PHYSICAL PROPERTIES OF THE NIAL INTERMETALLIC COATING PRODUCED BY IRRADIATION WITH A LOW-ENERGY HIGH-CURRENT ELECTRON BEAM

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Outline:

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2. Installation for formation surface alloys;
3. The investigated three-layer system;
4. Morphology of the studied samples;
5. The study of microhardness;
6. Study of the phase composition;
7. Conclusion.

Background

Currently, there are many methods for applying intermetallic coatings. All of them have their own advantages and disadvantages. One of them is methods based on the formation of surface alloys by liquid-phase mixing of film-substrate systems by concentrated energy fluxes, namely, pulsed intense laser, electron and ion beams, as well as plasma flows. The advantage of these methods is that, despite the relatively short time of high-energy exposure, the surface alloy is formed precisely as a result of liquid-phase mixing of the film and substrate materials. The possibility of forming an intermetallic compound using LEHCEB was also studied.

The purpose of the work is to select the optimal irradiation mode of the surface alloy using a low-energy high-current electron beam, to study physical properties and morphology.

Installation for formation surface alloys

<u>Installation advantages:</u>

-The magnetron sputtering system and the LEHCEB source are located in the same vacuum chamber

-The processes of film deposition and its liquid-phase mixing with the substrate proceed in a single vacuum cycle.

<u>Properties:</u>

-Electron energy is 10–30 *keV*

-Current strength up to 25 *kA*

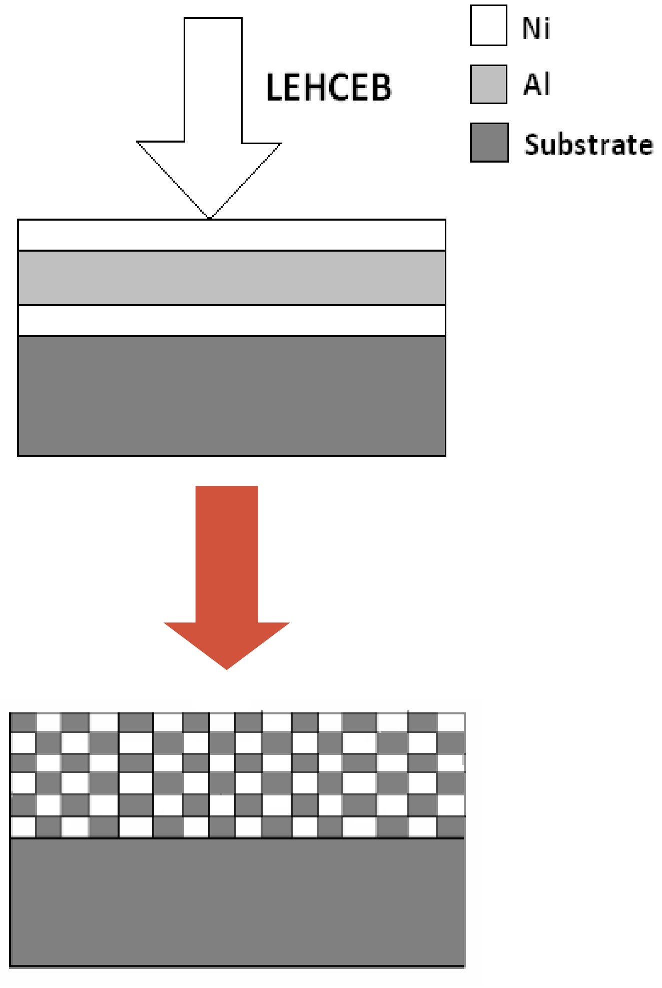
-Energy density up to 15 J/cm^2

-Pulse duration of 2–4 μs

-Beam diameter of up to 80 *mm*

-Pulse repetition rate – 0.2 *Hz*

The investigated three-layer system



<u>Layer ratio:</u> Ni (0.5 μm)
Al (1.5 μm)
Ni (0.5 μm)
Substrate (St3)

