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# FABRICATION AND SELECTED PROPERTIES OF MULTILAYER Fe/Cu SYSTEMS

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The paper presents investigation results of the structure and selected physical properties of multilayer systems obtained by the electrolysis method. The obtained samples compose of 20 alternate layers of Fe/Cu with the following single layer thicknesses: 50 nm and 100 nm. The multilayer Fe/Cu systems for electromagnetic field shielding are characterized by relatively good quality. On the basis of topographical tests, no major defects have been found. As a result of magnetic studies, it has been found that the samples are magnetically soft materials.

*Key words:* Fe/Cu systems, electrolysis method, electromagnetic fields shielding, multi coating, structural tests

## INTRODUCTION

Nowadays, the man is exposed to a large number of electromagnetic waves, thus suppressing (shielding of) those waves is an important problem [1].

Theoretically, each barrier located between the source and the receiver of such waves - which to some extent reduces the strength of interference - may be considered as an electromagnetic screen [2].

The material which the screen is made from, as well as the frequency and the distance from the source of the wave [3, 4] have the most important influence on the shielding effectiveness.

Development of new coating technologies made it possible to obtain multilayer materials with increasingly thinner layers, with the thicknesses of about several nanometres [5 - 7].

Multilayer metal systems are used to improve the quality of screening. The use of such methods as electroplating or physical vapour deposition (PVD) allows achieving a high level of shielding. The whole concept is based on alternate use of conductive and ferromagnetic layers.

Those materials have many interesting magnetic, optical, electric and mechanical properties.

The prefabricated multilayer systems dedicated for electromagnetic waves shielding must fulfil several conditions in order to achieve maximum efficiency [8]:

– to achieve the minimum depth of electromagnetic field penetration in a material one must obtain high values of relative permeability of the shielding material, its magnetic permeability and the static losses. This is due to the fact that the smaller the penetration depth, the greater the absorption coefficient,
– to design a low thickness screen one needs materials with the above mentioned properties. This, in turn, will result in the increase of impedance of the screen, and therefore the reflection coefficient, and will lead to a multiple reflection inside the screen,
– the greater the difference in the wave impedance of the combined materials, the greater the wave reflection.

M. Spilka, A. Kania, R. Nowosielski, Silesian University of Technology, Institute of Engineering Materials and Biomaterials, Gliwice, Poland.
A. Maciej, Silesian University of Technology, Department of Inorganic, Analytical Chemistry and Electrochemistry, Gliwice, Poland.

## EXPERIMENTAL DETAILS

The substrate for research was a copper foil with dimensions of 50 x 50 mm and 50 *µm of thickness*. The samples were made by electrolysis. 20 alternate layers of Fe and Cu were applied and the thickness of a single layer was 50 nm and 100 nm. The electrolysis process involved alternate immersion of samples in a copper and iron bath (Table 1). The copper plating process took place in a cyanide bath with current density of $J_k$ = 0,25 mA/cm$^3$.

The iron plating process took place in a sulphate bath, $J_k$ = 5,0 mA/cm$^3$.

Observation of the surface structure of deposited coatings was made using a scanning electron microscope (SEM) Supra 25 by ZEISS.

The topography of the samples was examined using an atomic force microscope by Park System X-E 100. The aim of the study was to observe irregularities of the surface on obtained coatings. The results were compared with irregularities on the substrate. Moreover, existing irregularities were roughly measured.

Three samples with the dimensions of 120 x 120 mm were studied. The first one was the sample of the substrate – copper foil. Another one was the sample with Fe/Cu (50 / 20) coating and with Fe/Cu (100 / 20) coating. For all the samples, the tested area was 25 x 25 µm.

The test of magnetic properties was carried out in a vibrating sample magnetometer.

## RESULTS AND DISCUSSION

The surface structure of the obtained multilayer systems is shown in Figures 1-4.

