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L. I. Fedorenkova

Oles Honchar Dnipropetrovsk National University, Dnipropetrovsk, Ukraine
**e-mail: Luba.Fed@gmail.com*

STRUCTURE AND PROPERTIES OF THE SURFACE LAYER ON AL-BE ALLOY AFTER A TREATMENT IN ELECTROLYTIC PLASMA

The structure and properties of the diffusion layer formed on the Al-Be alloy surface after treatment in the electrolytic plasma are investigated. As a result of X-ray analysis the Be_2B and AlB_{10} phases were basically identified in the diffusion layer. Treatment of Al-Be alloy in electrolytic plasma leads to the specific Be crystal orientation and anisotropy. It is found the diffusion layer formed on the Al-Be (3.6 % Be) alloy surface includes nano-sized finely dispersed beryllium borides and to a lesser extent aluminum borides that are concentrated basically at grain boundaries and phases and provided dispersion hardening of the alloy surface. Discharge action provides the structural changes and metastable states in surface layers of the alloy. It is observed a noticeable reduction in the aluminum and beryllium lattices with anisotropy of the latter after Al-Be alloy treatment. This produces residual internal stresses which affect micromechanical properties of the alloy. The microhardness of the treated Al-Be alloy surface in 2 - 3 times higher than the untreated, and depends on current density.

Keywords: nonequilibrium conditions, microhardness, diffusion layer, beryllium borides, dispersion hardening.

Досліджуються структура та властивості дифузійного шару, утвореного на поверхні Al-Be сплаву після обробки в електролітній плазмі. За результатами рентгеноструктурного аналізу в дифузійному шарі в основному ідентифікуються фази Be_2B и AlB_{10}. Обробка в електролітній плазмі Al-Be сплаву приводить до певної орієнтації кристалів Be та виникнення анізотропії. Встановлено, що дифузійний шар, отриманий на поверхні сплаву Al-Be (3.6 % Be) в результаті обробки в електролітній плазмі, включає нанорозмірні мілкодисперсні бориди берилію і в меншому ступені алюмінію, що зосереджені в основному по границям зерен та фаз, і які забезпечують дисперсійне зміцнення поверхні сплаву. Дія розряду забезпечує структурні зміни і створення метастабільних станів в поверхневих шарах сплаву. В результаті обробки сплаву Al-Be в електролітній плазмі спостерігається помітне зменшення періоду кристалічних решіток алюмініюта берилію з анізотропією останнього. При цьому виникають остаточні внутрішні напруження, які впливають на мікромеханічні властивості сплаву. Мікротвердість обробленої поверхні сплаву Al-Be в 2 – 3 рази вище за необроблену і залежить від щільності струму.

Keywords: нерівноважні умови, мікротвердість, дифузійний шар, бориди берилію, дисперсійне зміцнення.

Исследуются структура и свойства диффузионного слоя, образованного на поверхности Al-Be сплава после обработки в электролитной плазме. По результатам рентгеноструктурного анализа в диффузионном слое в основном идентифицируются фазы Be_2Bи AlB_{10}. Обработка в электролитной плазме Al-Be сплава приводит к определённой ориентации кристаллов Be и возникновению анизотропии. Установлено, что диффузионный слой, полученный на поверхности сплава Al-Be (3.6 % Be) в результате обработки в электролитной плазме, включает наноразмерные мелкодисперсные бориды бериллия и в меньшей степени алюминия, сосредоточенные в основном по границам зерен и фаз и обеспечивающие дисперсионного упрочнение поверхности сплава. Действие разряда обеспечивает структурные изменения и создание метастабильных состояний в поверхностных слоях насыщаемого сплава. В результате обработки Al-Be сплава в электролитной плазме наблюдается заметное уменьшение периода кристаллических решеток алюминия и бериллия с анизотропией последнего. При этом возникают остаточные внутренние напряжения, которые влияют на микромеханические свойства сплава. Микротвердость обработанной поверхности сплава Al-Be в 2 – 3 раза выше, чем необработанной и зависит от плотности тока.

Keywords: неравновесные условия, микротвердость, диффузионный слой, бориды бериллия, дисперсионное упрочнение.

