UDC 544

RESEARCH INTO TEMPERATURE DEPENDENCE OF SOME PHYSICAL CHARACTERISTICS OF THERMO-STABLE NICKEL COATINGS ON ALUMINUM ALLOYS

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Research into some electric and mechanical characteristics (specific resistance, Yung modulus, internal friction) of electrolytic nickel coatings obtained from nickel plating persulphate solution on aluminum base before and after thermal treatment is presented in the paper. It revealed that following thermal treatment operation properties of the coating increases, adhesion improves and inter-granular distance decreases. Coatings obtained may be used for functional purposes in different technologies.

Keywords: *nickel coatings, aluminum alloys, thermo-stable, specific resistance, Yung modulus, internal friction.*

Introduction

Aluminum alloys are the main construction materials in aviation, instrument engineering, electro-technical industry and production of ground-surface transport. Owing to their assets (low density, good electro- and heat conduction), the application range of aluminum alloys in other branches tends to expand permanently.

The construction materials do not always satisfy requirements to components operating in the extreme conditions. Emerging difficulties may be solved by producing functional surface-based coatings that use operation properties of components.

If the components made from aluminum alloys (space systems' junctions, thermal power engineering, antenna feeding systems' junctions, steam-injection tubes) dispose of high electro-conductivity with heightened heat resistance, the coating of these components by nickel will be considered acceptable (melting temperature of aluminum alloys is 635-660^{0}C, specific resistance is ~ 2.6–2.95·10^{-8} Ohm·m, nickel melting temperature is 1453^{0}C, specific resistance of nickel is ~ 6.84·10^{-8}Ohm·m). As for structural and mechanical transitions, which may occur in the course of heating of construction materials, they cannot be extended to the coatings automatically because of their structural features.

The paper deals with producing heat-resistant nickel coatings on aluminum alloys with conservation of high adhesion and electro-conductivity during heating and examining their electric and mechanical properties.

Experimental results and discussion

Electrolytes of various compositions for producing nickel coatings from aqueous electrolytes are widely spread today [1-3]. We selected persulfate electrolyte of direct nickelling for aluminum [4, 5] (composition: nickel sulfate – 150—250 g/l, boric acid - 23—30 g/l, sodium fluoride - 1-3 g/l, sodium chloride - 1-3 g/l, potassium persulfate - 1-3 g/l). No operations on modification of the coated surface with the help of electroplating method are available. Note that preliminary preparations provide for purification (degreasing and clarification) of products only. Analyzed aluminum samples (according to the fluorescent analysis – Al - 95.17%, Cu-2.99%, Si-0.61%, Mg-0.52%, etc.) of required sizes were cut out on the electro-spark machine tool with special accuracy.

The electric (specific resistance) and mechanical (Yung modulus and internal friction) properties of nickel coatings were examined with the use of electron-beam technology while the surface structure analyzed on scanning electron microscope.

The electro-conductivity of substrate was measured at first. Electro-conductivity, Yung modulus, internal friction and structure of the samples were measured after electro-deposition of nickel on aluminum. The same samples coated by nickel were placed subsequently in vacuum camera and heated within 30 seconds at a temperature of 600^0C with subsequent slowed cooling. Then again, the same parameters at different temperatures were measured.

Standard four-point contact method was used to measure electric resistance. Note that mechanical properties (Yung modulus and internal friction) of the sample in question were researched by means of acoustic spectrometer. The dependencies of resistivity of the samples of substrate made from aluminum alloy and pure nickel are presented on Fig.1 and 2.

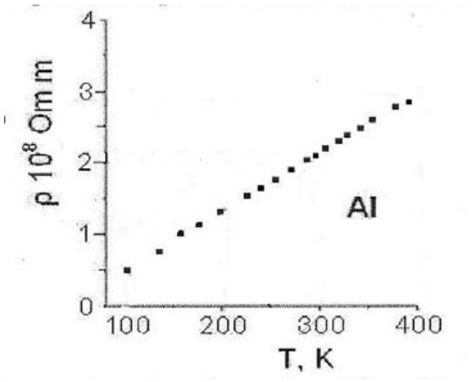


Fig.1

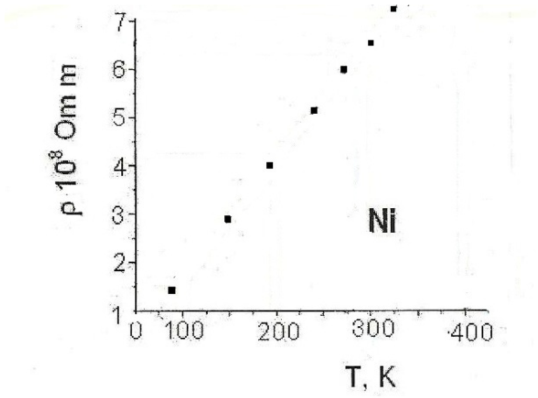


Fig.2

Resistivity of aluminum alloy (Fig.1) and pure nickel (Fig.2) subject to temperature ρ=*ƒ*(T).

The dependencies of resistivity upon the temperature of the aluminum alloy coated with nickel before and after thermal treatment (400 and 600^oC) are presented in Fig. 3.

