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FERROMAGNETIC GLASS-COATED MICROWIRES AND THEIR APLICATIONS

Eugen MANTA[1], Mirela M. CODESCU[2], Maria PETRESCU[3]

Studiile şi cercetările experimentale s-au axat pe realizarea unor microfire feromagnetice acoperite cu sticlă care să fie utilizate în aplicaţii industriale. Cercetările au avut la bază studii asupra metodelor de obţinere şi caracterizare ale microfirelor feromagnetice şi utilizarea lor în industrie. Microfirele au fost caracterizate din punct de vedere structural şi magnetic. S-a făcut o comparaţie între trei tipuri de microfire din acelaşi aliaj (Fe-B-Si) obţinute în condiţii diferite, adică distanţa dintre vârful picăturii şi răcirea cu apă a fost modificată. S-au studiat condiţiile de obţinere a compozitelor armate cu microfire feromagnetice pentru aplicaţii ca etichete anti-furt cu microfire feromagnetice, elemente de securizare a produselor şi documentelor de valoare securizarea hârtiilor de valoare, respectiv ecranarea contra radiaţiilor electromagnetice.

The studies and experimental researches focused on the development of some ferromagnetic glass-coated microwires that can be used in industrial applications. Researches were based on studies related to the preparation and characterization of ferromagnetic microwires and their use in industry. Microwires have been characterized structurally and magnetically. It has been done comparison between three types of microwires of the same alloy (Fe-B-Si) obtained in different conditions, meaning that the distance between the drop of molten alloy and cooling water was modified. It has been studied the conditions for obtaining composites reinforced with ferromagnetic microwires for applications such as anti-shoplifting labels based on glass coated microwires, elements for securisation of products and documents authentication, or shielding against electromagnetic radiation

Keywords: ferromagnetic glass-coated microwires, Taylor-Ulitovsky method

1. Introduction

This paper takes into the account an original subject, that of preparation of ferromagnetic microwires for specific applications. The novelty of this work

[1] PhD student, Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Romania, e-mail: eugen_12_01@yahoo.com
[2] PhD, National Institute for R&D in Electrical Engineering ICPE - CA, Bucharest, Romania
[3] Prof., Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Romania

consists into the preparation of ferromagnetic microwires, which can be used for complex applications.

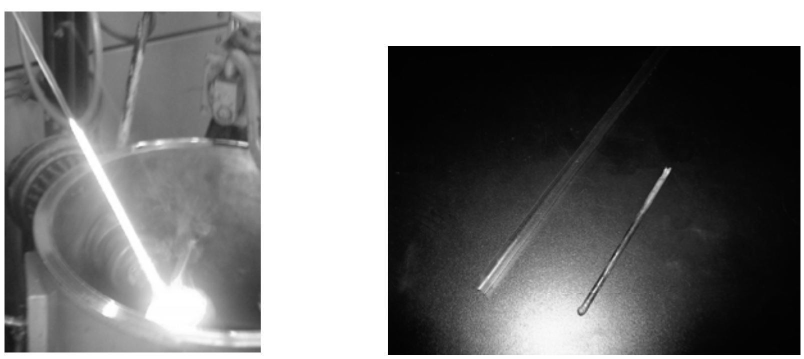
Amorphous microwires, being among the softest magnetic materials, present outstanding peculiarities. Those with large and positive magnetostriction, exhibit bistable behavior with magnetization reversal through a giant Barkhausen jump originating in the propagation of a single-domain wall [1].

A number of outstanding magnetic properties, such as magnetic bistability, enhanced magnetic softness, and GMI effect (up to 600%), have been discovered recently in such microwires [1–5].

The preparation of insulated glass microwires was reported for the first time in 1941 by G. E. Taylor. [6] To obtain microwires, Taylor put metal in a horizontal glass tube. With a gas burner, the metal and glass tube were heated, and after metal melting and glass softening, the glass tube was quickly spread. In 1948, A. Ulitovsky proposed a method for obtaining glass coated microwires, through heating and pulling glass capillary filled with metal [7].

