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EVALUATION OF DIELECTRIC PROPERTIES OF MICRO-ARC COATINGS ON DEFORMABLE ALUMINUM ALLOYS

Yu.G. Gutsalenko[1], E.K. Sevidova[1], I.I. Stepanova[1], V.E. Strel'nitskij[2]
[1]National Technical University "Kharkov Polytechnic Institute", Kharkov, Ukraine;
[2]National Science Center "Kharkov Institute of Physics and Technology", Kharkov, Ukraine
E-mail: yu.gutsalenko@gmail.com

The dielectric properties of MDO coatings on deformable alloys AK6 and D16T formed on an alternating current in the regime of an arbitrarily falling power in alkali-silicate solutions have been studied. It is shown that the increase in the oxidation time in twice (from 1 to 2 hours) leads to a decrease in the index ρ_v in 2–5 times, depending on the grade of the alloy and the solution composition. It has been established that the best dielectric values $\rho_v = (4...9)\cdot 10^9\ \Omega\cdot m$, $E = 13...14\ V/\mu m$ are provided by coatings on both alloys formed in solution 1 g/l KOH + 6 g/l W.G. (water glass). A small advantage in terms of the value ρ_v of 2 to 2.5 times with comparable thicknesses have MAD layers on the alloy AK6.

The processes of microarc oxidation (MAO) or plasma electrolytic oxidation (PEO) are used under the surface treatment of valve metals, most often aluminum alloys. Coatings that are formed in these processes are polyfunctional, since they are characterized by high values of hardness, wear resistance, heat and corrosion resistance, etc. [1–3]. This serves as a prerequisite for their wide introduction into various branches of science and technology, including engineering, instrument making, aerospace, electronics, medicine, construction, etc. The possibilities of the MAO method are far from exhausted; its technological parameters continue to be actively investigated as new prospects for the effective use of coatings appear.

It is of interest to investigate the dielectric properties of MAO coatings in order to determine the possibilities of their use as electrical insulating materials. In particular, within the framework of the tasks of radiation material science, such function can be implemented on structural components of temperature monitoring and control devices made of deformable aluminum alloys with the subsequent formation of an insulating coating by the MAO method.

The aim of the work is to investigate the technological possibilities of microarc oxidation with regard to deformable aluminum alloys and to evaluate the dielectric properties of the obtained coatings.

MATERIALS AND METHODS

Experimental samples were made of two types of deformable aluminum alloys, which are used as constructional materials for carrying parts in instrument engineering – D16T and AK6. The dimensions of the samples are 20x15x1.5 mm (D16T) and ∅30 mm, 5 mm thick (AK6). Formation of coatings was carried out at anode-cathode (alternating) current in the regime of randomly falling power during 1 and 2 hours at the initial current density 20 A/dm^2. Three solutions were used as the investigated electrolytes: silicate – 12 g/l L.G. (0:12) (L.G. – technical solution of liquid sodium glass, density 1.4 g/dm^3), alkali-silicate – 2 g/l KOH + 12 g /l L.G. (2:12) and more dilute 1 g/l KOH + 6 g/l L.G. (1: 6).

The thickness of the coatings was measured by a non-destructive method by vortex-current thickness gauge NOVOTEST TP-1.

Volumetric resistance was evaluated using a terameter E-13 at an operating voltage of 100 V.

The breakdown voltage (respectively, the electrical strength) was measured at alternating current (50 Hz).

DISCUSSION OF THE RESEARCH RESULTS

Analysis of the thicknesses of MAO coatings formed under identical electrolysis conditions shows (Table) that it depends on the alloy grade, the composition of the electrolyte, and the oxidation time. In general, the thickness of coatings on D16T alloy is greater than on AK6 ones. The advantage increases with the transition to more "aggressive" electrolytes containing in its composition caustic alkali – from 25...30% in a solution of 0:12 to 80...90% in a solution of 2:12. The probable reason of this difference is the different etching rate of intermetallic compounds entering into alloys [4].

