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PREPARATION OF COMPOSITE WIRE Fe_XNi_{100-X}/Cu WITH MAGNETOIMPEDANCE (MI) EFFECT

PART II - RELATION BETWEEN COMPOSITION, STRUCTURE, MAGNETIC PROPERTIES AND MI EFFECT

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SUMMARY

Relation between composition and structure, magnetic properties and magnetoimpedance (MI) effect of electrodeposited composite wire Fe_xNi_{1-x}/Cu were investigated. Results showed that the increase of Fe content enhanced the bcc phase and decreased the grain size of the deposited alloy. The coercively H_c of the composite wire Fe_xNi_{100-x}/Cu varied with composition and achieved the lowest value of 1.49 Oe with the wire composition of $Fe_{54}Ni_{46}/Cu$. MI effect was strongly influenced by the wire composition and corresponded well with the change of coercively. the maximum values of MIr_{max} were 110% (f = 4.5 Hz) and 23% (f = 10.7 Hz) with the wire composition of $Fe_{54}Ni_{46}/Cu$.

I - INTRODUCTION

In the first part of this paper, we have demonstrated that Fe_xNi_{100-x}/Cu composite wire prepared by electrodeposition technique could achieve MI ratio up to 120%. It was known that the MI effect, which appears as result of the magnetic transport in the surface layer of the wire, is closely related to the magnetic properties of the Fe_xNi_{100-x} layer [1, 2]. On the other hand, the magnetic properties of the electrodeposited Fe_xNi_{100-x} layer are strongly influenced by their composition and structure [3, 4]. Therefore, in order to control the MI effect of the Fe_xNi_{100-x}/Cu composite wire, it is useful to understand the relation between compositions, structure, magnetic properties of the materials.

This paper will present results on the influence of deposited layer composition on structure, magnetic properties and MI effect of the Fe_xNi_{100-x}/Cu composite wire.

II - EXPERIMENT

The five wire compositions used in this investigation are Ni/Cu, $Fe_{55}Ni_{45}/Cu$, $Fe_{71}Ni_{29}/Cu$, $Fe_{77}Ni_{23}/Cu$, $Fe_{95}Ni_5/Cu$. The procedure and electrodeposition and electrolyte concentration were described in the first part of this paper. Current density used electrodeposition is $D_c = 125\ mA/cm^2$.

Grain size of Fe_xNi_{100-x}/Cu magnetic layer was determined from the X-ray diffraction (XRD) using Sherrer formula [5]:

$$L = \frac{0.9\lambda}{B.\cos\theta} \quad \text{(P2)}$$

Where λ is wavelength of Ni (λ = 0.1542 nm), B is effective full width at maximum (determined from the Gaussian distribution function of (111) peak), 2θ is diffraction angle. Magnetic properties were investigated by vibrating sample magnetometry (VSM). MI-ratio was measured by MI-measure equipment at Lab. of Amorphous and Nanocrystalline Materials (Hanoi University of Technology). The measurement frequencies used in this study are f = 4.5 MHz and f = 10 MHz.

III - RESULTS AND DISCUSSION

Fig. 1 displays SEM images of $Fe_{55}Ni_{45}$/Cu composite wire and surface of the deposited layer. It can be observed that the $Fe_{55}Ni_{45}$ layer is uniformly deposited on the Cu wire and surface of the layer is relatively smooth. These factors are important since a non-uniformed and rough surface may cause unclear and noised MI effect of the wires.