2. Experimental

The experiments consisted in preparation of road samples (see Fig.1), from Fe-B-Si and Co-Fe-B-Mn-Cr-Si alloys. Melting and alloying was carried out in an induction furnace, Leybold-Heraeus type, starting from pure elements, namely: electrolytic Cr, Mn (99.9% purity), Si (technical purity) Fe (99.7% purity), and Fe80-B20 masteralloy.



a) b)

Fig. 1 Preparation of rod sample in a Heraeus furnace a); resulted rods b)

In order to prepare glass-coated microwires through Taylor-Ulitovsky method, the alloys rods were used as precursors. The processing technique for microwires preparation consists in placing a glass tube in which a metal or alloy rod was inserted in a field of a high frequency induction. Under the influence of the electromagnetic field the metal melts forming a drop. Part of the glass tube in contact with the molten metal softens and forms a sheath (mantle), covering the drop. In certain operating regimes, this glass and metal softened by drawing trains, leading to the formation of microwires, which are collected on spools. Fig. 2 presents aspects during the microwires fabrication process.

The chemical composition of the prepared alloys was investigated by EDS technique, on the FESEM-FIB Auriga integrated workstation.

The structure and the magnetic properties of the prepared alloys and compounds, were investigated by optical microscopy (using a Karl Zeiss Jena microscope), SEM, XRD (using an X-ray diffractometer Brucker AXS D8 ADVANCE type), and magnetization measurements, performed on vibrating sample magnetometer, 7300 Lake Shore type.

The microwires tensile strength and elongation were measured using a tensile testing system (provided by W + b Walter AG BAI AG).

Fig. 2 Aspects during the microwires preparation process

3. Results and Discussion

The alloys analyzed by SEM revealed similar morphological and structural features. Figs. 1 and 2 show the micrographs of typical glass-coated microwires, where their composite character can be clearly seen.

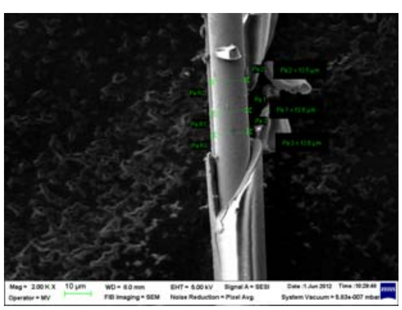


Fig. 3 Micrograph of a glass-coated microwire from the Co-Fe-B-Mn-Cr-Si system

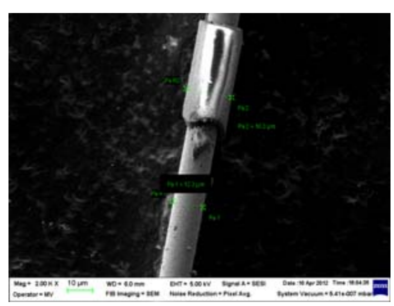


Fig. 4 Micrograph of a glass-coated microwire from the Fe-Si-B system

Fig. 5 shows the diffraction patterns obtained for three microwires, prepared in different conditions, meaning that the distance between the drop of molten alloy and the glass edge was different. One can notice the appearance of peaks of different intensities, depending on this distance. As the distance is greater, the peak's intensity is higher, due to higher crystallization time sufficient for the appearance of a higher proportion of crystalline phase. The conclusion that emerges is clear: structural features of microwires can be tailored by adjusting their processing parameters. So, one can obtain glass-coated microwires with various structures of the metallic core: amorphous or polycrystalline, characterised by different sizes of crystals (microcrystalline or nanocrystalline).