The thickness of MAO coatings, μm, on deformable aluminum alloys under various conditions of electrolysis

alloy grade	The composition of electrolytes					
	0:12		2:12		1:6	
	1 hour	2 hours	1 hour	2 hours	1 hour	2 hours
Д16Т	80	150	100	210	70	170
АК6	60	120	55	120	40	90

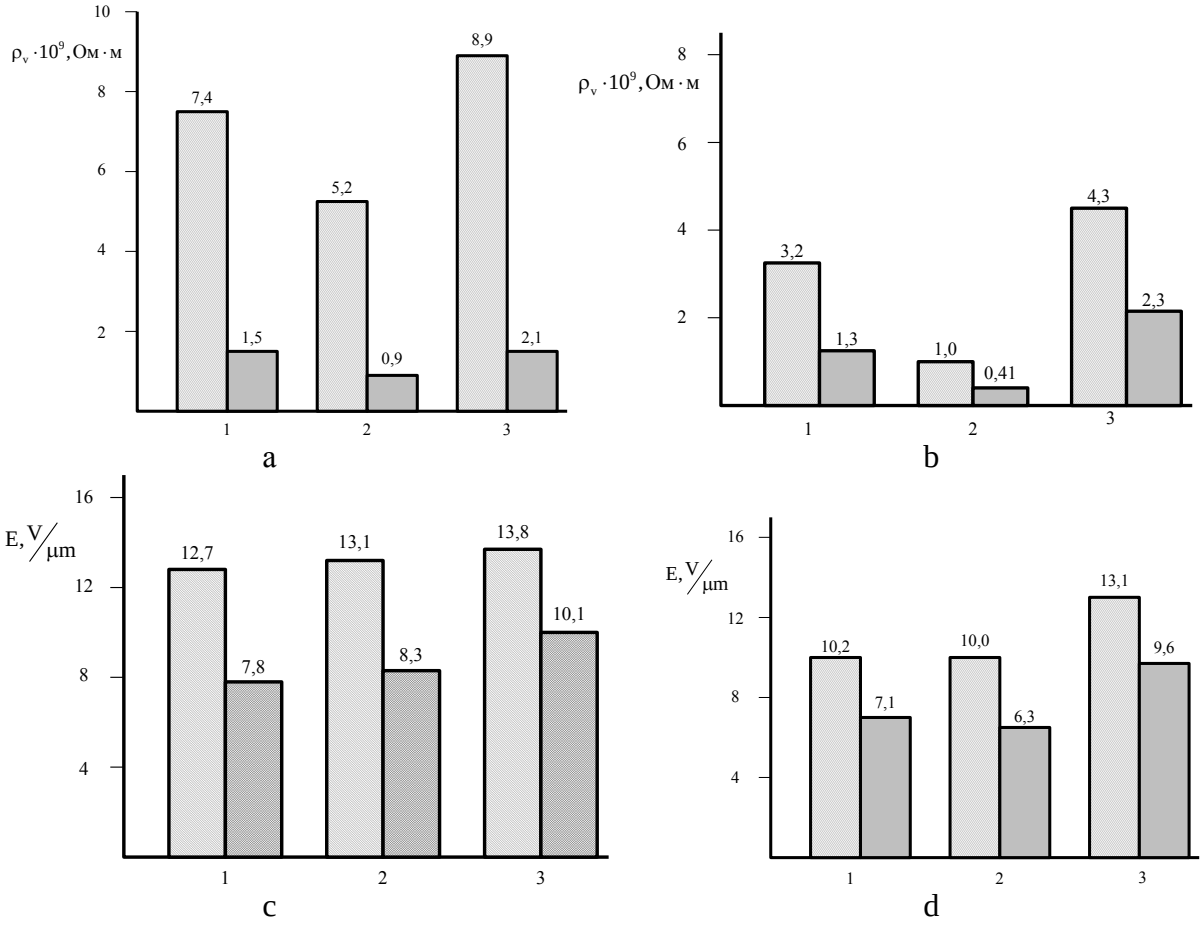

Fig. 1. Dependence of the specific volume resistivity (a, b) and electric strength (c, d) of MAO coatings on the oxidation time of the alloys AK6 (a, c) and D16T (b, d) in different electrolytes:
1 – 12 g/l L.G.; 2 – 2 g/l KOH + 12 g/l L.G.; 3 – 1 g/l KOH + 6 g/l L.G.
– 1 hour, – 2 hours

The subsequent measurement of the coatings dielectric characteristics, its specific volume resistivity and the electrical strength E indicate (Fig. 1) the predominant effect of thickness on their values. In particular, an increase in the oxidation time, and, correspondingly, of the thickness, in two times on the AK6 alloy, led to the deterioration of the ρ_v index in 4...5 times in all electrolyte solutions (see Fig. 1,a). Less pronounced this effect was displayed on the alloy D16T – the corresponding decrease was 1.9...2.5 times (see Fig. 1,b).

The fact that the dielectric properties of MAO coatings deteriorate with increasing thickness can be explained by the increasing heterogeneity of the phase-structure composition, by improving the conditions for migration and diffusion of alkali metal ions (K and Na) under the influence of temperature, by "capturing" current-carrying ions into the composite porous structure of the oxide layer [5].