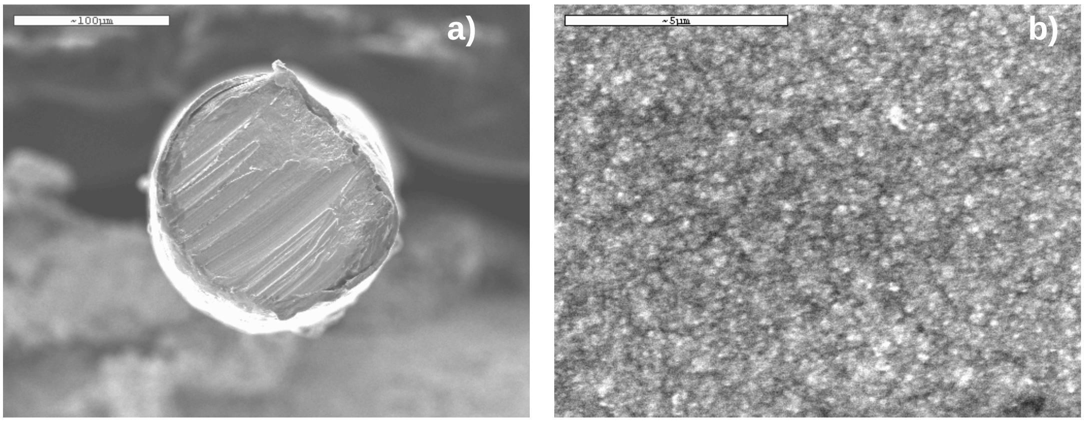

Fig. 1: SEM images of $Fe_{55}Ni_{45}$/Cu composite wire
(a) cross- section (b) surface of the wire

Fig. 2 represents XRD patterns of Fe_xNi_{100-x} (x = 0 - 95) alloys electrodeposited on Cu wires. It can be observed that the structure of the deposited alloys are characterized by bcc phases ((111) and (110) orientations) and fcc phases ((200) orientation). Tab. 1 shows intensity ratio I_{bcc}/I_{fcc} and the mean grain size L of the FeNi alloy calculated from XRD pattern. It can be observed that with increasing Fe content in the alloy, the I_{bcc}/I_{fcc} ratio tends to increase and the grain size of the crystal decreases.

Table 1: Intensity ratio I_{bcc}/I_{fcc} and mean grain size L of the Fe_xNi_{100-x} alloy calculated from XRD patterns (Fig. 2) using Sherrer equation (1)

Alloys	Ni	$Fe_{55}Ni_{45}$	$Fe_{75}Ni_{29}$	Fe_{77} Ni_{23}	$Fe_{95}Ni_5$
I_{bcc}/I_{fcc}	12,1	10,7	5,2	3,6	1,5
L (nm)	34	25	29	35	34

Fig. 3 displays hysteresis loops and correspondent coercively H_c of the Fe_xNi_{100-x}/Cu wires with different alloy composition. Results show that lowest H_c (1.9Oe) was obtained with wire $Fe_{59}Ni_{41}$/Cu, while H_c of the wires Fe_xNi_{100-x}/Cu (x = 71 - 95) do not show remarkable changes (H_c = 4.1 - 4.9 Oe). This result can be explained by the fact that the composition $Fe_{56}Ni_{44}$ is quite close to the perm alloy composition $Fe_{55}Ni_{45}$, which is reported to have lowest coercively [7]. I should also be mention that these results also agree with the XRD analyses, which confirms that the bcc phases are dominated and the grain size is smallest for the wires $Fe_{56}Ni_{44}$/Cu.