<u>The parameters of the LEHCEB:</u>

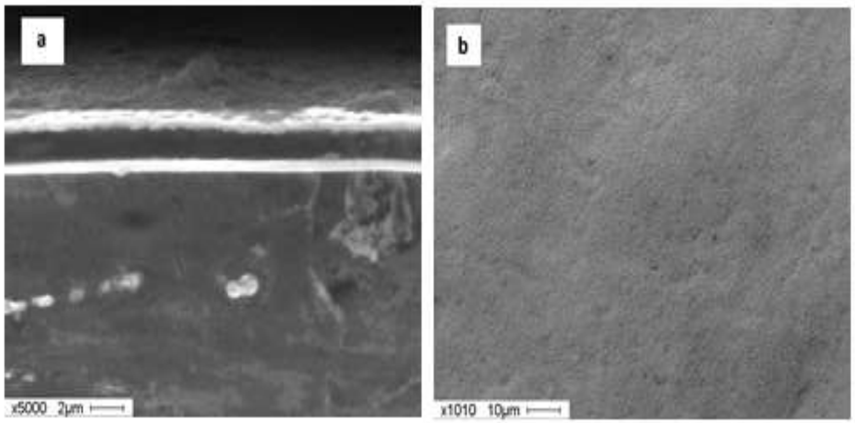
- Electron energy is 20 *keV*
- Pulse duration of 2,5 μs

The films were deposited in such a way that the equiatomic composition of Ni and Al was 50/50 at.%.

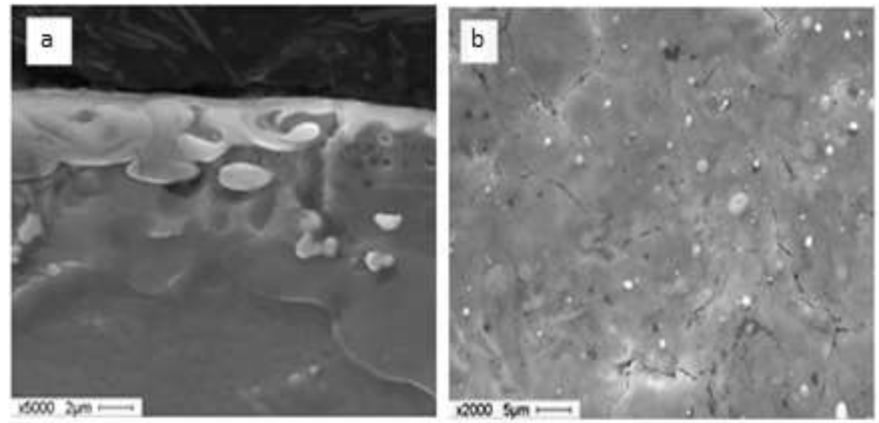
<u>Step 1:</u> Magnetron deposition of nanofilm

<u>Step 2:</u> Electron-beam mixing of the "film-substrate" system using 1, 2, 4, 8 pulses

Morphology of the studied samples



SEM images of cross section (a) and surface alloy (b) before irradiation

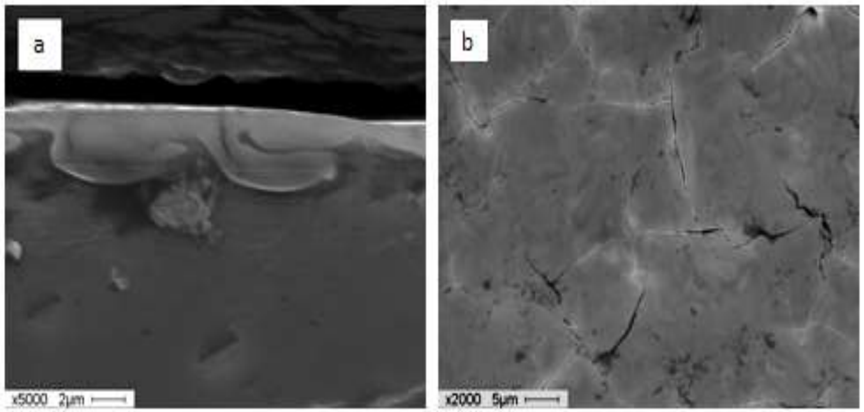


SEM images of cross-section (a) and surface alloy (b) after single pulse irradiation

