Voltammetry Characteristics of Ceramic Coatings Obtained by Pulse Microplasma Processes on Aluminium, Titanium and Magnesium Alloys

A.I. Mamaev, T.I. Dorofeeva, V.A. Mamaeva, V.N. Borikov, Yu.Yu. Budnitskya, A.A. Makarov

Institute of Strength Physics and Materials Sciences of the Siberian Branch of the Russian Academy of Science, 2/1 Akademicheskii ave, Tomsk, 634055, Russia, telephone 3822 – 492091, atte@mail.tomsknet.ru

Abstract – The measurement results of electrical parameters of pulsed microplasma processes by the computer aided measurement system are submitted. The form changes of voltammetry curves of microplasma processes in electrolytic solutions from the electrolyte composition, coating time and a working electrode composition are revealed.

1. Introduction

Microarc oxidation method is one of the most effective and economic for obtaining multifunctional coatings on the valve alloys surface for various purposes. The ceramic coatings on aluminium, titanium, and magnesium alloys obtained in the microplasma conditions in electrolytic solutions find the increasing application in the air, automobile and other areas of an industry. The similar coatings have a high adhesion, high wear resistance, corrosion resistance, heat resistance, various porosity, decorative and insulating properties [1–4]. The precision parameter measurements means application of the microplasma process and the computer simulation process of the gradient oxide coating deposition allow operating of technological process to obtain these coatings [5–6].

The purpose of the given work is the equipment development and the researches physical and chemical coatings characteristics during the coatings deposition in the pulse mode with high accuracy and adequacy of processing of the obtained data.

The developed technique for recording voltammetry dependencies allows us both to define a kind and mark of an alloy and to estimate influence of electrolyte components on the voltammetry curve form and coating deposition rate. This equipment and obtained voltammetry dependencies are useful for optimisation conditions of the microplasma deposited ceramic coatings and the optimum consisting electrolytes solution, and also power parameters of technological processes.

2. Results and Discussion

Advantage of the technique and the developed equipment is a rapid analysing, allowing in time up to 100 mcs to look through the signals of voltage and current with a step-type behaviour 25 mV and 1 mA respectively. The coating are obtained in the pulse conditions at voltage up to 500 V and the voltage rate 10^8 V/s. It is possible to determine a value of an active and pseudo-capacitor current and to estimate the influence of voltage and various electrolyte components concentrations by the developed method. The changes of electrical signal form of microplasma processes in electrolytes from the solution composition, the nature and structure of working electrodes, voltage and time of process are shown.

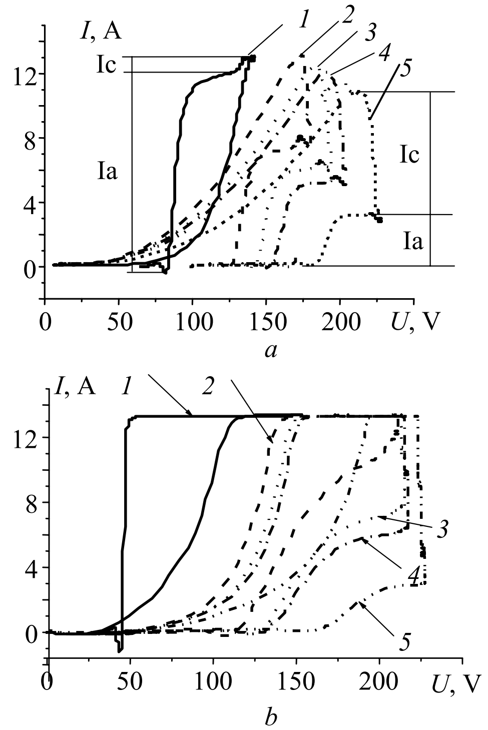

Fig. 1. The voltammetry curves of an aluminium alloy 2021 (*a*) and of a titanium alloy VT5 (*b*) at the various deposition process time, min: *1* – 0; *2* – 1; *3* – 2, *4* – 3, *5* – 5

We can estimate both an active current and a capacitor current (Fig. 1) and look after their dynamic changes in time on various alloys at different component concentration in a solution based on the measured electrical parameters of microplasma oxidation and voltammetry characteristics statistical graphing.

