Crater Formation at the $Ti_{49.5}Ni_{50.5}$ Surface Modified by Low Energy High Current Electron Beams

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Abstract – Investigation results on evolution of surface morphology of the $Ti_{49.5}Ni_{50.5}$ alloy caused by influence of the Low Energy High Current Electron Beams (LEHCEBs) are reported. The $Ti_{49.5}Ni_{50.5}$ samples were treated with following parameters of the LEHCEBs: the energy density 3÷8 J/cm^2, the pulse duration 2,2÷4 μs and number of pulses from 1 to 50 pulses per single sample. The modified zone of material is formed in the subsurface area of the $Ti_{49.5}Ni_{50.5}$ alloy after LEHCEBs impact. This zone differs from the $Ti_{49.5}Ni_{50.5}$ substrate by chemical, physical and mechanical properties.

Analysis of SEM (scanning electron microscopy) images has shown, that processing of the TiNi samples surface by LEHCEBs is often accompanied by crater formation. The most typical craters have following forms: circular craters, single- and multi-centered discs, secondary craters. Craters classification depending on their form and dimensions was carried out. It was found that the centers of craters formation on the TiNi samples surface are frequently particles of the secondary Ti_2Ni phase. The next reason of crater formation on the TiNi samples surface is parameters of the LEHCEBs irradiation.

1. Introduction

It is known that the surface condition determines many properties of the materials. Structural-phase condition, chemical and mechanical properties of the surface and subsurface layers are very important. The surface morphology of metals and alloys, atomic and defect structure formed within the subsurface layers determine, for example, their corrosion and mechanical properties. Therefore the main attention is devoted to the processes allowing to design and reconstruct surface and subsurface layers of the different materials and to manage their properties as a whole.

The energy density, pulse duration and number of pulses of the LEHCEBs impacts are more important parameters influenced on the surface morphology and changes of structural-phase transformations in modified layers of materials.

The aim of this work is to investigate mechanisms of craters formation on the surface of the TiNi alloy depending on the LEHCEBs parameters.

2. Experimental

The studied $Ti_{49.5}Ni_{50.5}$ alloy was prepared from nickel of grade NO and iodide titanium using sixfold arc remelting. Samples with the size of (1×15×15) mm^3 for Scanning Electron Spectroscopy (AES) and Optical Metallography (OM) were used. Before the measurements, all samples were annealed at 1073 K for 1 h in vacuum higher than 10^{-3} Pa and then cooled in a furnace. Then the surface of the samples was etched electrolytically using a solution containing 90 % acetic acid and 10 % $HClO_4$. The LEHCEBs treatment was made in Institute of High Current Electronics SB RAS and used with the following irradiation parameters: the energy density – (3÷8) J/cm^2, the pulse duration – (2.5÷4) μs and numbers of pulses – (1÷50).

Surface morphology of the alloys was studied by SEM and OM analysis using scanning electron microscope Philips SEM 515 and optical microscope Axiovert 200 MAT ("ZEISS", Germany).

3. Experimental Results and Discussion

Analysis of the SEM and OM images has shown that the surface processing of the studied $Ti_{49.5}Ni_{50.5}$ alloy using the LEHCEBs is frequently accompanied by crater formation on the sample surfaces.

Figure 1 illustrates evolution of surface morphology of the $Ti_{49.5}Ni_{50.5}$ alloy along the beam spot boundary after single the LEHCEBs impact. It is seen that the initial mechanically polished surface changes its morphology after melting of a thin surface layer.

Figure 2 illustrates evolution of the $Ti_{49.5}Ni_{50.5}$ surface morphology caused by the LEHCEBs processing with a variation of the electron treatment parameters. It is seen that amount of craters and their sizes increase with increasing of the energy density of the electron beam or number of the LEHCEBs pulses. Additionally, craters with small diameters (~10 μm) were observed when the energy density of the single pulsed electron beam did not exceed 4 J/cm^2 and the time duration of the pulse consisted of ~2–3 μs.

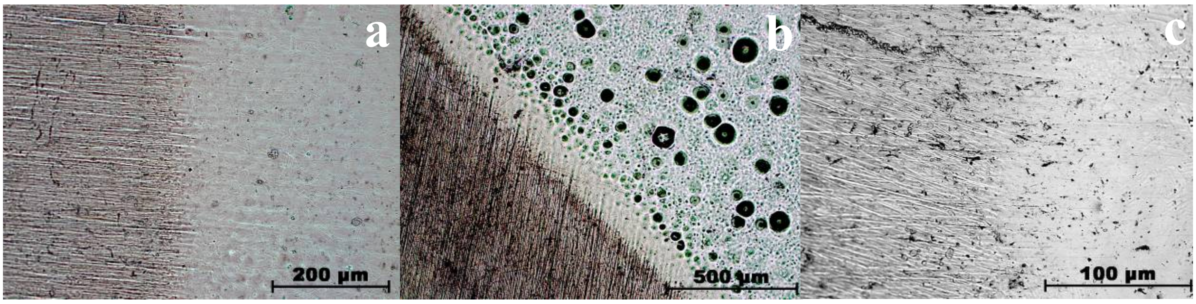

Fig. 1. Surface morphology of the studied $Ti_{49.5}Ni_{50.5}$ alloy near the LEHCEB spot boundary: a) energy density 4 J/cm^2, number of pulses – 1; b) energy density ~8 J/cm^2, number of pulses – 1; c) energy density 8÷10 J/cm^2, number of pulses – 50

