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The electrochemical copper structure forming in the presence of the magnetic field

Abstract. *In the presence metallic layers settled on the surfaces by the electrocrystallization method play significant role in the engineering. Many kind of factors, including the magnetic field presence, decide about the metal's structure and its quality. The influence that can render the magnetic field in the electrochemical environment is significant. In the article the electrocrystallization issue and the effects of electrocrystallization received under the influence of different kind of the magnetic configuration are presented. There are shown phenomenons existing in the electrochemical bath and the effects of electrocrystallization process as the based microscope structure.*

Streszczenie. *Obecnie bardzo dużą rolę w inżynierii odgrywają warstwy metalowe osadzane na powierzchniach metodą elektrokrystalizacji. O strukturze metalu i jej jakości decyduje wiele czynników, do których dodano jeszcze obecność pola magnetycznego. Znaczący jest wpływ, jaki wywierać może obecność pola magnetycznego w środowisku elektrochemicznym. W pracy przedstawiono samo zagadnienie elektrokrystalizacji oraz porównano efekty otrzymane w wyniku elektrokrystalizacji pod wpływem różnego rodzaju czynników magnetycznych. W artykule przedstawiony zostanie przebieg zjawisk zachodzących w kąpieli elektrochemicznej i efekty procesu elektrokrystalizacji w postaci wyników badań mikroskopijnych otrzymanych struktur. (**Elektrokrystalizacja powłoki miedzianej pod wpływem pola magnetycznego**)*

Keywords: electrocrystallization, electrode processes, copper surface layer, magnetic field, MHD effect.
Słowa kluczowe: elektrokrystalizacja, procesy elektrodowe, powierzchniowa warstwa miedzi, pole magnetyczne, MHD zjawisko.

Introduction

The external world has a continual influence on the fabricated objects (electromagnetic field, corrosion or erosion). The above issue is the subject of researches in the material engineering. Nowadays the copper electrochemical deposition process is great interest of different industry branches. Metallic copper layers could be applied as moulding forms, which must have great resistance (mechanical, thermal one etc.). The possibilities of controlling the electrochemical process are simplified by the investigation during the electrodeposition with using e.g. the uniform magnetic field (s.p.m.). The researches of many scientists verify the magnetohydrodynamic (MHD) effect's emergence. In the article there are considered effects of changing settings of the magnetic source – neodymium magnets - and the electrode surface. Their orientation has an impact on the Lorentz's force location and a deposited setting layer. A parallel alignment with the electrode surface and magnetic field lines causes an increase in the Lorentz force. As results of it, a quality improvement of the deposited layer is observed [4].

The objective of the presented research was to show the correlation between the electrochemically deposited crystalline structure of metal and magnetic components near the electrolyte environmental. Moreover, the researchers concerned on measuring a surface potential distribution in a test sample. As a result, different metallic layers on a metallic object were obtained.

Electrochemical process of the copper setting

The electrocrystallization is the process where metallic layers are deposited on the cathode surface. It is the result of two processes – reduction and oxygenation, which occur at the electrodes.

$$Ox + ne^{-} \underset{k_{Ox}}{\overset{k_{Red}}{\leftrightarrow}} \mathrm{Re}\,d \qquad (1)$$

where: *kRed*, *kOx* – speed coefficient of the reduction and oxidation reaction, *n* – number of electrons which participate in the reaction.

The same velocity of both reactions caused the dynamic stability state of the electrocrystallization process.

This process consists of the following stages [2]:

- transport of the metal ions from the centre (electrolyte) to the cathode surface,
- reduction of metal ions to the atomic structures that applies on the cathode surface,
- creation of the crystalline centres called crystalline embryos and their growth.

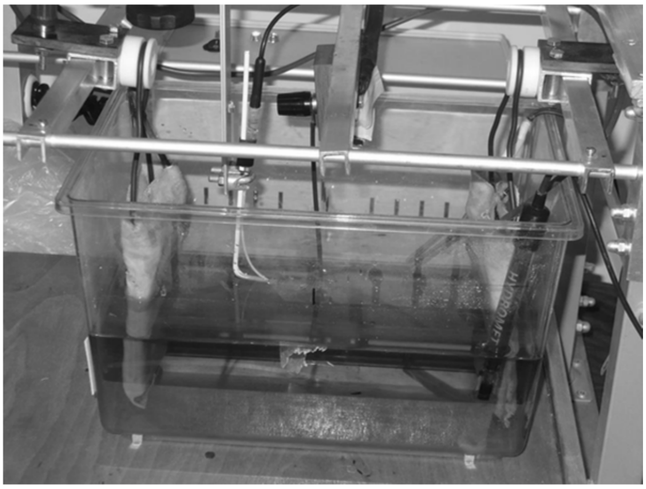


Fig.1. The general view of the electrolytic bath and measuring electrodes connected to the EMU system.