It is possible to reveal the dependence of the specific active resistance from the certain coating thickness and the process time (Table 1) (the sample's area is 7 cm^2) due to voltammetry curves.

Table 1. The dependence of the coating thickness and the active resistance from process time on the aluminium alloy 2021

t, min	Thickness, mcm	*R*, Ohm
1	4.16	16.98
3	8.16	23.21
5	9.13	21.11
10	11.33	27.61
15	17.66	31.11

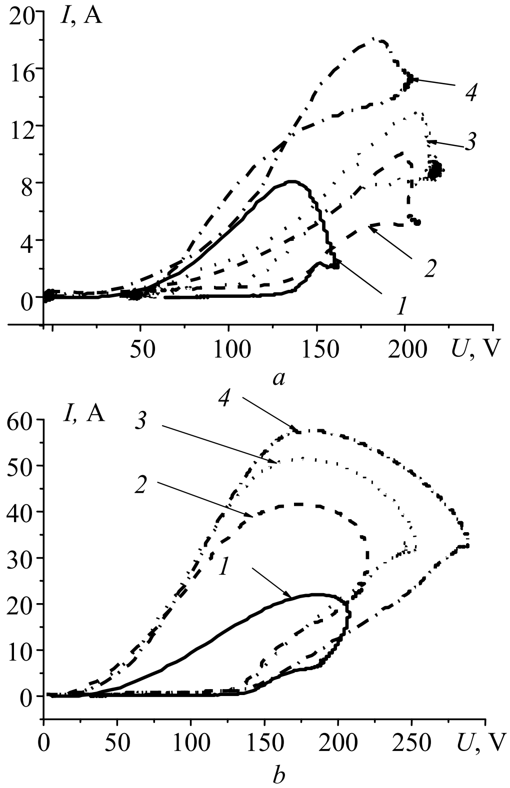

Fig. 2. The voltammetry characteristics of titanium alloy VT-5 in solutions H_3PO_4 (*a*) and KOH (*b*) at a various voltage, V: 1 – 200; 2 – 250; 3 – 300; 4 – 350

Figure 2 shows the dependence of the voltammetry curve form and the process voltage in the acid and the alkaline electrolytes. As it is seen from the diagram, the voltammetry curves of the acid and the alkaline electrolytes differ from each other both by the form and the value of a total current. The processes occurring in the acid and the alkaline electrolytes at microplasma conditions are various. The current is dislocated in the high values region with increase of an anodic voltage. The total limiting current value in the acid electrolytes does not exceed 20 A; in the alkaline it varies from 22 up to 60 A depending from the process parameters.

We can optimise the coatings deposition process analysing the obtained curves. The coating deposition is occurred in the electrolyte, which faster coating deposition of required quality. The developed measurement technique supervises the behaviour of voltammetry curves in each time from the beginning of the process. The kind of voltammetry curve reflects processes occurring in this time at coating deposition; according to the coatings properties will depend also on a form of voltammetry curve.