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1. Introduction

Technical progress in a number of important industries determined by the quality of light alloys based on aluminum. Among them, the aluminum-beryllium alloys are most widely used due to the small specific weight, high specific strength and high corrosion resistance. They as structural materials are widely used in aviation, electronics, missile and space engineering. Usually, small amounts of beryllium are introduced into high aluminum alloys to prevent oxidation of the aluminum and other alloy components during subsequent treatment, for example, melting and casting [1].The mechanical properties of aluminum-beryllium alloys are increased by introducing of thinly dispersed hardening phase [2]. The presence of the dispersed phase causes stresses in the beryllium matrix (in the case of allocating from the solid solution), or prevents the spread of sliding (in the case of intermetallic compounds formation). The degree of hardening depends on amount and type of the hardening phase, from its connection with the matrix, size of its particles and distance between them [3].Treatment of aluminum alloys by boriding in the electrolytic plasma [4, 5], obtained in an aqueous electrolyte solution, promotes to the surface layers formation with improved micromechanical characteristics, that include finely dispersed nano-sized aluminum boride phases of different modification. Depth layer and its micromechanical characteristics at identical treatment conditions depend on the aluminum alloy composition. It should be noted the presence of Si and Mg in the alloy promotes formation of a coating with greater depth and microhardness. The hardening of Al-Be alloy by borated in electrolytic plasma [5], in fact, may be an alternative to the Al-Be-B alloy [7].

In this work the structure and properties of the diffusion layer formed on the Al-Be alloy surface after treatment in the electrolytic plasma produced around the cathode by electrolysis in an aqueous electrolyte solution were studied.

2. Experimental details

Investigations were carried out on Al-Be (3-3.5 %) alloy samples, treated in the aqueous electrolyte solution containing boron. The treatment was realized in the regime of electrolyze at a voltage of 30-50V, current density of 1.4 – 2.2 A/sm^2 for 15 minutes.

The microstructure of the treated samples was revealed by etching in 0.5% solution of HF. Metallographic analysis of the samples was performed on a microscope "Neophot-21" and micro durometer PMT-3 under a load of 50 g. The phase components identification of the diffusion layer was performed by X-ray diffraction on a DRON-2 in the iron and copper radiations. The structure and composition of the surface layer were investigated by micro X-ray and spectral analysis [6].

3. Results and discussion

According to X-ray analysis (Table 1) in the diffusion layer obtained after treatment in the electrolytic plasma Be_2B and AlB_{10} phases are mainly identified. Proceeding from the quantities of the elastic model [8], Be_2B phase is the most stable. The system of chemical bonds in Be_2B is determined of strong covalent bonds Be-Be (2s2p - hybridization), which is complemented by covalent bonds Be-B and B-B. The presence of high-boron compounds BeB_6 and $BeB_{12}$is caused, apparently, by boron segregation at the grain boundary beryllium in local action of temperature. The compound Be_2B is unstable under equilibrium conditions [7, 8] and decomposes into Be_4B and Be_2B_3as eutectoid at temperatures below 985 °C. However, this process does not have time to occur under non-equilibrium conditions of the electrolytic plasma with high rates of cooling and heating. The formation of beryllium borides dominates over the aluminum borides formation. That is, boron is primarily inclined to form compounds with beryllium, since the value of the standard enthalpy of formation for Be_2B is 64.85 kJ/mol [10] and for AlB_{12} – 266.1 kJ/mol [10] or 184.2 kJ/mol [12].

According to spectral analysis the boron microalloying does not exceed 1% when diffusion processes in the electrolytic plasma are realized. At this concentration of boron in Al-Be-Balloys [7] beryllium boride is located on the beryllium grain boundaries and crystallized together with aluminum-based phase promoted to hardening without sharp reduction in relative elongation. After treatment of the Al-Be alloy in electrolytic plasma beryllium borides are also formed at the beryllium grain boundaries.

Table 1

The results of X-ray analysis of surface layer on the Al-Be alloy after the treatment

№	Regime of treatment	Phase combination
1	U=60V, j=2,42A/см^2, t=15min	Be_2B, BeB_6, AlB_{10}
2	U=30V, j=2,2A/см^2, t=15min	Be_2B, BeB_{12}, AlB_{10}, AlB_{12}

The values of the aluminum lattice parameter of Al-Be alloy computed for the diffraction peaks 220 have shown that the lattice constant decreases from 4.0409 Å for the untreated sample up to 4.032Å for treated sample at a current density 1.3 A/sm^2 and up to 4.0353 Å for j = 2.2A/sm^2. The change of the beryllium lattice parameters in Al-Be alloy occurs in the direction of 100 from a = 2.275 Å for the untreated sample up to a = 2.240 Å for treated sample. The beryllium lattice parameter c changes in direction of 002 from c = 3.58 Å up to 3.54 Å. of The beryllium lattice parameter in the direction of 200 treated alloy is not changed. Al-Be alloy treatment in electrolytic plasma leads to the specific orientation of the Be crystals, an anisotropy, becomes possible to greatly improvement of properties.