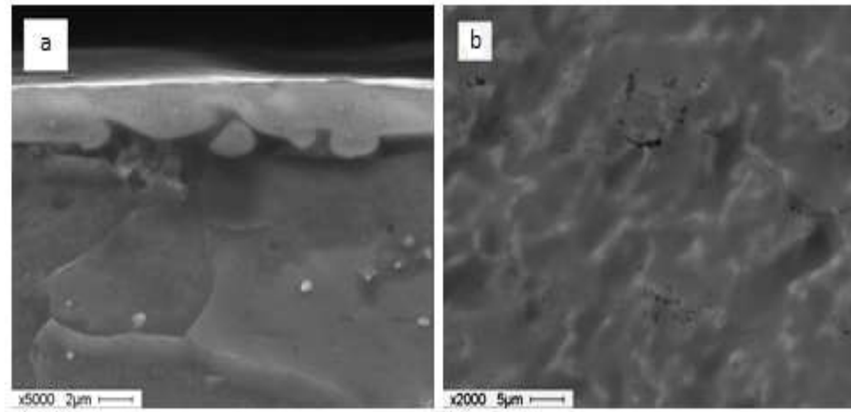
The coating is a uniform alternating film of Ni and Al. The total thickness of the system was 2.27±0.06 μm. The surface of the original system is homogeneous without cracks

Melting and mixing of three layers and the formation of a transition layer with tongue-like and globular formations are observed. The thickness alloy over the entire area is not uniform, the average thickness is 2.37±1.41 μm. The surface of the sample is uneven, cracks are observed. The crack formation factor is 0.4%.

Morphology of the studied samples



SEM images of the cross section (a) and surface alloy (b) after irradiation with two pulses.

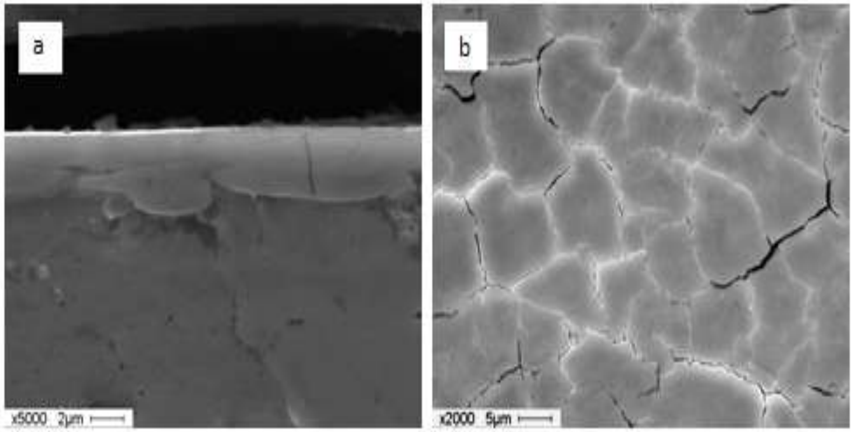


SEM images of the cross section (a) and surface alloy (b) after irradiation with four pulses.

When increasing to two pulses, the average film thickness is 2.13±1.21 μm, a slight alignment of the layer is seen. The thickness of microcracks reaches 0.63 μm, and their length is 46 μm. The crack formation factor is 1%.

The average alloy thickness is 2.45±0.64 μm, which indicates an improvement in uniformity. There are no cracks on the surface. Distributed stress centers are formed on the sample surface, forming a network structure.

Morphology of the studied samples

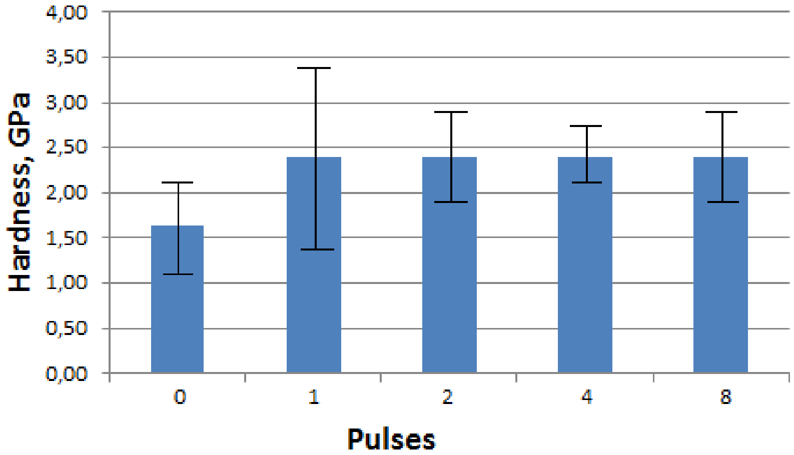


SEM images of cross-section (a) and surface alloy (b) after irradiation with eight pulses

The most smooth and uniform layer with respect to the substrate is visible. On the surface of the sample, one can visually trace the formation of distributed stress centers that form a network structure. The alloy thickness was 2.77±0.71 μm. Microcracks again form on the surface, both single, up to 14 μm long, and forming cells up to 26 μm in size. The thickness of microcracks reaches 0.4 μm. The crack formation factor is 2%.