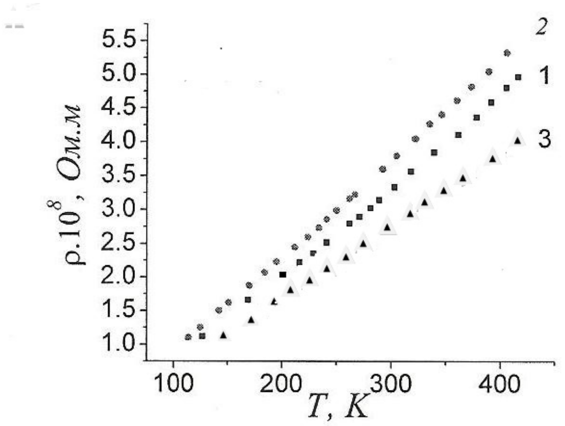


Fig.3. Resistivity of aluminum alloy coated with nickel (h=30 mcm) subject to temperature ρ=*ƒ*(T). 1 – initial; 2 – after annealing at 400^0 C; 3 - after annealing at 600^0 C.

As is evident from the Fig. 3, the resistivity of heated (600^{0}C) and then cooled down to room temperature of sample decreases (by 0.6 Ohm·m) as compared with resistivity of initial sample plated by nickel and approximate resistivity of aluminum alloy ($\rho_{Al спл.298^oK}=2.2\cdot10^{-8}$ Ohm·m; $\rho_{Al спл.+Ni.298^oK}=2.6\cdot10^{-8}$ Ohm·m; $\rho_{Ni.298^oK}=6.84\cdot10^{8}$Ohm·m), which is primarily linked with the improvement of the structure of the sample. Temperature dependence of Yung modulus curves and internal friction are shown in Fig. 4.

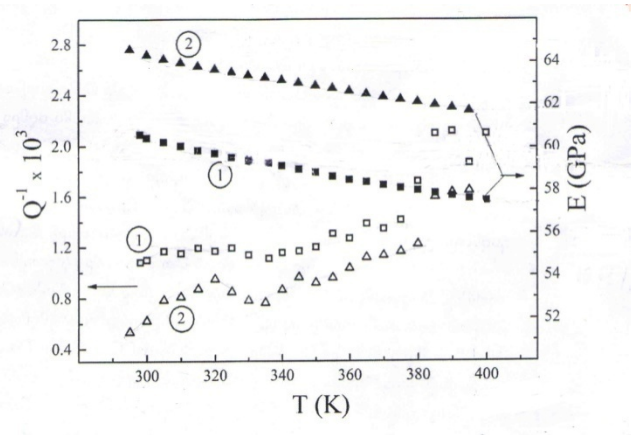
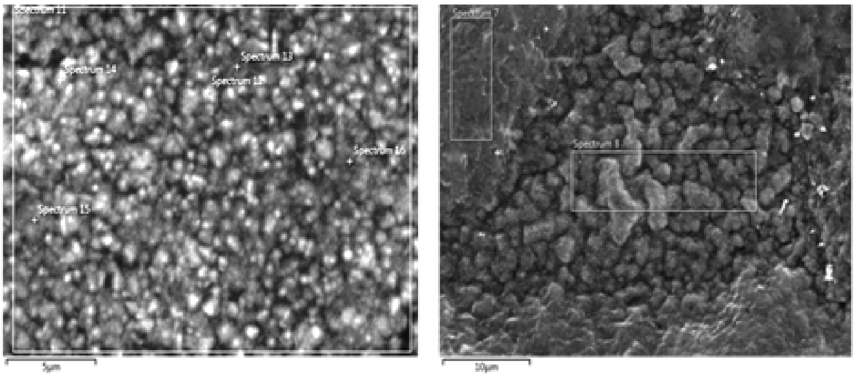


Fig.4. Temperature dependencies of Yung modulus (E) and internal friction (Q^{-1}) for aluminum sample coated by nickel (h=30 mcm) before (1) and after (2) thermal treatment (600^{0}C).

It is obvious from Fig. 4 that the numerical value of the Yung modulus lies in in the range of 40-65GPa and approximately coincides with Yung modulus for aluminum alloys (65.5-70.4 GPa). The change of the Yung modulus in the measured temperature range is ~4%. The level of the internal friction decreases after thermal treatment in the range of 100^{0}C temperature. Structures of nickel before (a) and after thermal treatment 600^o C(b) are presented in Fig. 5.



(a) (b)

Fig. 5. Structures of nickel deposition before (a) and after (b) thermal treatment 600^{o}C

An improvement in the structure of the coating, a decrease of inter-granular distances, an increase in the diffusion zone between the base and the coating, as well as an improvement in adhesion take place after thermal treatment. On the basis of the present research it is possible to conclude that electric and mechanical properties of aluminum alloys coated with nickel are practically preserved after thermal treatment, following which their thermo-stability increases.

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ИССЛЕДОВАНИЕ ТЕМПЕРАТУРНОЙ ЗАВИСИМОСТИ НЕКОТОРЫХ ФИЗИЧЕСКИХ ХАРАКТЕРИСТИК ТЕРМОСТОЙКИХ НИКЕЛЕВЫХ ПОКРЫТИЙ НА АЛЮМИНИЕВЫХ СПЛАВАХ

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В работе представлены результаты исследования электрических и механических характеристик (удельное сопротивление, модуль Юнга, внутренее трение) никелевых покрытий, полученных из персульфатного раствора никелирования на алюминиевой основе, до и после термической обработки. Установлено, что после термообработки увеличиваются эксплуатационные данные никелевого покрытия, улучшается адгезия с основным металлом, уменьшаются межзеренные границы. Полученные покрытия могут быть использованы для функциональных целей в разных технологиях.

Ключевые слова: *никелевые покрытия, алюминиевые сплавы, термостойкость, удельное сопротивление, модуль Юнга, внутреннее трение.*

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