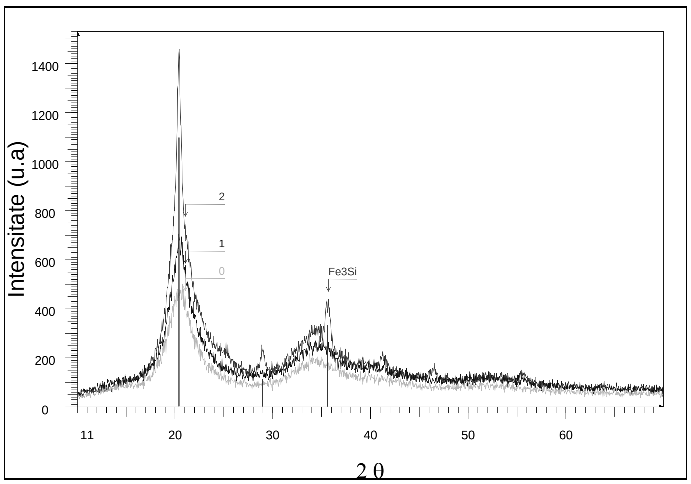


Fig. 5 XRD pattern for Fe-Si-B microwires

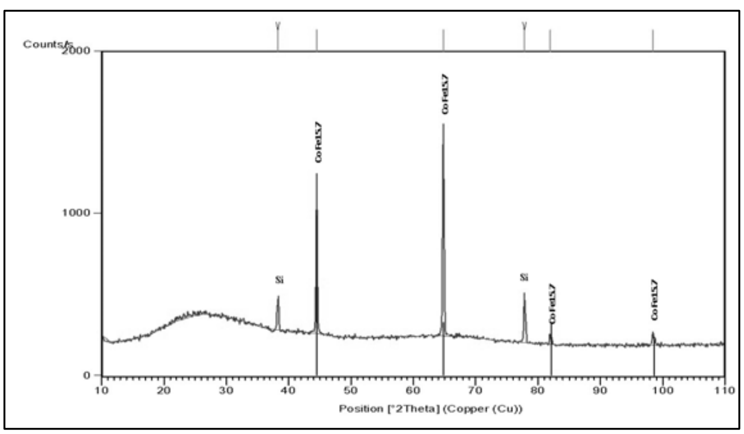


Fig. 6 XRD pattern for Co-Fe-B-Mn-Cr-Si microwires

From Fig. 6 we can remark that the microwires structure is microcrystalline for the Co-Fe-B-Mn-Cr-Si alloy, being evidenced by the presence of peaks identified in the database as belonging to Si (2 peaks, at angles 2θ = 38° and 2θ = 78°) and to the $CoFe_{15.7}$ phase (4 peaks, at angles 2θ = 44.5°, 2θ = 65°, 82° and 2θ = 98.5°). It is assumed that the other elements found in the composition of the metalic core of the Co-Fe-Mn-Cr-B-Si microwires are in amorphous state in the form of elementary or solid solutions.

For magnetic characterization, it was necessary to plot the hysteresis cycles. This indicates the magnetic behaviour of alloys, the magnetic moment of each alloy and the saturation.

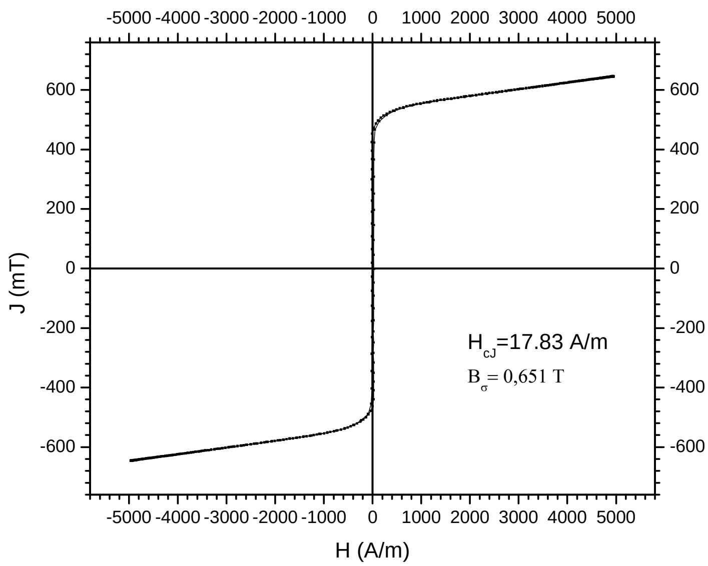


Fig.7 Hysteresis loops for Fe-Si-B microwire

Fig. 7 presents the hysteresis loop for a Fe-B-Si microwire. Based on this loop we can determine the microwires main magnetic characteristics: B_S = 0,651 T and H_c = 17,83 A/m.

