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THE FORMATION OF ALUMINOTITANIZED COATINGS ON COPPER ALLOYS UNDER SELF-PROPAGATION HIGH-TEMPERATURE SYNTHESIS

The paper presents the results of obtaining doped aluminum-titanated coatings using the self-spreading high-temperature synthesis (SHS) technology on copper alloys. The proposed method of hardening contributes to a significant increase in the corrosion resistance of copper alloys in a 3% solution of sodium chloride increases by 1.5 ... 1.8 times, as well as an increase in the scale resistance of brass and bronze in 8—12 times compared with non-titanium. Differences in the quality of the surface, structure, phase, composition, microhardness and the content of alloying elements in the diffusion layers on copper alloys are determined by the temperature of the process, the aging time and the composition of the SHS mixture.

Keywords: *self-propagating high-temperature synthesis, protective coating, copper alloys, corrosion resistance.*

В роботі представлені результати отримання легованих алюмотитанованих покриттів з використанням технології саморозповсюджувального високотемпературного синтезу (СВС), на мідних сплавах. Пропонований метод зміцнення сприяє значному підвищенню корозійна стійкість сплавів міді в 3% -ому розчині хлориду натрію збільшується в 1,5 ... 1,8 рази, а також підвищенні окалиностійкості латунь і бронза в 8—12 разів в порівнянні з не титанованими. Відмінності в якості поверхні, структурі, фазовому, складі, мікротвердості і змісті легуючих елементів в дифузійних шарах на мідних сплавах визначаються температурою процесу, часом витримки і складом СВС-суміші.

Ключові слова: *високотемпературний синтез, захисне покриття, мідні сплави, корозійна стійкість.*

Introduction

Currently, the multi-component composite coatings based on titanium are widely used in the world. The use of parts with similar coatings increases the physical and mechanical properties and service life.

To improve the bond between the protective coating and the substrate, we propose using a more efficient, economical and environmentally friendly method. This method of applying gas-transported SHS-coatings is proposed by E.A. Shtessel and co-authors in 1978 [1] and subsequently developed in the works.

Coatings applied in SHS processes during the course of accompanying gas-transport reactions are very peculiar. They consist of a film of the deposited product, both in the case of gas-phase deposition (GO) and a broad transition diffusion (gradient) zone as in diffusion saturation (DN). As a consequence of this, gas-transported SHS-coatings have better features of their analogs — they have the properties of the deposited material (they can be much more wear-resistant or heat-resistant than the substrate) and high adhesion strength [2—4].

Formulation of problem

The technology of deposition of SHS coatings with a thickness of 10—120 μm is simple: a gas transport additive (iodine) and parts to be coated are added to the prepared mixture of Ti, Si, Cr, Al powders; after passing through the combustion wave, a part of the combustion product is formed on the surface of the part in the form of a film (coating) [4—7].

This technology is especially promising for applying wear-resistant and corrosion-resistant coatings to parts of complex shape [8—10].

The results of the investigation of Ti-Al-Si, Ti-Al-Cr brass and bronze in the conditions of SHS are given in the work. The saturation process was studied at temperatures of 750 ± 850 °C with exposure at these temperatures in the range of 0.5—1.5 h. As studies have shown, the process of titanium-alumino-siliconization at a temperature of 800 °C and a process duration of 1.5 hours is most intensive. With an increase in exposure for more than 1.5 hours, the depth of the diffusion layer varies insignificantly. At a temperature of 850 °C and a duration of 1.5 hours, the samples are reflowed. The change in the depth of the diffusion layer as a function of the temperature and duration of the SHS process is shown in Fig. 1.

