# Amorphous-microwires-based sensing elements and magnetic nanoparticles for GMI biosensor

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***Abstract.*** The influence of a liquid suspension of iron nanoparticles on the magneto-impedance (MI) of an array of glass-coated amorphous microwires array was studied. The array sensitivity increases as the number of the active microwires increases. The highest variation of 59 % was found for 10 microwires, measured with and without magnetic nanoparticles, when using a current intensity of 10 mA.

## I. Indroduction

In the research field of the magnetic bio-detection, following the giant magneto-resistance GMR) biosensor emergence, new biosensor prototypes, based on giant magneto-impedance (GMI) effect, were studied [1]. A biosensor is a compact analytical device incorporating a biological or biologically-derived sensitive element, integrated or associated with a physico-chemical transducer [2]. The GMI effect consists in an abrupt variation of the impedance of a soft magnetic conductor passed by a high frequency current when subjected to a small D.C. magnetic field [3].

Giant magneto-impedance (GMI) sensors can be highly influenced, in certain condition, by magnetic particles. Therefore, biodetection systems based on magnetic particles and GMI magnetic sensing elements can be designed for biomolecules detection. The role of the magnetic particles is to mark the target biomolecules and subsequently to modify the impedance of magnetic sensor. In MR biosensors, a magnetic field of small magnetic particles works as a physical transducer, and information transference includes precise sensing of small fields of these particles employed as markers [4]. The detection is affected by the type of both magnetic sensing elements and nanoparticles.

In our study, an array of Co-Fe-Si-B glass-coated amorphous microwires were used as GMI sensing elements in order to detect iron nanoparticles that can work as magnetic markers. This prototype relying on glass-coated microwires as sensing elements, and magnetic nanoparticles could be used as magnetic biosensor for target biomolecules detection and identification.

## II. Experimental

Co–Fe–Si–B glass-coated amorphous microwires, 39 mm in diameter and 70 mm in length, were prepared by glass coating melt-spinning method [5] and selected as GMI sensing element. The thickness of the glass layer was about 7 mm. The MI measurements were performed using a precision impedance analyzer, Agilent, when using a current of 10 mA.

The GMI ratios were defined as follows:

$$\left(\frac{\Delta Z}{Z(f)}\right)_{\max} = \frac{Z_{\max}(H) - Z(H=0)}{Z(H=0)} \cdot 100 \text{ for frequency dependence,}$$

where $Z_{max}$ represents the maximum MI obtained for each given frequency.

The relative change in MI response was evaluated using the following calculus formula:

$$\eta = \frac{Z_{1\max}(H) - Z_{2\max}(H)}{Z_{1\max}(H) - Z_1(H=0)} \cdot 100$$

Z represents in all the formulas the modulus of the impedance.

The array consisted in 10 flexible, slightly tensioned glass-coated amorphous microwires, placed as close as possible to each other inside the hollow of a non-magnetic support (figure 1). The hollow size was of about 50 mm x 500 μm x 500 μm. The amorphous microwires were connected by means of copper conductive leads so that the sense of the A.C. current to be the same through all the 10 glass-coated microwires. The conductive leads were placed under the non-magnetic support, at 10 mm distance towards the amorphous microwires array. Thus, it can be assumed that the magnetic field produced by the copper conductive leads is negligible.

The non-magnetic support along with the microwires array was placed inside a solenoid generating the bias D.C. magnetic field.

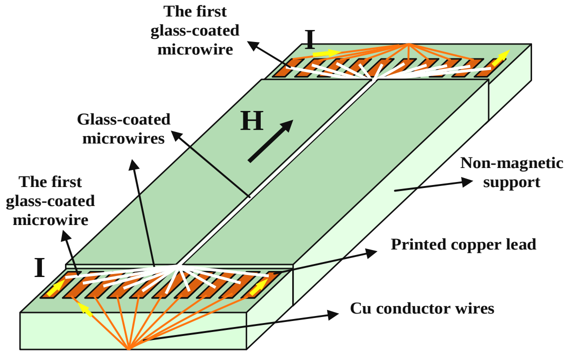
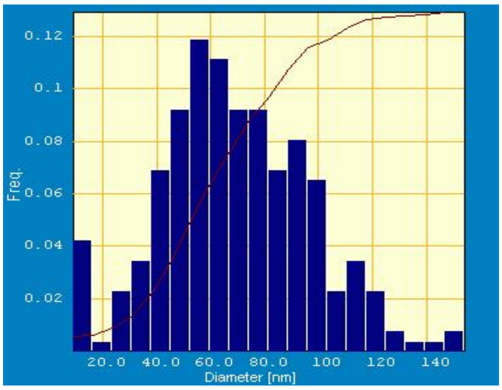



Figure1. Schematic view of the experimental device.

For MI measurements, the number of the connected (active) microwires was progressively increased from 1 to 10.

*Magnetic nanoparticles*. Iron nanoparticles of 50-100 nm (figure 2a), prepared in our lab by a chemical route (the "polyol process") were used in ethylene glycol (EG).