Changes in the aluminum lattice parameter occur under plastic deformation by discharge, due to alloying with components of the electrolytic plasma near the cathode, in particular with boron and hydrogen in the process of new phases formation. With increasing current density energetic influence on a metal surface increases resulting the microstructure of the surface layer changes. This produces residual internal stresses residual internal stresses which affect the micromechanical properties of the alloy.

Fig. 1 shows the change in microhardness to a depth of layer depending on the treatment regime. In comparison with other aluminum alloys [5] Al-Be alloy after treatment in the electrolytic plasma has a microhardness of 1.5-2 times exceeding the microhardness of the untreated surface. While under the same processing conditions on the Al-W alloy surface the layer is formed with a microhardness 4-7 times greater. This can be explained as follows. Hard strengthening beryllium particles in combination with a plastic aluminum matrix are barriers to dislocation motion and lead to decrease of the dislocations diffusion and boron diffusion moving with them. All this eventually decreases the microhardness of the layer.

The results of phase analysis showed the presence of lines AlB_{10}, AlB_{12} phases, formed appears at the aluminum grain boundaries. Possibility of simultaneous formation of beryllium and aluminum borides is most probable under non-equilibrium conditions of the electrolytic plasma formed in discharges near the cathode. The diffusion layer includes finely dispersion metal boride phases formed primarily in the places of local action of the discharge temperature in a high-speed heating and cooling promoted of directional self-organization of nano-sized boride phases. The uniqueness of obtained layer is that borides primarily are formed at grain boundaries, in dislocations and microdefects and have a nanoscale size. This leads to dispersion surface hardening with particles of boride phase.

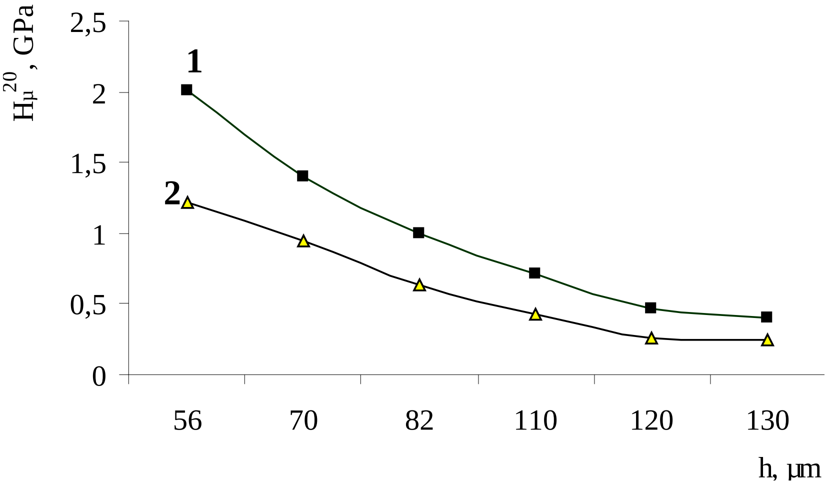

Fig. 1Microhardness distribution on the diffusion layer depth for Al-Be (3-3.6% Be) alloy treated in the regimes: 1 – U = 60 V, j = 2.42 A/cm^2, t = 15 min; 2 - U = 30 V, j = 2.2 A/cm^2, t = 15 min.

4. Conclusions

Thus, the diffusion layer formed on the alloy Al-Be (3,6% Be) surface after treatment in the electrolytic plasma includes nanosize finely dispersed beryllium borides and to a lesser extent aluminum borides concentrated basically at grain boundaries and phases and provided dispersion hardening of the alloy surface. Discharge action provides the structural changes and metastable states in surface layers of the alloy. It is observed a noticeable reduction in the aluminum and beryllium lattices with anisotropy of the latter after Al-Be alloy treatment. This produces residual internal stresses which affect micromechanical properties of the alloy. The microhardness of the treated Al-Be alloy surface in 2 - 3 times higher than untreated, and depends on current density.

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