UDC 669.187.001.2

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ECOLOGICALLY CLEAN EVAPORATION-CONDENSATION METHOD APPLICATION FOR OBTAINING OF ELECTRICAL CONTACTS BASED ON COPPER COMPOSITE MATERIALS

Abstract. *In this paper is considered the electron-beam technology on new materials creation, including copper and its alloys, as one of the most promising directions of modern electrometallurgy. The formation process of condensed composite materials (CCM) using this technology is absolutely environmentally clean, because it occurs in a vacuum, in addition, similar materials are obtained in a single technological cycle, what is economically profitable.*

It is shown that this method was used for the first time to obtain structural composite materials Cu-Mo, Cu-W, Cu-Cr (massive sheet condensates weighting up to 30 kg separated from the substrate), which were used for electrical contacts and electrodes. The most industrial applications found the condensed from the vapor phase CM of Cu-Zr-Y-Mo and Cu-Cr-Zr-Y-Mo systems for discontinuous electrical contacts.

The mechanical properties of materials of Cu-Zr-Y-Mo system have been studied and it is shown that these materials are characterized by a sufficiently high electrical conductivity, hardness, strength and satisfactory plasticity, and mostly allows to refuse from silver-containing contacts, since they are not inferior, and in some cases exceed them for their operational reliability.

Key words: *method; evaporation-condensation; copper; composite materials; electrical contacts.*

Introduction

Historically, emissions of sulfur dioxide, which amount – 75%...80% of the total amount of pollutants produced during melting in the off-gas, are the most urgent environmental problem connected with the production of copper and its alloys. The main quantities of pollutants, except sulfur dioxide, fall on such elements as dust, nitrogen oxides, carbon monoxide generally presenting emissions of non-ferrous metallurgy enterprises and copper smelters in particular.

The presence of gases, vapors, particles of liquid and solid substances in the air adversely affect man and the surrounding biosphere. In terms of dust emissions, non-ferrous metallurgy is also one of the main polluting industries, its part is 2.8%. Therefore, to capture emissions of process gases in the production of copper and its alloys, more attention is paid to thorough design of process plants and processes, which requires additional material expenses and, accordingly, leads to a rise of the production process cost.

Main part

Modern technology requires for its development the elaboration of new and improvement of existing materials using production methods that do not harm the surrounding atmosphere [1]. One of such promising directions for creating fundamentally new materials, including copper and its alloys, is electron-beam technology [2, 3]. The process of condensed composite materials (CCM) formation is absolutely environmentally clear, as it occurs in a vacuum, in addition, similar materials are obtained in a single technological cycle, what is economically profitable.

Evaporation and subsequent condensation of metal and non-metal in vacuum is a relatively new scientific and technological direction in materials science. Until recently, evaporation-condensation processes exclusively were used as application of protective coatings (corrosion-resistant, heat-shielding, etc.) on products. For the first time this method was used in the SPE "Eltechmash" to produce constructional composite materials Cu-Mo, Cu-W, Cu-Cr (massive sheet condensates weighing up to 30 kg separated from the substrate), which were applied for electrical contacts and electrodes. For the first time, it has become possible to obtain bulk (massive) nanocrystalline materials at a deposition temperature above 300^{o} C, which have a complex of properties that are not specific of traditional polycrystalline materials (Fig. 1).