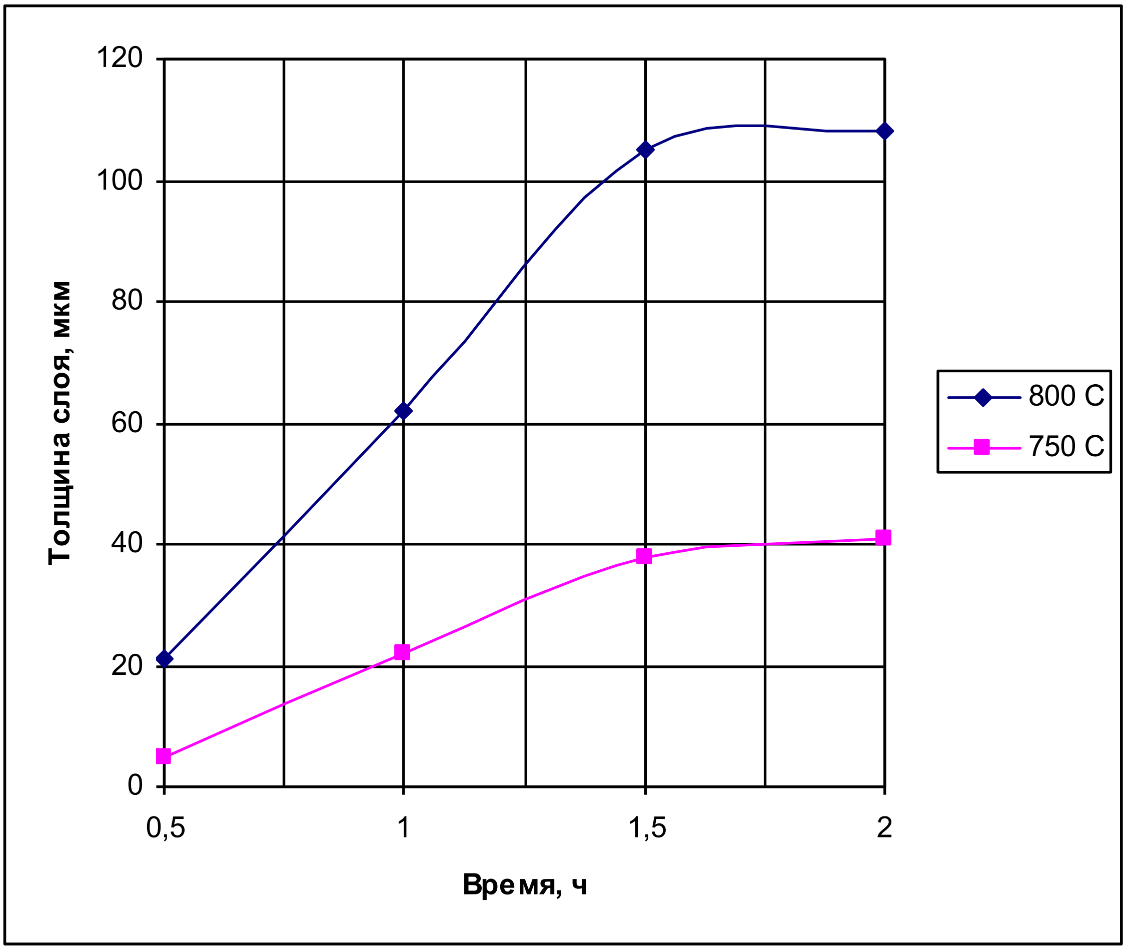
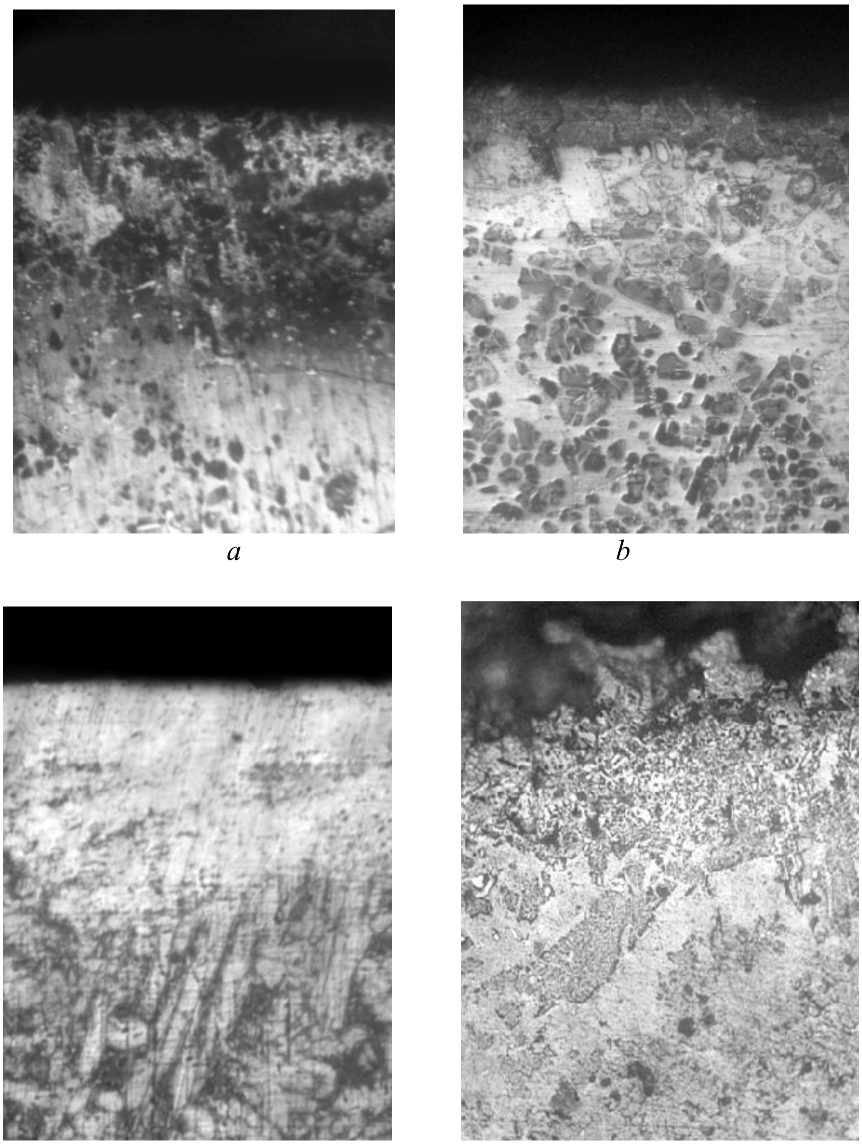