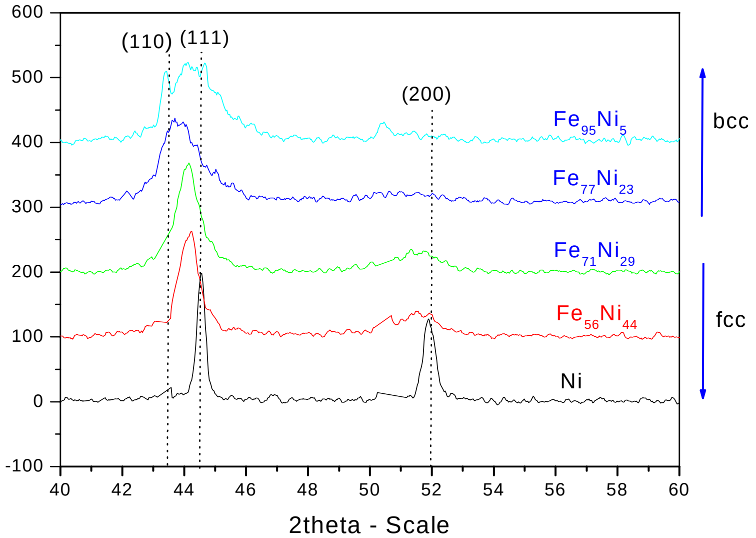

Fig. 2: XRD patterns of electrodeposited Fe_xNi_{100-x} (x = 0 - 95) alloys

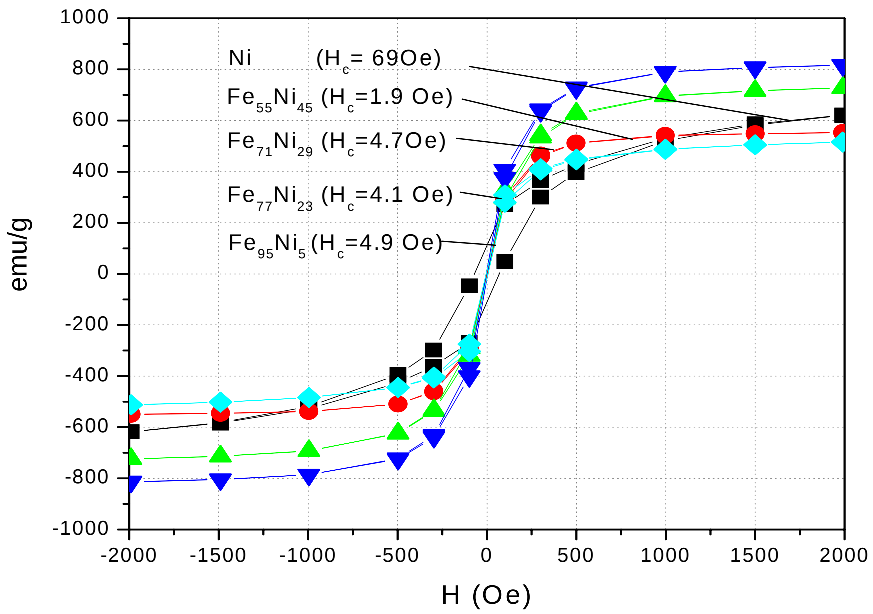

Fig. 3: Hyteresis loop of the electrodeposited wires Fe_xNi_{100-x}/Cu (x = 0 - 95)

The MI curves of Fe_xNi_{100-x}/Cu (x = 0 - 95) wires measured at frequencies f = 4.5 Hz and f = 10.7 Hz are presented in Fig. 4. It can be observed that for all Fe_xNi_{100-x} alloy composition, the wires have MI effect with characteristic double-peak behaviour. However, the MIr values are strongly dependent on composition of the electrodeposited Fe_xNi_{100-x} layer and measurement frequency. The changes of maximum MIr values (MIr_{max}) depending on wire composition and measurement frequency shown in Fig. 5 clearly indicate that the maximum MIr_{max} value was obtained by the alloy $Fe_{55}Ni_{45}$ and the MIr_{max} value increases with decreasing frequency. It is also interesting to note that the changes of MIr_{max} and coercively H_c follow in the same rules e.g. H_c increases causes the decreasing of MI and vice versa (Fig. 5). This behaviour can be explained by the fact that composition decides coercively H_c of the deposited Fe_xNi_{100-x} layer, and on the other hand MIr increases with decreasing H_c via the increase of effective permeability μ_{eff} following the equation (1),(2) [2]:

$$MIr = \frac{Z(H) - Z(H=0)}{Z(H=0)}(\%) \qquad (1)$$

$$Z = A\sqrt{f\mu_{eff}(f, H_c)} \qquad (2)$$

Where A is constant, f is frequency, μ_{eff} is effective permeability, H_c is coercivity. Those relations explain the obtained results shown in Fig. 5.