The electrocrystalization process may be divided in two parts. In the first stage of this process the reduction reaction of the metallic ions (Cu^{2+}) to the atomic structures (Cu^{0}) on the cathode surface occures. In the second stage the centres of crystallization (new seed crystals) are formed and their growth is later observed. This part generally decides about crystal structures and the quality of the electrochemically deposited metal (Cu). The metallic layer could be characterized as a fine-grained structure, a coarse grain structure and a dendrite structure. The first kind of these structures shows a high level of smoothness. The second kind of the structures presents a high level of roughness. The third kind of a layer cannot be used in technical processes.

The final view of the product depends on several factors, for example: the crystal phase, the electrolyte type, the substrate material, its structure and other parameters - such as current density, temperature of an electrolytic environment, its pH. The above-described process is widespread and is applied in many industry branches. The fabrication of moulds during production is very important. The deposited metallic layer should be a form of an exact copy of the final product.

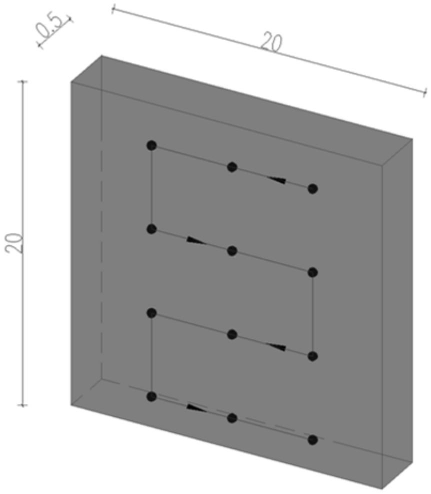


Fig.2. The general view of the dimensioned cathode [mm] and measurement places of this cathode.

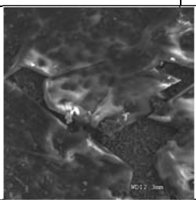
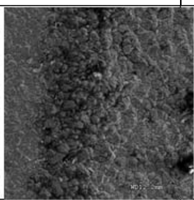
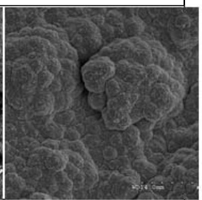
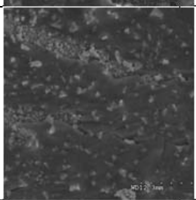
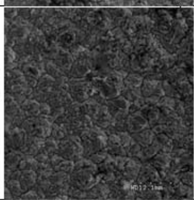
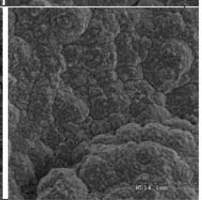
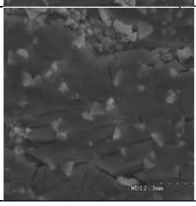
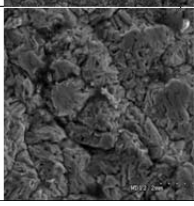
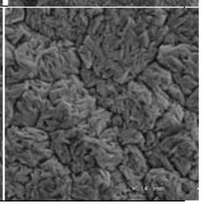
Increase	Probe 2	Probe 3	Probe 4
500			
1000			
2000			

Fig.3. Structure of the received copper's layers with increase changing (Probe 2, Probe 3, Probe 4 - with the magnetic field applying).

Research procedure and achieved results

The copper electrocrystallization process is conducted in the electrolyser filled with the multicomponent solution ($CuSO_4 \cdot 5H_2O$, H_2SO_4, HCl). Three electrodes – two Copper anodes (100×90×10 mm) and the silver cathode (20x20x0.5 mm) – are sunk in the bath. External power supply extorts the current flow (0.4 A) in an electrolytic environment [1]. Source of the magnetic field - a set of two magnets ($Nd_2Fe_{14}B$ - 40×15×5 mm) which indicate a homogenous magnetic field (300 mT each one) - were placed in various ways relatively to the electric field in an electrochemical environment. All experiments were carried out at room temperature. The laboratory stand was built as an independent control device connected to an arm steered by motors (a step of every 0.5 mm) that are controlled by the microcontroller (Fig.1., Fig.2.). Thanks to the above-mentioned solution was possible to measure and register values of the potential, the temperature coefficient, the electrochemical coefficient and the current on the PC computer, concurrently [5].