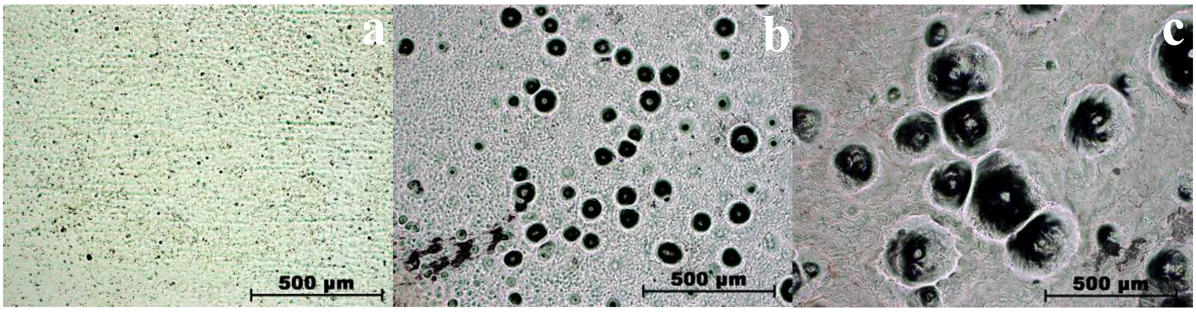

Fig. 2. Surface morphology of the $Ti_{49.5}Ni_{50.5}$ alloy in center of the LEHCEB spot: a) energy density 4 J/cm^2, number of pulses – 1; b) energy density 8 J/cm^2, number of pulses – 1; c) energy density 8÷10 J/cm^2, number of pulses – 50

As seen from Fig. 2, *a*, *b*, increase in the energy density from 4 J/cm^2 up to 8 J/cm^2 in the single impact of the electron beam leads to increasing both the craters density and their size variation. Diameters of craters at this condition of the LEHCEBs influence were varied from ~10 μm till 100 μm (Fig. 2, *b*). It was found that the preferred crater size was equal to ~80 μm when the impact was realized once or twice.

As seen from Fig. 2, *b*, *c*, increase in number of the electron beam impacts from 1 till 50 was accompanied by increasing both the craters density and their sizes, when the energy density was not changed and consisted about 8 J/cm^2. It was found that in this case many craters with diameters ~100÷300 μm besides the craters with diameters ~10÷100 μm were observed at the LEHCEBs modified surface of the samples.

Using the special computer program "Axiovision 4.4" a qualitative and quantitative statistical analysis of all modified surfaces of the $Ti_{49.5}Ni_{50.5}$ samples was made in this work. This optical analysis have revealed that distribution of the craters are heterogeneous as for their dimension as distribution density at the sample surface. As seen from Fig. 2, *b*, *c*, areas with craters having the small (diameter ~10 μm) and middle (diameter ~30÷100 μm) sizes alternate areas where the average diameter of craters equal to ~300 μm.

Classification of V.A. Shulov [1–3] of craters forms depending on the mechanisms of crater formation was used in this work. According to SEM and OM analysis the preferred forms (types) of craters are following: the faceted craters (Fig. 3, *a*), circular crater with convexity in its center(Fig. 3, *b*), faceted

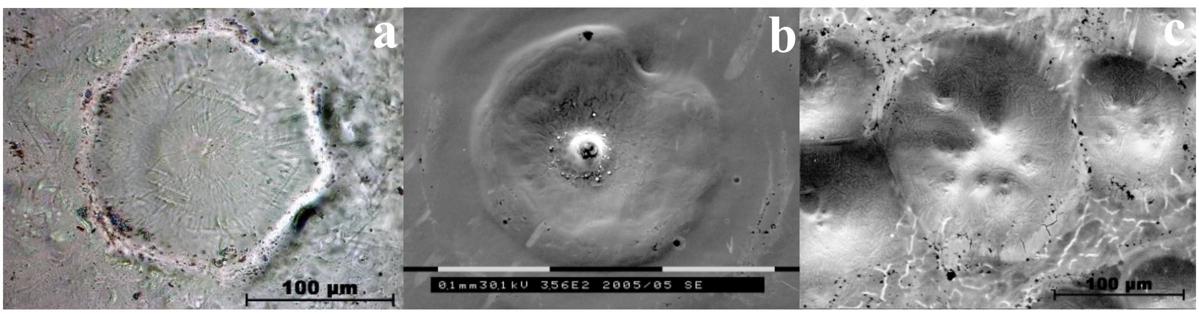

Fig. 3. Typical forms of the craters generated on a surface of the $Ti_{49.5}Ni_{50.5}$ samples by the LEHCEBs processing: a) the faceted crater; b) circular crater with convexity in its center; c) faceted multi centered crater (according to [1, 2])

multi centered crater (Fig. 3, *c*), secondary craters. Remarkable that it can find different types of craters on all modified sample surfaces independent on the parameters of the LEHCEBs processing.

It is established, that the points of craters formation on the $T_{i49.5}Ni_{50.5}$ samples surface are frequently the Ti_2Ni particles distributed along the grain boundaries of parent B2 phase. Another reason for crater formation at the surface of the studied alloy кратерообразования is assembly of the irradiation parameters when craters formation occurs as a result of local melting, boiling and evaporation of the thin surface layer during multi-pulsed the LEHCEBs impact.

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References

[1] V.A. Shulov, G.E. Remnev, N.A. Nochovnaya, Poverhnost, 7, 117 (1994).

[2] V.A. Shulov, G.E. Remnev, N.A. Nochovnaya, Poverhnost, 11, 24 (1995).

[3] A.V. Smirnova, G.A. Kokorin, S.M. Polonskaya, *Electronic microscopy in metallurgical science, Reference edition*, Moscow, Metallurgy, 1985. 192 pp.