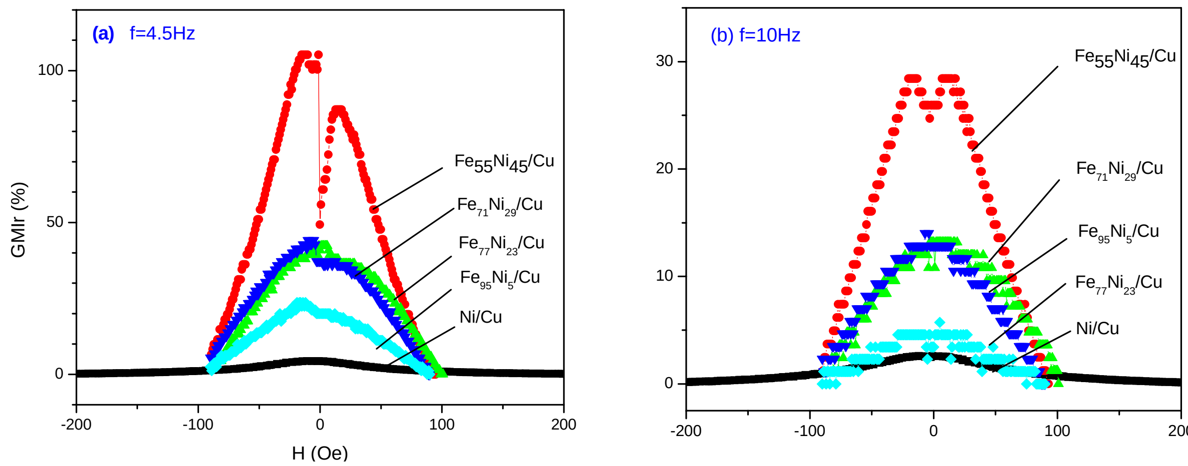

Fig. 4: MI curves of the electrodeposited wires Fe_xNi_{100-x}/Cu (x = 0 - 95)

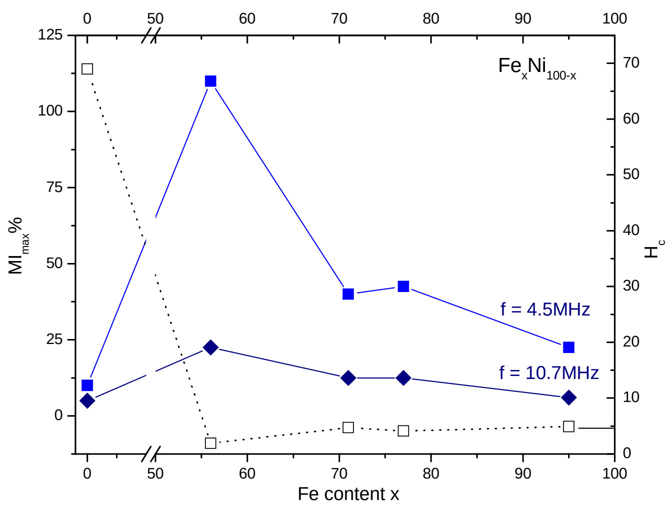

Fig. 5: Influence of Fe content (x) on MI_{max} *(solid curves)* and H_c *(dashed curve)* of the electrodeposited wires Fe_xNi_{100-x}/Cu (x = 0 - 95)

IV- CONCLUSION

We investigated systematically the influences of composition of the electrodeposited Fe_xNi_{100-x} layer on structure and MI effect of the wires Fe_xNi_{100-x}/Cu (x=0-95). Results showed that as Fe content in the alloy increases, the bcc phases in the deposited

Fe_xNi_{100-x} layer increases and the grain size decreases. The coercivity H_c of the composite wire Fe_xNi_{100-x}/Cu varies with composition and achieved the lowest value of 1.49 Oe with the wire composition of $Fe_{54}Ni_{46}$/Cu. MI effect was strongly influenced by the wire composition and closely related to the change of coercively H_c. the maximum values of MI_{max} were 110% (f = 4.5 Hz) and 23% (f = 10.7 Hz) with the wire composition of $Fe_{55}Ni_{45}$/Cu.

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