Fig. 1. Influence of temperature and duration of Ti-Al-Si process on the thickness of the diffusion layer.

The structural features and chemical composition of the silicide layers exert a noticeable influence on the distribution of microhardness over the thickness of the silicate coatings. Reducing the maximum hardness of the resulting coatings compared with the use of traditional silicon-based compounds is a very positive factor for certain operating conditions.

Metallographic studies of the structure of the samples under study show that the saturation zone has a different phase composition (Fig. 2).



a *b*

c *d*

a — BRAJ9-4-1, *b* — LC40MC3J, *c* — BrOF 10-1, *d* — BRAJMc 10-3-1,5

Fig. 2. Microstructures of Ti-Al-Si and Ti-Al-Cr plating of brass and bronze

With the help of mechanical compression tests it is established that the role of the diffusion layer is not limited only to the surface protection functions of the samples, but it has a significant effect on its bulk properties. Diffusive saturation of alloys with titanium and aluminum increases the compressive strength by 52%.

The high propagation velocities of the combustion wave together with the high temperature determine short synthesis times and high process productivity. Typical values of the linear combustion rate are 0.5—5 cm/sec, and in some cases it can reach large values (up to 20 cm/s). Often in the wave itself, synthesis reactions do not finish, and volumetric reaction takes place and the formation of the final product structure behind the combustion front takes place. But also this process proceeds quickly enough because of high temperatures of burning.

Large combustion rates change the ratio of the lengths of different technological stages. If in furnace technology synthesis is one of the slowest stages in the general cycle of raw materials, then in SHS-technology this is the fastest stage. Due to this circumstance, the industrial organization of SAF sets the task of improving auxiliary operations [11]. At the attrition abrasion test facility, studies were made of the effect of silicate coatings on the wear of samples (V_{sk} = 2.5 m/s, P = 1.0 MPa). As a counterbody used bars from high-speed steel P6M5, hardened to hardness HRC 62—65 [12]. Tests were subjected to two batches of samples of 10 pieces each: the first batch without coating, the second with silicated coatings of 40—100 microns in thickness. For the wear criterion, the ability of the treated surface of the test specimens to resist abrasion was accepted, which was estimated from the time of the test to the appearance of bursts on the chart tape caused by the process of setting the sample and counterbody.

Comparison of the properties and technology of titanium gas-transported SHS-coatings with gas-phase deposition. So, for example, with gas-phase deposition, the technological cycle is 3 times longer, and the cost of the coating material is 2 times greater than for SHS. Typical values of the wear resistance coefficient of machine parts are 4—6 times, in some cases 8—10 times.

Table 1. Some technological characteristics of applying titanium-alumo-chromium coatings on brass and bronze.

Characteristic	DS	SHS
1. Duration of the technological cycle	2-20	1.5-2
2. The cost of basic equipment	1	0.3
3. Production areas occupied by technological equipment	1	0.2
4. Electricity theaters	20-25	1
5. Use of the recycled product in the subsequent synthesis,%	80	80
6. Recycling	no	yes

Conclusion

As a result of research, it can be concluded that the regime of thermal autoignition, characterized by a short duration, is recommended to be used in place of the traditional methods of chemical-thermal treatment of copper alloys. it is the most economical and has the advantage over other methods. The proposed method of hardening contributes to a significant increase in the corrosion resistance of copper alloys in a 3% solution of sodium chloride increases by 1.5 ... 1.8 times, as well as an increase in the scale resistance of brass and bronze in 8—12 times compared with non-titanium. Differences in the quality of the surface, structure, phase, composition, microhardness and the content of alloying elements in the diffusion layers on copper alloys are determined by the temperature of the process, the aging time and the composition of the SHS mixture.

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