A small volume (2 μl) of nanoparticles in ethylene glycol, with concentration of 35 mg/ml, was dispersed on the array surface. Subsequently, for magneto-impedance measurements, an increasing D.C. magnetic field, generated by a coil, was applied parallel to the microwires longitudinal axes. The MI measurements were done from zero fields to saturation, from one to ten microwires. In order to test all the microwires of the array, about 10 minutes were necessary.



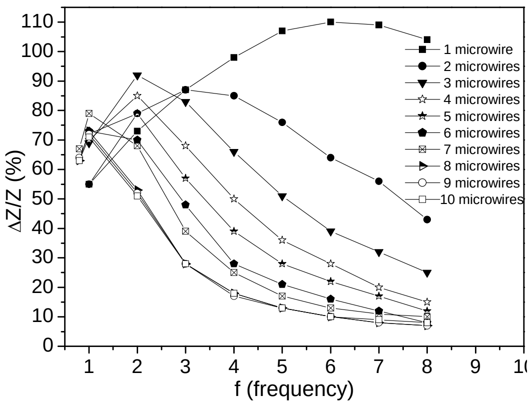




Figure 2. (a) Size distribution histogram for iron nanoparticles; (b) frequency dependences (Eq. (1)) of the MI as function of the active Co-Fe-Si-B glass-coated amorphous microwires number

For studying the effect of the settling time of the nanoparticles on the MI variation, a second measurement was done 4 h after the magnetic nanoparticles in EG were dispersed on the array surface.

## III. Results and discussions

The MI response of the array depends on several parameters such as the number of the active microwires and the current frequency.

Figure 2b shows the frequency dependence of the MI for all the microwires. The highest magneto-impedance variation was found close to 6 MHz for single microwire, 3 MHz for two microwires, 2 MHz for three, four and five microwires, and 1 MHz for the next microwires, when using a current of 10 mA.

Significant differences of MI variations were obtained as the number of the active glass-coated microwires in the array increases. With and without nanoparticles in EG, respectively, a MI variation of about 13 % was obtained for single microwire, whereas for 9 and 10 microwires a variation of about 59 % was achieved (figure 3a). After about 4 hours a significant variation of MI response was also observed (figure 3b). This can be explained by the increasing concentration of the nanoparticles close to the microwire's surface over time.

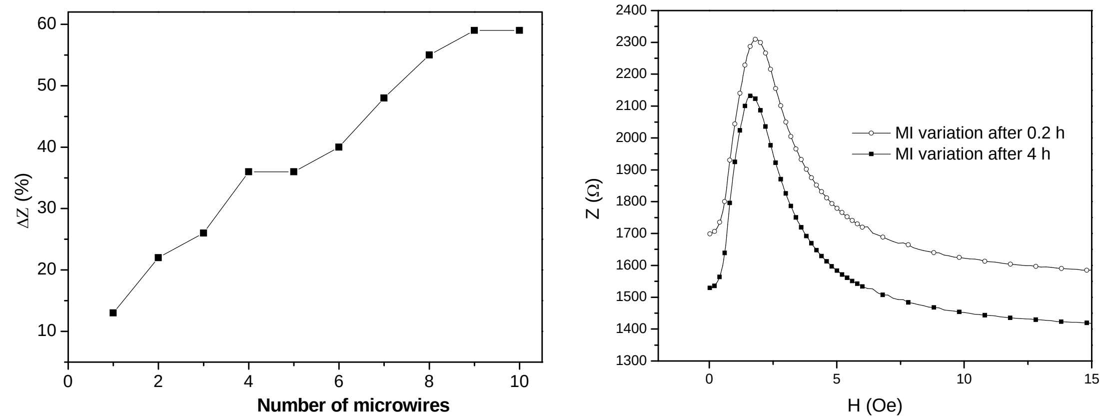


Figure 3. (a) The MI responses (Eq. (2)) as function of the number of the glass-coated microwires when the array was tested with EG and magnetic nanoparticles in EG, respectively; (b) the MI variation (about 190 Ω) after 4 h.

The magnetic nanoparticles can be detected inside the studied GMI-based sensing system because their magnetic fringe fields modify the external DC magnetic field to which the glass-coated amorphous wires are exposed. The magnetic fields of the nanoparticles are induced by the resultant field of the DC magnetic field inside the solenoid and the magnetic field created by the AC flowing through the amorphous wires. The increase in response to the increasing number of wires is connected with the interaction between the wires and the particles. Each particle modifies the impedance of each wire, resulting in an increase of the change of total impedance with the number of wires. An increase in background noise is therefore not expected and was not observed also.

It is also important to note, that by their glass layer, the microwires could offer both chemical stability in many aggressive chemical media and immobilization support for different types of biomolecules such as single stranded DNA or antibodies.

Moreover, the flexible glass-coated microwires confer mechanical stability and the possibility to use them to build up different geometries of arrays for simultaneous biodetections.

## IV. Conclusions

The results of our studies pointed essentially out the excellent magnetic detection characteristics of the glass-coated microwires array in comparison with single microwire. Higher sensitivities were found as the number of active microwires increases. The highest MI variation of about 59 % was found for magnetic nanoparticles when all the microwires in array were active. Therefore, due to the revealed particular characteristics, the glass-coated microwires, arranged in an array, could be used as sensing elements in magnetoimpedance-based biosensor for biomolecules detection.

## References

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