Figure 1 presents the sample surface of Fe/Cu with a single layer thickness of 50 nm, while Figure 2 presents the surface of the sample with a single layer thickness of 100 nm.

The obtained coatings are continuous. Grains of the copper crystal with distinct grain boundaries can be seen.

The surface of Fe in the Fe/Cu system is characterized by a compact, continuous structure with visible peaks, derived probably from the substrate (Figure 3).

Grains of the Fe crystal with random layout with visible areas of crystal boundaries and local pores can be seen on the surface (Figure 4).

After observation of the surface in the scanning electron microscope, it was found that the coating applied on the copper foil by the electrolysis process is of good quality.

The process of applying the iron layer was more difficult to carry out. At first, slow growing crystal nuclei were formed.

Then, observation of the sample surface topography was carried out.

Figure 5 shows a three-dimensional visualization of topography of the copper foil – the substrate. Elevations and the level of the surface roughness can be observed.

Measurements of differences in the position of selected points are shown in Table 2.

Two following samples were subjected to corresponding observations. An example of visualization of the sample topography with Fe/Cu 100 / 20 coatings is shown in Figure 6.

Table 2 **Measurements of the differences in markers position – the substrate (copper foil)**

| ΔX / µm | ΔY / µm | angle / degree |
|---|---|---|
| 4,199 | 822 | 11,081 |

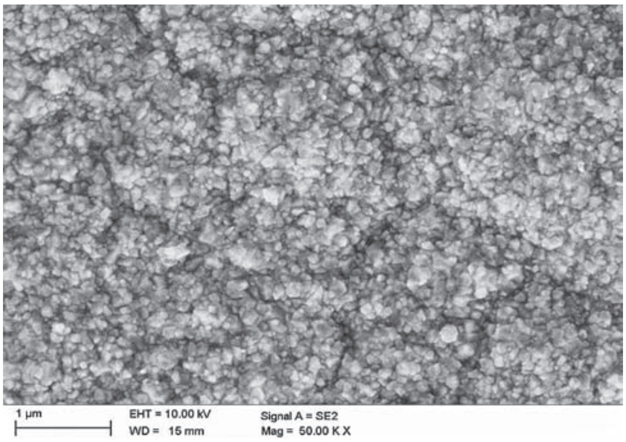


**Figure 1** Cu coating in Fe/Cu system, a single layer thickness is 50 nm, 50 000 x

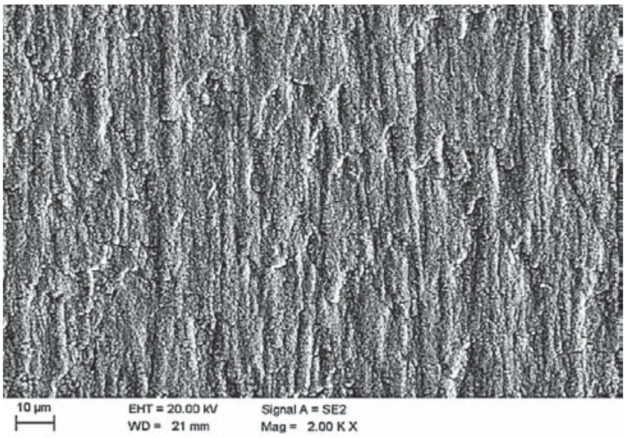


**Figure 3** Fe coating in the Fe/Cu system, a single layer thickness is 50 nm, 2 000 x

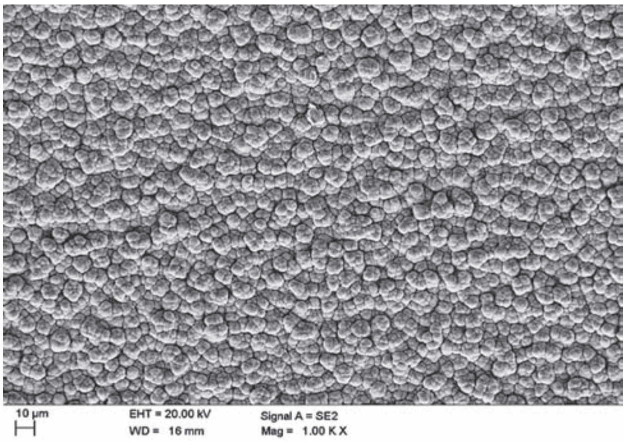


**Figure 2** Cu coating in Fe/Cu system, a single layer thickness is 100 nm, 1 000 x

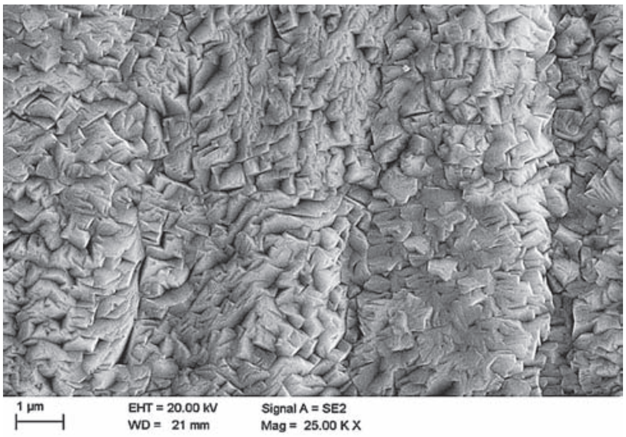


**Figure 4** Fe coating in the Fe/Cu system, a single layer thickness is 100 nm, 25 000 x

Table 1 **Parameters of iron and copper plating processes**

| Sample symbol | Layer thickness / nm | Bath temperature / °C | Duration of iron plating / s | Duration of copper plating / s |
|---|---|---|---|---|
| Fe/Cu 50 - 20 | 50 | room temperature | 30 | 330 |
| Fe/Cu 100 / 20 | 100 | room temperature | 60 | 660 |

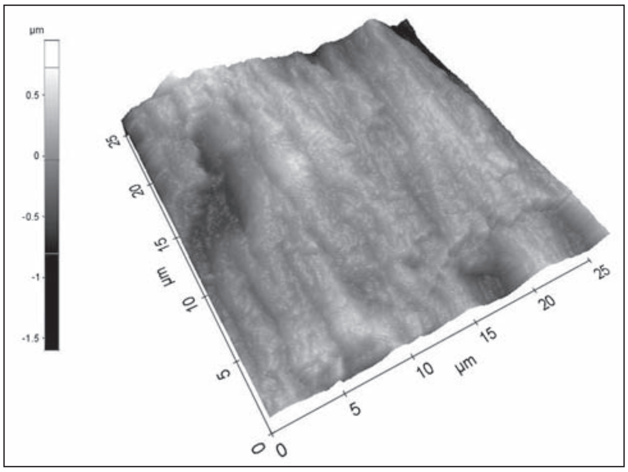

**Figure 5** Three-dimensional visualization of topography of sample surface (copper foil)

Measurements of the differences in the position of the selected markers are presented in Table 3.

Table 3 **Measurement of the differences in position markers (Fe/Cu 100 / 20 sample)**

| ΔX / μm | ΔY / μm | angle / degree |
|---|---|---|
| 6,348 | 1 180 | 10,533 |

The magnetic properties of the analysed systems were analysed using the vibrating sample magnetometer.