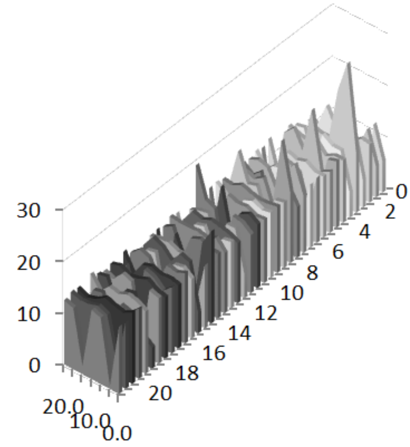


Fig.4. The potential distribution on the cathode surface with the use of neodymium magnets during the electrodeposition (Probe 2). Horizontal axis – number of measurement places of this cathode. Vertical axis – values of the potential [V].

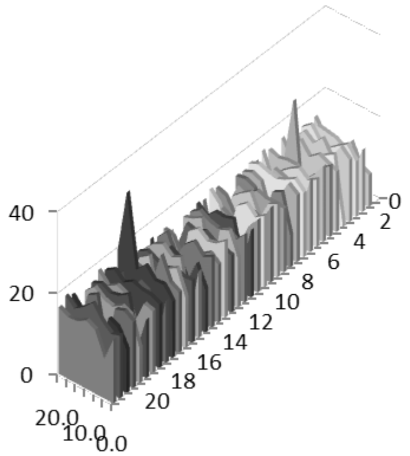


Fig.5. The potential distribution on the cathode surface with the use of neodymium magnets during the electrodeposition (Probe 3). Horizontal axis – number of measurement places of this cathode. Vertical axis – values of the potential [V].

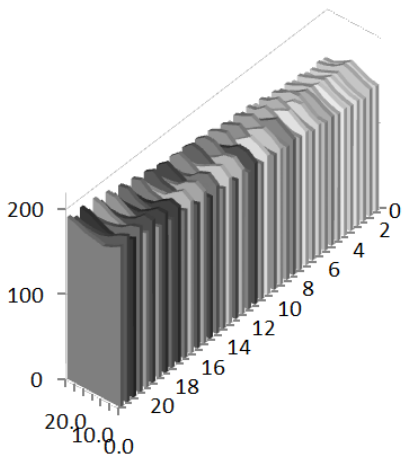


Fig.6. The potential distribution on the cathode surface with the use of neodymium magnets during the electrodeposition (Probe 4). Horizontal axis – number of measurement places of this cathode. Vertical axis – values of the potential [V].

Conclusions

Different kinds of the magnetic field's effects on the electrode surface during the electrocrystallization of Cu alloys were examined. SEM investigations were conducted and the surface morphology was studied. Measurements of the potential values in the surroundings of the cathode surface were carried out. During the Probe 2, Probe 3 and Probe 4 of the experiment different surfaces were formed under the influence of the magnetic field. A variable setting of neodymium magnets was to purpose of receiving diverse structures (Fig.3.). One structure has a fractal dimension (Probe 2). It is result of unsimilarity of field surrounding the cathode and sign of occurrence of edge effect. After the electrodeposition with the use of neodymium magnets, received surfaces are characterized as different crystal structures. During experiments with the use of the magnetic field, as it was possible to expect values of the potential around the cathode were more irregular than during the experiments without the magnetic field (researches carried out earlier). The potential dimension is dependent on intersecting lines of electric and magnetic field forces (Fig.4., Fig.5., Fig.6.). The correlation between the potential gradient and the magnetic field was confirmed during the research with the use of the magnetic field. Violent changes of the potential distribution were observed and measure in cases of a different orientations of the magnetic field sources (Fig.4., Fig.5.). It is possible to receive different values of potentials at the same current, but different specificity of coats. The electrocrystallization process could be influenced by the magnetic factor – the magnet and it gives us information about expected copper settings.

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