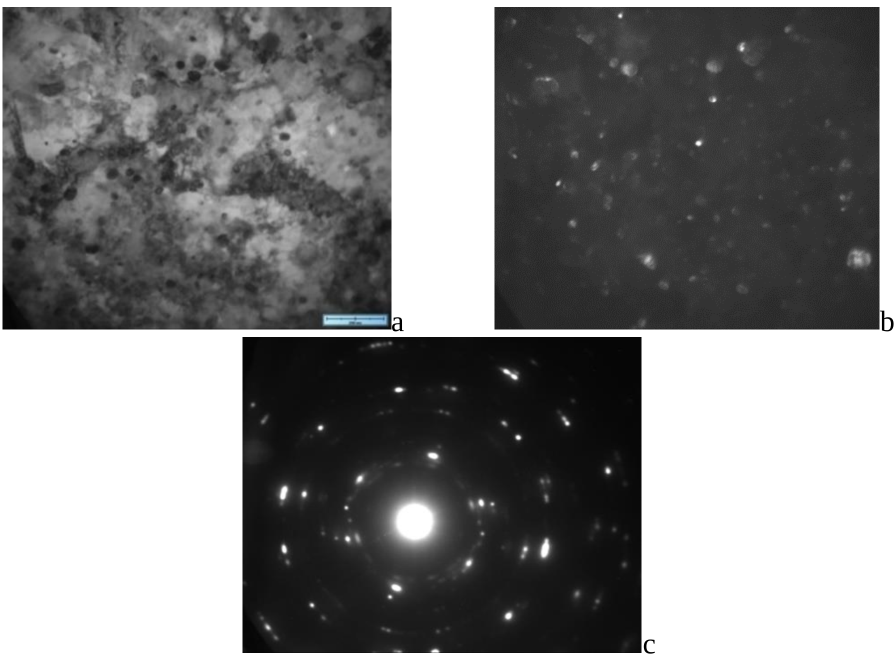

Fig. 1 – Light-field (a), dark-field (b) electron microscopic image of the structure and microelectronogram (in) CM (Cu-0.1% Zr, Y) -8-12% Mo

Application of CCM mostly allows to refuse from silver using, as the Cu-W contact materials are not inferior, and in some cases exceed the silver-containing compositions in terms of their operational reliability. Their cost is approximately in 1.5–1.7 times lower compared to powders and in 2–2.5 times lower compared to silver-containing compositions, and according to operational characteristics they correspond to them or 1.5 times higher depending on operating conditions.

To produce composite materials for electrical contacts, industrial equipment (installation L-5) has been developed (Fig. 2).

This makes it possible to produce about 12 tons of condensed composite materials per year, from which about 1 million electrical contacts and various electrodes can be produced (Fig. 3). Payback of such equipment is 2–3 years.