The best index ρ_v provide coatings on both alloys, formed in alkali-silicate electrolyte 1:6, the lowest - in 1.7...4 times, in a solution of 2:12. In general, the coatings obtained within 1 hour in the thickness range 40...60 μm on the AK6 alloy and 70...100 μm on the D16T one are characterized by high specific resistivity $(1\ldots9)\cdot10^9$ Ω·m, but the relative advantage of this index (in 2...2.5 times) have MAO- layers on AK6.

The electrical strength of the coatings E (see Fig. 1,c,d), like the specific resistivity ρ_v, unambiguously decreases with increasing thickness, although the total breakdown voltage in this case increases. The latter is associated with a decrease in open porosity and end-to-end defects, which are a “trouble spot”, since the electrical strength of the air in them is only 3 V/μm.

The reasons for the E deterioration with increasing the coatings thickness are the same, which lead to deterioration ρ_v – heterogeneity, the presence in the composition of aluminum oxides of different structures, mullites, sillimanites and other compounds with lower dielectric properties.

The index E is less dependent than ρ_v on the alloy grade and the electrolyte composition, but a slight advantage of 10...30% is observed in MAO coatings formed in a 1:6 electrolyte solution; in this case the value of E reaches 13…14 V/μm.

CONCLUSIONS

Investigations of the dielectric properties of microarc coatings formed on AC6 and D16T alloys with alternating current in the regime of random falling power were carried out. It is shown that the value of the

specific volume resistance ρ_v and electrical strength E is mainly influenced by the thickness of the coatings, as well as the alloy grade and the electrolyte composition.

It is established that the best results of the dielectric properties on both alloys ($\rho_v = (4…9)\cdot10^9$ Ω·m and E = 13…14 V/μm) provides alkali-silicate electrolyte 1 g/l KOH + 6 g/l L.G. The achieved characteristics of the dielectric properties of MAO coatings on deformable alloys AK6 and D16T make it possible to use them as insulation layers for parts, structural elements, integrated microcircuits in instrumentation, including for nuclear power station.

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ОЦЕНКА ДИЭЛЕКТРИЧЕСКИХ СВОЙСТВ МИКРОДУГОВЫХ ПОКРЫТИЙ НА ДЕФОРМИРУЕМЫХ АЛЮМИНИЕВЫХ СПЛАВАХ

Ю.Г. Гуцаленко, Е.К. Севидова, И.И. Степанова, В.Е. Стрельницкий

Проведены исследования диэлектрических свойств МДО-покрытий на деформируемых сплавах АК6 и Д16Т, сформированных на переменном токе в режиме произвольно падающей мощности в щелочно-силикатных растворах. Показано, что увеличение времени оксидирования вдвое (от 1 до 2 ч) приводит к ухудшению показателя ρ_v в 2–5 раз в зависимости от марки сплава и состава раствора. Установлено, что наилучшие диэлектрические показатели $\rho_v = (4...9)\cdot10^9$ Ом·м и $E = 13...14$ В/мкм обеспечивают покрытия на обоих сплавах, сформированные в растворе 1 г/л КОН + 6 г/л Ж.С. Небольшое преимущество по значению ρ_v в 2–2,5 раза при соизмеримых толщинах имеют МДО-слои на сплаве АК6.

ОЦІНКА ДІЕЛЕКТРИЧНИХ ВЛАСТИВОСТЕЙ МІКРОДУГОВИХ ПОКРИТТІВ НА ДЕФОРМОВАНИХ АЛЮМІНІЄВИХ СПЛАВАХ

Ю.Г. Гуцаленко, О.К. Севидова, І.І. Степанова, В.Є. Стрельницький

Проведено дослідження діелектричних властивостей МДО-покриттів на деформованих сплавах АК6 і Д16Т, сформованих на змінному струмі в режимі довільно падаючої потужності в лужно-силікатних розчинах. Показано, що збільшення часу оксидування вдвічі (від 1 до 2 год) призводить до погіршення показника ρ_v в 2–5 разів залежно від марки сплаву і складу розчину. Встановлено, що найкращі діелектричні показники $\rho_v = (4...9)\cdot10^9$ Ом·м і $E = 13...14$ В/мкм забезпечують покриття на обох сплавах, які сформовані в розчині 1 г/л КОН + 6 г/л Р.С. Невелика перевага за значенням ρ_v в 2–2,5 рази при порівнянних товщинах мають МДО-шари на сплаві АК6.