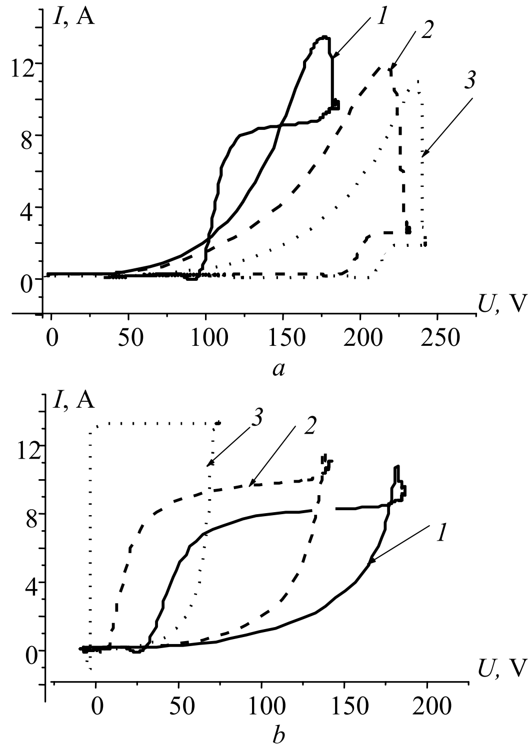

Fig. 3. The voltammetry dependencies of aluminium alloy D16 (*a*), magnesium alloy AZ91D from boric acid concentration (*b*), g/l: *1* – 6; *2* – 18; *3* – 27

As the analysis of voltammetry curves allows supervising process of coatings deposition, it is possible to judge, for example about the coating thickness from the voltammetry dependence with the increasing of the electrolyte component concentration. The influence of concentration is ambiguous on the various alloys. Therefore, the increase of boric acid concentration results in coating growth on aluminium alloys, but there is a return process on the magnesium alloy (Fig. 3).

Thus, the physicochemical processes occurring during microplasma processing of a valve metal surface depend on many factors that are directly reflected on the form of the voltammetry curve.

We consider that the measurements computer system opens new opportunities in the research of a nature and the laws of the microplasma processes in a pulse mode, and the mechanism of the ceramic coatings deposition.

The constructed voltammetry curves have proved the assumption that voltampermetric dependence change not only from a solution composition, the process time and the specifying voltage but also from an alloy material at identical time and identical component concentration in the solution (Fig. 4).

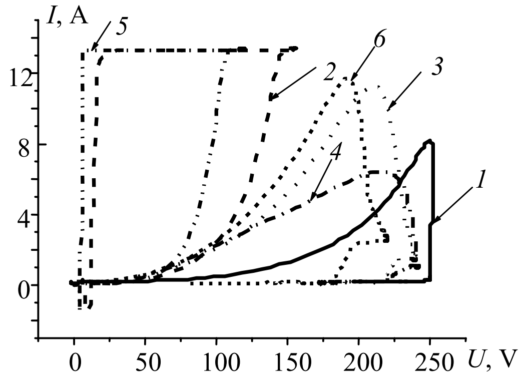

Fig. 4. The dependence of a voltammetry curve's form of microplasma process from the substrate composition in an electrolyte solution: *1* – 2021; *2* – AM60B; *3* – AMc; *4* – AMg; 5 – AZ91D; 6 – D16

3. Conclusion

Thus, the developed technique in aggregate and the computer simulation process allows to record voltammetry characteristic with high accuracy and resolution in the both an active current and a capacitor current range of microplasma processes in electrolyte solutions. Now it is important for the description of the coatings properties.

The dynamics research of voltammetry characteristic change has shown time dependence of the electrolyte concentration, the substrate nature and process voltage.

The given researches help to predict quality of received coatings, the physicochemical characteristics of them, and also completely to supervise the process and to operate it in time at various stages, setting necessary coatings properties. Besides, the given technique allows optimisation of the process from the point of view of the power and the material inputs.

References

[1] A.I. Mamaev, J.M. Ramazanova, Yu.A. Savelyev, *Patent 2046157 C 25D*, 1995.

[2] A.I. Mamaev, Yu.Yu. Chekanova, J.M. Ramazanova, Physics and chemistry of materials treatment **4**, 41 (1999).

[3] Yu.Yu. Budnitskya, A.I. Mamaev, V.A. Mamaeva, S.N. Vibornova, Advanced materials **3**, 48 (2002).

[4] A.I. Mamaev, S.N. Vibornova, V.A. Mamaeva Advanced materials **6**, 31 (1998).

[5] A.I. Mamaev, J.M. Ramazanova, P.I. Butyagin et al., Protection of metals **32**, 203 (1996).

[6] A.I. Mamaev *Physicochemical laws of high current pulsed processes in solutions at oxide coatings deposition and surface modifying*. Diss. … doctor of chem. sciences, Tomsk, 1999.