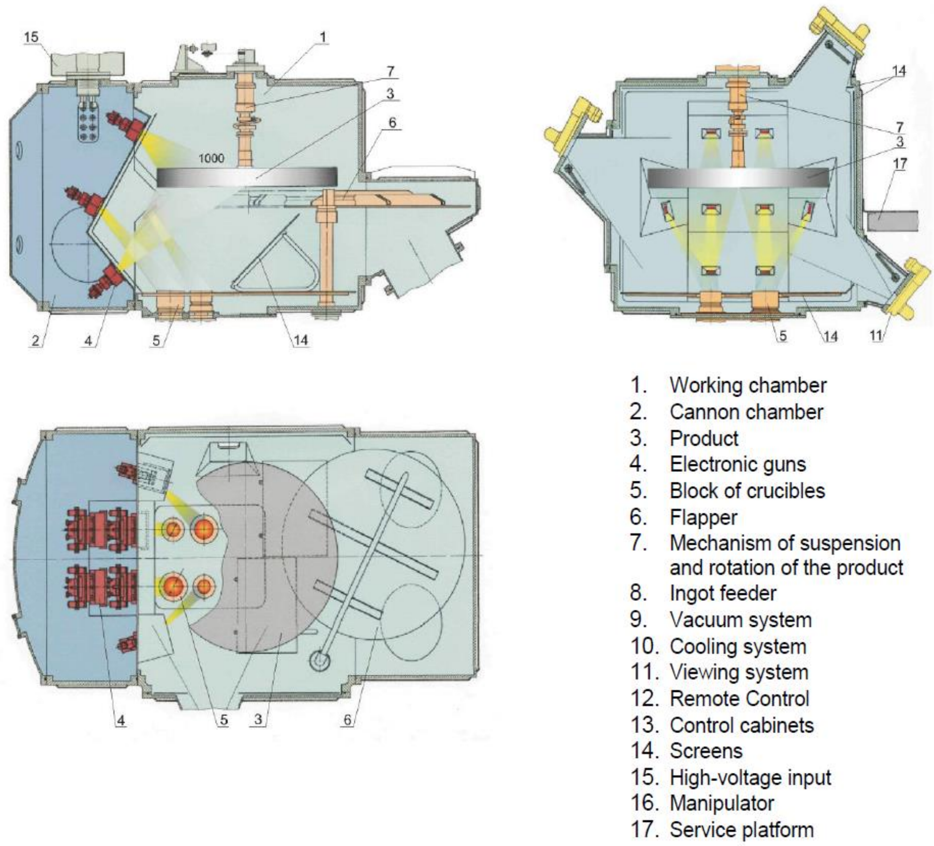

Fig. 2 – Installation L-5 scheme

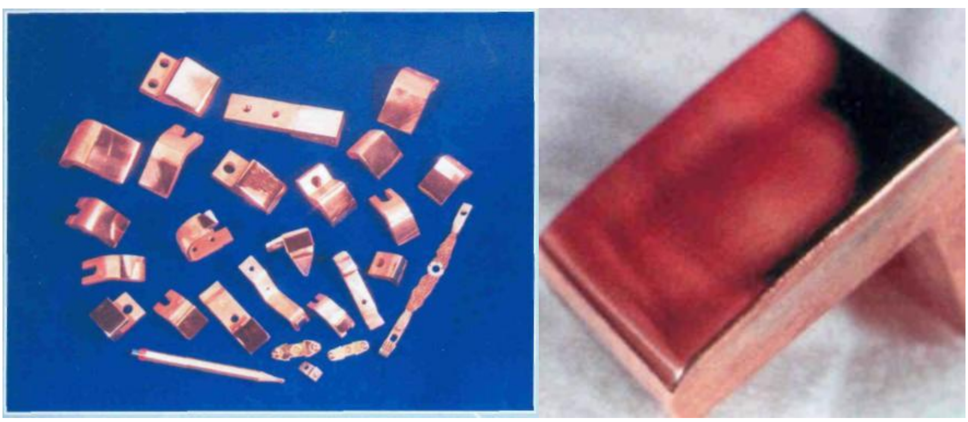

Fig. 3 – Types of electrical contacts

The condensed CM from the vapor phase of Cu-Zr-Y-Mo and Cu-Cr-Zr-Y-Mo systems found the largest industrial applications for discontinuous electrical contacts [4]. Materials, which received the name of MDK, are certified and manufactured in accordance with the technical specifications TCU 20113410.001-98, ISO-2009. Patents of Ukraine and the Russian Federation [4–7] protect the technology of their manufacture. These materials are characterized by a sufficiently high electrical conductivity, hardness, strength and satisfactory ductility (Table 1).

Table 1 – Physical, chemical and mechanical properties of CM on the base of Cu-Zr-Y-Mo

chemical composition, % mass.	density, γ, kg/m^3	electrical resistivity, ρ, μOm*m	Micro-hardness HV	Mechanical properties					
				Before annealing			After annealing, 300°C, 1h		
				$\sigma_{0,2}$, МПа	$\sigma_в$, МПа	δ,%	$\sigma_{0,2}$, МПа	$\sigma_в$, МПа	δ,%
Cu-Zr-Y 3-5% Mo	8980-9000	0,021-0,022	1000-1500	210-370	300-430	10,3-7,3	200-360	295-420	17,6-9,5
Cu-Zr-Y 5,1-8% Mo	9000-9050	0,022-0,024	1500-1650	380-530	440-630	7,25-3,4	365-510	425-600	9,45-4,9
Cu-Zr-Y 8,1-12% Mo	9050-9100	0,024-0,028	1650-1800	550-750	635-785	3,25-1,8	520-695	605-730	4,85-3,9
Cu-Cr- Zr-Y 8,1-12% Mo	9050-9100	0,026-0,030	1650-1800	560-760	641-792	3,21-1-7	531-699	618-742	4,70-3,6

A number of specialized electron beam devices for metals and alloys smelting and refining are known [1, 8], deposition of protective coatings [9–11], obtaining of massive composite materials separated from the substrate [12].

The design and manufacture of specialized electron beam installations is not always economically viable, since only a certain scientific and technological problem can be solved on this type of equipment (for example, the development of new types of protective coatings).

Conclusions

The creation of universal equipment that allows, after a small adjustment, to solve a number of applied research tasks is more promising. A distinctive feature of such equipment is the possibility of implementation, on one installation, the majority of typical technological processes, which are currently being implemented with the help of various special-purpose electron beam systems. Cleaning of the installation with the ion-cleaning device and the process gas inlet system also expands the technological capabilities of the equipment for carrying out experimental work to improve the technologies for obtaining protective coatings.

The developed contact materials based on copper and molybdenum as silver substitutes (containing no noble metals) (TCU 31.2-20113410-003-2002) passed successful industrial tests at more than 200 enterprises in Ukraine, Russia, Poland, Romania, Georgia, etc. Contact areas made of these materials (MDK-3, TCU 24.4-33966101-001: 2014) are successfully operated with alternating voltage and currents from 1 to 1000 A.

