PULSED ELECTRON-BEAM ASSISTED SYNTHESIS OF A NI-AL SURFACE ALLOY

V.I. PETROV[1], A.B. MARKOV[1], A.V. SOLOVJEV[1], E.V. YAKOVLEV[1,2], D.A. SHEPEL' [1]

[1] Tomsk Scientific Center SB RAS, Laboratory of Advanced Technologies, Tomsk, Russia
[2] Institute of High-Current Electronics, Tomsk, Russia

The Ni-Al multilayer system is an interesting object for research, not only because it is a "storage" of chemical energy, which can be released at high rate in the form of heat during the formation of bonds between atoms of Ni and Al [1], [2]. It also provides a number of intermetallides such as Al_3Ni, Al_3Ni_2, AlNi, $AlNi_3$, which can be synthesized during this reaction. Of greatest important is AlNi intermetallic material, which has the highest melting point of all nickel and aluminum intermetallic compounds. Due to the combination of a high melting point and relatively high thermal and electrical conductivity, NiAl intermetallic have considered as a candidate for use as a matrix material in the manufacture of vacuum interrupter electrodes, i.e. replacements of copper used now in this quality [3], [4].

The results of numerical and experimental studies on the synthesis of Ni-Al surface alloy on a steel substrate are presented. The alloy was formed by preliminary magnetron sputtering of multilayer Ni-Al coatings of two types, consisting of thin (type I) ~ 0.1 and thick (type II) ~ 1 μm films and their subsequent irradiation and mixing by a pulsed electron beam transported to the samples in a plasma-filled diode. In the work, the optimal irradiation mode was determined by the numerical method for the formation of a Ni-Al surface alloy where intensive melting of all deposited films occurs, and there is no evaporation of the surface material. It is experimentally shown that, as a result of pulsed electron-beam melting, a Ni-Al surface alloy is formed, which is represented by NiAl high-temperature intermetallic phase. In the case of Ni-Al multilayer system made up of thin films, the surface alloy formed is homogeneous, but a network of cracks appears on the surface. In the case of Ni-Al multilayer system made up of thick films, the surface alloy formed is heterogeneous, both along the surface and along the depth of the target. Its structure is a composite, combining the alternation of hard (but brittle) and soft (but ductile) components, corresponding to NiAl high-temperature intermetallic phase and (Al, Ni, Fe) solid solution, respectively. It is precisely this structure of the Ni-Al surface alloy that makes it possible to obtain a crack-free surface with high tribological and high-temperature corrosion properties (Fig. 1).

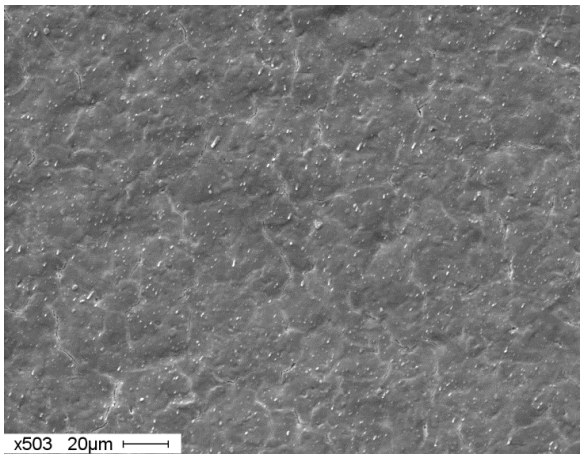

Fig. 1. SEM image of the Ni-Al surface alloy formed from multilayer system of type I.

REFERENCES

[1] Y. Wang, Z. Xing, Y. Qiao, H. Jiang, X. Yu, F. Ye, Y. Li, L. Wang, B. Liu, "Asymmetric atomic diffusion and phase growth at the Al/Ni and Ni/Al interfaces in the Al-Ni multilayers obtained by magnetron deposition," J. Alloys Compd., vol. 789, pp. 887–893, Jun. 2019, DOI. 10.1016/j.jallcom.2019.03.131.

[2] J. Wang, E. Benson, A. Duckham, S. J. Sprey, M. E. Reiss, O. M. Knio, T. P. Weihs, "Joining of stainless-steel specimens with nanostructured Al/Ni foils," J. Appl. Phys., vol. 95, no. 1, pp. 248–256, Jan. 2004, DOI. 10.1063/1.1629390.

[3] R. Watanabe, H. Andoh, K. Iwashita, Y. Kurosawa, "Electrical characteristics of Ni-Al-Cr alloy electrode for vacuum circuit breaker," J. Japan Inst. Metals, vol. 55, no. 3, pp. 337–343, Sep. 1991.

[4] R. D. Noebe, R. R. Bowman, M. V. Nathal, "The physical and mechanical metallurgy of NiAl," in Physical Metallurgy and processing of Intermetallic Compounds. Boston, MA, USA: Springer, 1996, ch. 7, pp. 212–296.