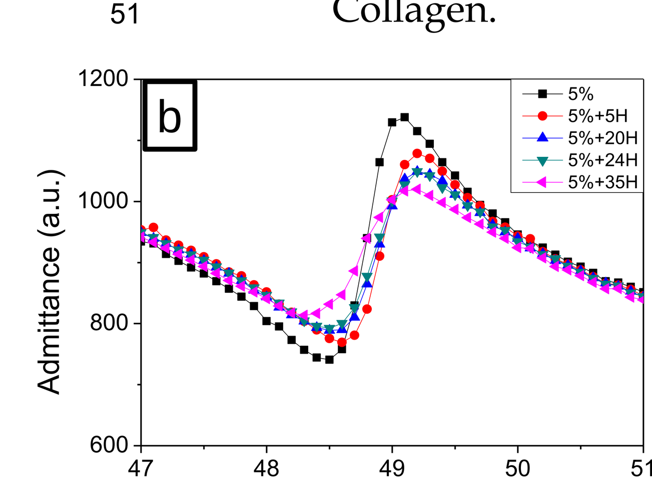
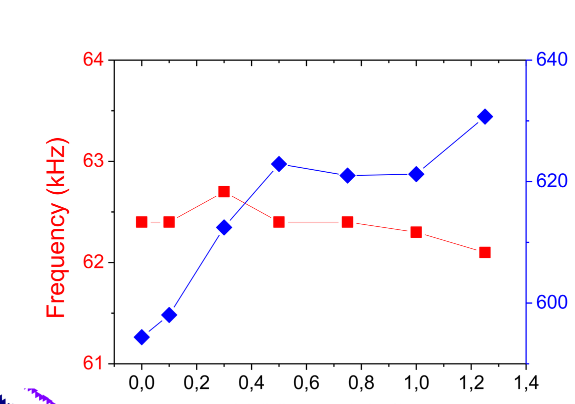


Fig 3: Resonance curves of ribbon a) for different rate of agar-agar powder ; b) For 5% and after several time in immersion

1.5ml Oil	0.1 ml (V) 1.4ml (O)	0.3 ml (V) 1.2 ml (O)	0.5 ml (V) 1 ml (O)	0.75 ml (V) 0.75 ml (O)	1 ml (V) 0.5 ml (O)	1.25 ml (V) 0.25 ml (O)	1.5 ml Vinegar



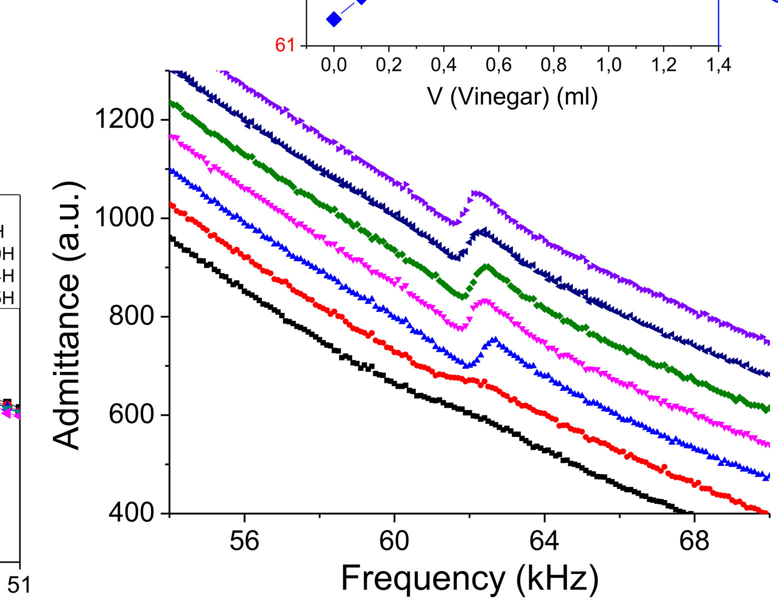


Fig 4: Ribbon's resonance frequency for different concentrations of Oil mixed with vinegar at 1Oe.

Conclusion

- The advantage of use microwires is in the size and that present resonant frequency at zero applied field
- It should be remarked that the amplitude of the resonance frequency depends on the viscosity (so a presence of damping force) but the frequency change is related to the additional mass added to the sensor surface.
- The experimental technique use in this work permit us to detected wirelessly the response of our sensor while we are limit to use microwires less than 30 µm of metal diameter.

References

[1] P. Marín, M. Marcos and A. Hernando. *Appl. Phys* **96**, 262512 (2010)
[2] C. Herrero-Gomez, P. Marın, and A. Hernando. *Appl. Phys* . **103**, 142414 (2013)
[3] Yating Chai et al. 978-1-4673-5221-5/13/IEEE (2013)
[4] Alfredo García-Arribas, Soft magnetic materials: from microsensors to cancer therapy, (2017).
[5] Keith T. Loiselle and Craig A. Grimes, Rev. Sci. Instrum., Vol. 71, No. 3, March 2000
[6] Craig A. Grimes1 et al. *Sensors* **2002**, *2*, 294-313

Acknowledgements

AMPHIBIAN