The technological problem of foundations developing for high-speed evaporation of copper through a zirconium-yttrium intermediary bath was solved in the process of this work implementation, so that the evaporation rate of the steam flow increased to 60 μm/min and specified materials have become competitive with similar compositions obtained by powder metallurgy techniques.

REFERENCES

1. Electron beam melting in foundry / Edited by S.V. Ladohin – K.: Publishing house "Steel", 2007 – 626 p.
2. Movchan B.A. Inorganic materials deposited from the vapor phase in vacuum // Modern Materials Science in the 21st Century. – K.: Naukova dumka, 1998. – P. 318–332.
3. Grechanuyk N.I., Kycherenko P.P., Grechanuyk I.N. The new electron-beam equipment and technologies for modern materials and coatings obtaining. Automatic welding №5 (649), may 2007. – P. 36–41.
4. Patent of Ukraine № 74155. A method of a microspherical heat-resistant material obtaining / N. I. Grechanuyk: 15.11.2005, Bul. № 11.
5. Patent of Ukraine № 34875. Composite materials for electrical contacts and method of its production / N.I. Grechanuyk, V.O. Osokin, I.B. Afanasiev, I.N. Grechanuyk: 16.12.2002, Bul № 12.
6. Patent of Ukraine № 86434. Composite material for electrical contacts and electrodes and method of its production / N.I. Grechanuyk, I.N. Grechanuyk, V.A. Denisenko, V.G. Grechanuyk: 27.04.2009
7. Positive decision on application № 4317/3A/13 from18.02.2013. Composite materials for electrical contacts and methodof its production / N.I. Grechanuyk, V.G. Grechanuyk, R.V. Minakova, ets.
8. Movchan B.A., Tihonovskiy A.L., Kyrakov U.A. Electron beammelting and refining of metals and alloys. – Kiev: Naukova dumka, 1973. – 239 p.
9. Pap P.A., Malashenko I.S., Ivanov A.M. Laboratory installation for the production of protective coatings for various purposes by electron beam condensation in a vacuum. Special electrometallurgy. – 1975. – 27, P. 98–104.
10. Movchan B.A., Malashenko I.S. Heat-resistant coatings, precipitated in vacuum. Kiev: Naukova dumka. 1983. – 230 c.
11. Movchan B.A., Yakovchuk K.U. Electron-beam devices for evaporation and deposition of inorganic materials and coatings. Modern electrometallurgy. – 2004. – № 2. P. 10–15.
12. Scherbitskiy V.V., Grechanuyk N.I., Kycherenko P.P. Electron-beam installation for obtaining multilayer materials. Problems of special electrometallurgy. 1982. – 16, P. 51–53.

Text of the article was accepted by Editorial Team 17.01.2018

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ЗАСТОСУВАННЯ ЕКОЛОГІЧНО ЧИСТОГО МЕТОДУ ВИПАРОВУВАННЯ-КОНДЕНСАЦІЇ ДЛЯ ОТРИМАННЯ КОМПОЗИЦІЙНИХ МАТЕРІАЛІВ НА ОСНОВІ МІДІ ДЛЯ ЕЛЕКТРИЧНИХ КОНТАКТІВ

Анотація. В роботі розглянута електронно-променева технологія зі створення нових матеріалів, в тому числі на основі міді та її сплавів, як один з найбільш перспективних напрямків сучасної електрометалургії. Процес формування конденсованих композиційних матеріалів (ККП) за цією технологією є абсолютно екологічно чистим, оскільки відбувається у вакуумі, крім того, подібні матеріали отримують за один технологічний цикл, що економічно вигідно.

Показано, що даний метод вперше використаний для отримання конструкційних композиційних матеріалів Cu-Mo, Cu-W, Cu-Cr (масивних листових конденсатів вагою до 30 кг, відокремлених від підкладки), які було застосовано для електричних контактів і електродів. Найбільше промислове застосування знайшли конденсовані з парової фази КМ системи Cu-Zr-Y-Mo і Cu-Cr-Zr-Y-Mo для розривних електричних контактів.

Досліджено механічні властивості матеріалів системи Cu-Zr-Y-Mo і показано, що зазначені матеріали відрізняються досить високою електропровідністю, твердістю, міцністю і задовільною пластичністю, що дозволяє в значній мірі відмовитися від використання контактів, що містять срібло, так як зазначені матеріали не поступаються, а в деяких випадках перевершують їх за своєю експлуатаційною надійністю.

Ключові слова: метод; випаровування-конденсація; мідь; композиційні матеріали; електричні контакти.

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