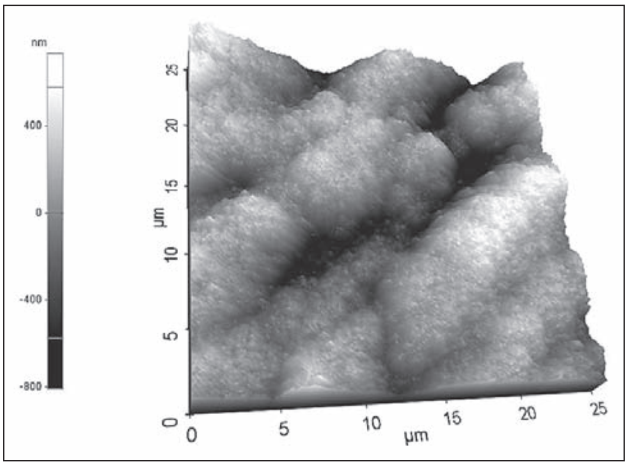

**Figure 6** The tree-dimensional visualization of the Fe/Cu 100 / 20 sample topography

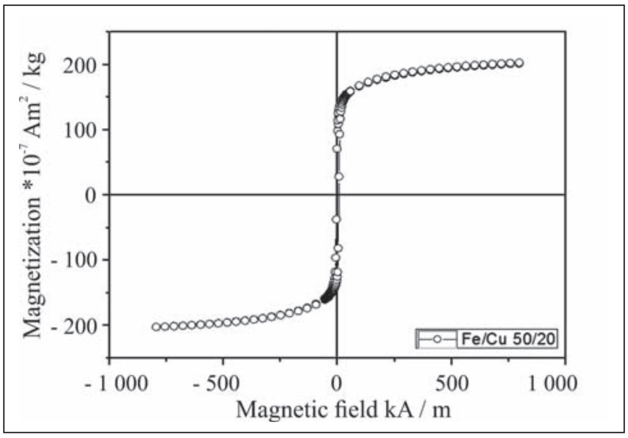


**Figure 7** The hysteresis loop of the Fe/Cu sample; the thickness of a single layer is 50 nm

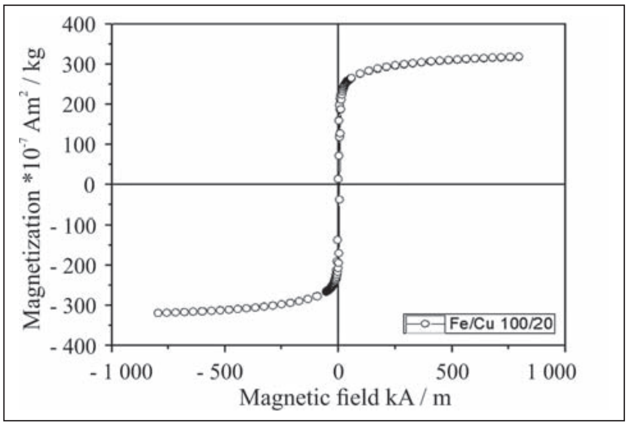


**Figure 8** The hysteresis loop of the Fe/Cu sample; the thickness of a single layer is 100 nm

Figures 7 and 8 show the hysteresis loops of Fe/Cu samples with a single layer thickness of 50 and 100 nm.

Figure 7 shows the hysteresis loop of the sample with a single coating thickness of 50 nm. The analysis was conducted within the range of -10 000 Gs ÷ 10 000 Gs. This measurement was additionally concentrated within the range of - 700 ÷ 700 Gs. The sample weight was 0,0052 g.

Figure 8 shows the sample with a thickness of a single coating of 100 nm. The measuring range was the same as in the case of the sample with a thinner coating (- 10 000 Gs ÷ 10 000 Gs, concentrated within the range of -700 Gs ÷ 700 Gs). The sample weight was 0,0063 g.

Based on the shape of the hysteresis loop it can be concluded that the obtained multilayer Fe/Cu systems are magnetically soft ferromagnetic.

## CONCLUSIONS

The electrolysis process allows applying good quality coatings, characterized by a continuous and compact structure.

Based on studies of the surface topography it has been found that the obtained coatings are of good quality, with irregularities similar to those occurring on the substrate.

In order to verify the effectiveness of the obtained multilayer Fe/Cu systems on electromagnetic fields screening, further studies are being conducted.

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**Note:** The responsible translator for English language is ITAMAR Group Sp. z o. o., Gliwice, Poland