With an increase in the number of irradiation pulses by LEHCEB, a tendency to an increase in the number of cracks on the surface of the samples is observed. However, the sample irradiated with 4 pulses falls out of this trend. At the same time, starting with 4 irradiation pulses, a more uniform transition layer is observed in the samples.

The study of microhardness



Microhardness values of the initial sample and samples irradiated by a series of pulses (0 - initial system)

Initial system – 1.63±0.5 GPa

1 pulse – 2.4±1 GPa

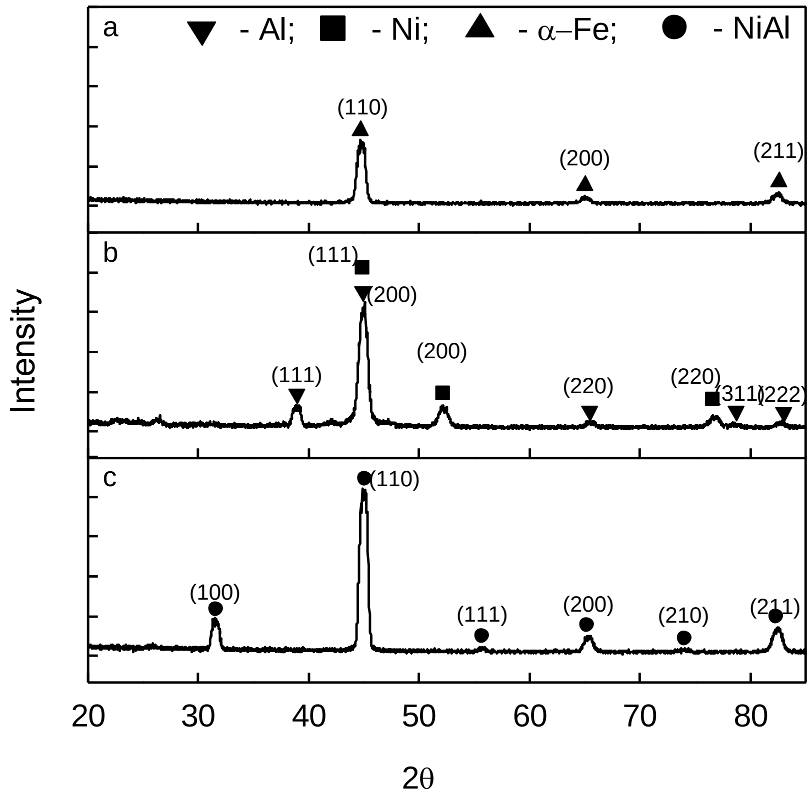
2 pulses – 2.4±0.5 GPa

4 pulses – 2.4±0.3 GPa

8 pulses – 2.4±0.5 GPa

The microhardness values do not depend on the number of LEHCEB pulses. A sample irradiated with 4 pulses has a minimum spread in microhardness values. This is due to the absence of cracks, a smooth surface, and a relatively uniform thickness of the formed alloy surface over the entire sample area.

Study of the phase composition



X-ray diffraction patterns of samples: a - substrate, b and c - samples with a multilayer Ni-Al coating before and after irradiation with LEHCEB, respectively.

- The phase composition of the substrate in the initial state is represented by the α-Fe phase.
- After deposition of a multilayer Ni-Al coating, Ni and Al peaks appear.
- The formation of a surface NiAl alloy leads to a change in the phase composition. The Ni and Al peaks disappear, instead the present peaks are identified as the NiAl intermetallic compound phase.

Conclusion:

1. With an increase in the number of pulses, the boundary of the transition layer of the formed surface alloy is leveled;
2. All formations in the transition layer of the surface alloy are reduced in both size and quantity;
3. Samples with a surface alloy have a microhardness value of 1.5 times that of the initial system;
4. Ni-Al alloys formed with LEHCEB showed similar microhardness results for all irradiation modes;
5. As a result of irradiation by the LEHCEB of a three-layer system, a surface alloy is formed, consisting of an intermetallic NiAl phase.

Thanks for your attention!