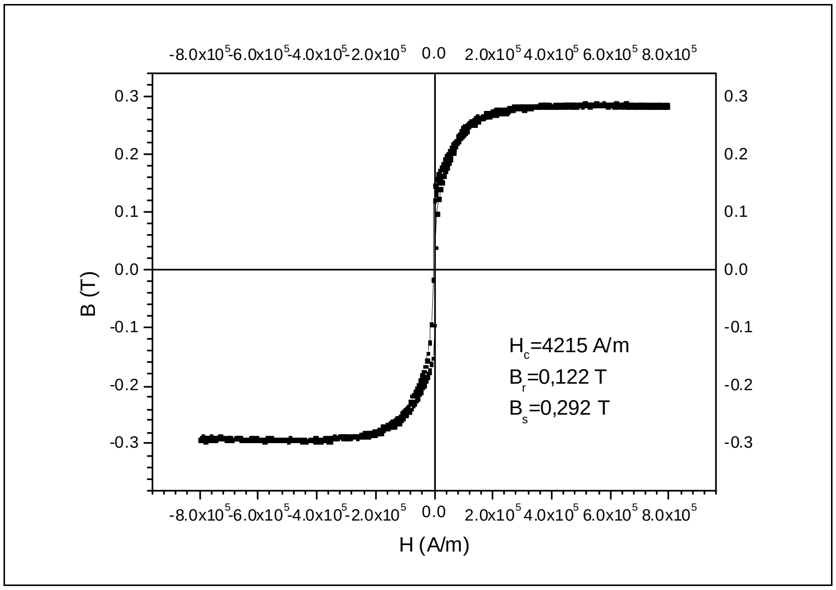


Fig. 8 Hysteresis loops for Co-Fe-B-Mn-Cr-Si microwire

Fig. 8 presents the hysteresis loop for a Co-Fe-B-Mn-Cr-Si microwire. Based on this loop we can we see: B_r = 0,122 T, B_S = 0,292 T and H_c = 4,21 kA/m. As it can be seen from the hysteresis loop shape and from the values of the principal magnetic characteristics, the microwire metallic core consists in soft magnetic material.

4. Aplication

Such novel materials as microwires have been introduced recently, mainly by European physicists in a laboratory level and proved to be very promising in many technological applications owing to their excellent magnetic and mechanical properties. [8 – 12]

Depending of the nature of metallic core, the microwires properties are very different. So the glass-coated microwires field of application can be very large: conductors-microcables for telecommunication, miniaturised high-voltage transformers, elements for magnetic encoding, sensitive elements for magnetic sensors, electromagnetic shields, anti-shoplifting labels based on glass coated microwires, elements for securisation of products and documents authentication, brand protection, and access control, encoding of information, under floor heating systems installed directly under all types of floor covering.

In these applications the ferromagnetic microwires can be embedded in different matrices. For example, to secure special documents, the microwires are embedded into a cellulose matrix and using a detector (see Fig. 10), can be detected the papers without microwires (Yes / No response method of authentication) [13].

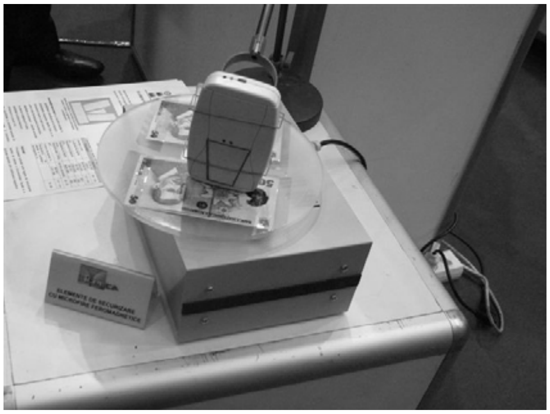


Fig. 10 System for detecting the microwires from special securised papers

Fig. 11 Composite textile with inserted microwires for electromagnetic shielding

The glass-coated microwires can be inserted in a textile matrix (see Fig. 11) or embedded in a polymeric matrix (constituted from siliconic or epoxy resins). The new composite materials, with ferromagnetic microwires as fillers, prove shielding properties against electromagnetic radiations generated by different sources.

5. Conclusions

The results obtained during the experimental research show that, through selection of the suitable alloys, using the Taylor – Ulitovsky technique, one can prepare glass-coated microwires, characterized by special electric, magnetic, resistive, conductive properties.

The remarkable properties, conjugated with the fine size and the corrosion resistance conferred by the presence of the glass coating, make the microwires potential candidates for key components in different fields: paper securisation, electromagnetic shielding, sensors, actuators, electronics and electrical engineering.

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