ACOUSTIC SIGNALS IN NI-AL COATED STEEL INDUCED BY IRRADIATION WITH A LOW-ENERGY HIGH-CURRENT ELECTRON BEAM

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Outline

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Background

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The increasing requirements of modern technologies for the formation of new materials and coatings the constant development of scientific methods, techniques of monitoring the characteristics and properties of materials during their modification is required. Exposure by the intense pulsed electron beams is a universal way of modifying the material and forming of various compositions surface alloys. In material or a coating during pulsed exposure by electron beam the thermoelastic stresses is occur. These thermoelastic stresses are sources of acoustic waves. Acoustic waves propagating from the interaction region carry information both on the energy properties and spatial distribution of the particle flux and on the thermodynamic processes during the formation of surface alloys. This acoustic effect can become the basis of a new method for studying the properties of new materials and processes during their formation.

This work is devoted to the description of acoustic signal morphology at formation of Ni-Al surface alloy on a steel substrate at irradiation by low-energy high-current electron beam for the purpose of development of radiation-acoustic diagnostics methods.

Surface alloys formation

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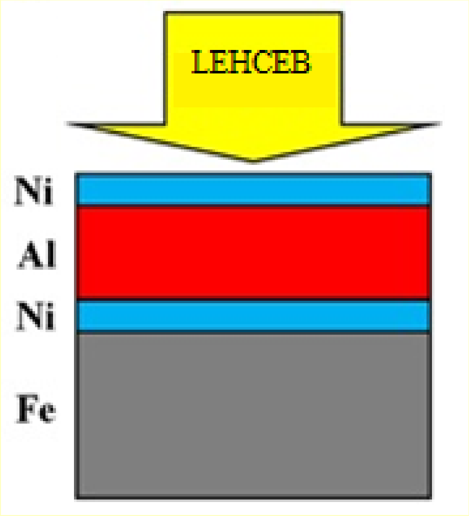

The electron-beam machine RITM-SP (Microsplav OOO, Tomsk, Russia) based on the source of low-energy high-current electron beams (LEHCEB) developed at the Institute of High-Current Electronics of the SB RAS was used for irradiation. Electron-beam machine RITM-SP combines on one vacuum chamber a magnetron spraying system and a source of low-energy (10-30 keV) high-current (up to 25 kA) electronic beams with pulse duration of 2-4 μs and beam diameter of 60-80 mm.

The NiAl multi-layer system on a steel substrate was investigated. Samples made of steel with dimensions 50×5×2 mm were used as substrates. The surface alloy was formed by single LEHCEB exposure of a multilayer system of alternating layers of nickel and aluminum with a total thickness of 2.5 microns (Ni(0.5)/Al(1.5)/Ni(0.5)/Fe). The ratio of Ni and Al thicknesses was chosen so that the total system had an equiatomic composition of nickel and aluminum. The layers were deposited by magnetron sputtering of nickel (99.95 wt.%) and aluminum (99.95 wt.%) targets. The deposition rate was 10.9 ± 0.6 and 9 ± 0.5 μm/h, respectively.

Acoustic waves registration

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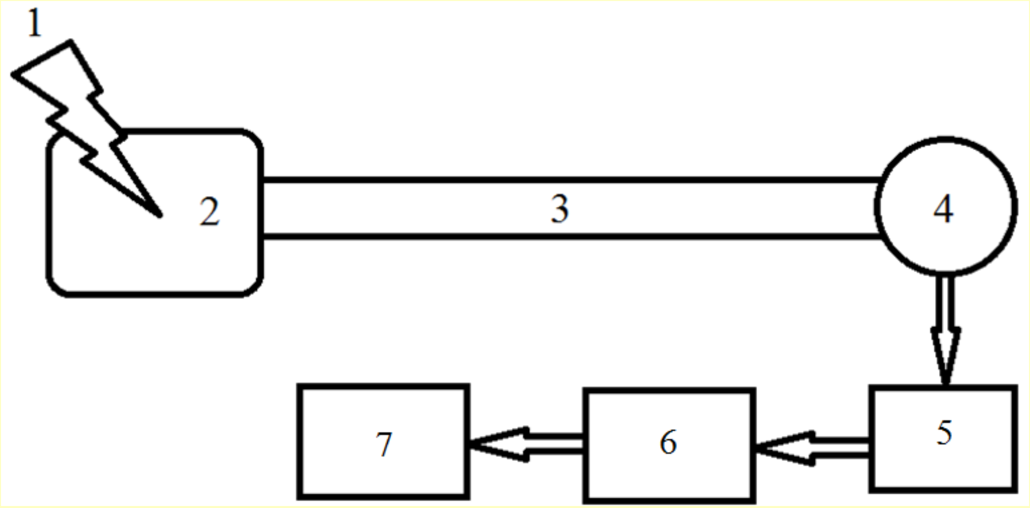

Scheme of recording of acoustic waves

The target (2), in this case the NiAl multilayer system on a steel substrate, is positioned perpendicular to the intense electronic beam (1). The target is rigidly connected to a copper conductor (3) of a rectangular cross section of 1×5 mm and a length of 3 m. The other end of the conductor is rigidly connected to piezoelectric transducer 4. After preliminary amplifier 5, electric analog signals from the piezoelectric transducer are fed to E14-440 analog-digital converter 6 and then are stored already in digital form in a database of personal computer 7. Sampling frequency of ADC was 400 kHz.

Acoustic signal type

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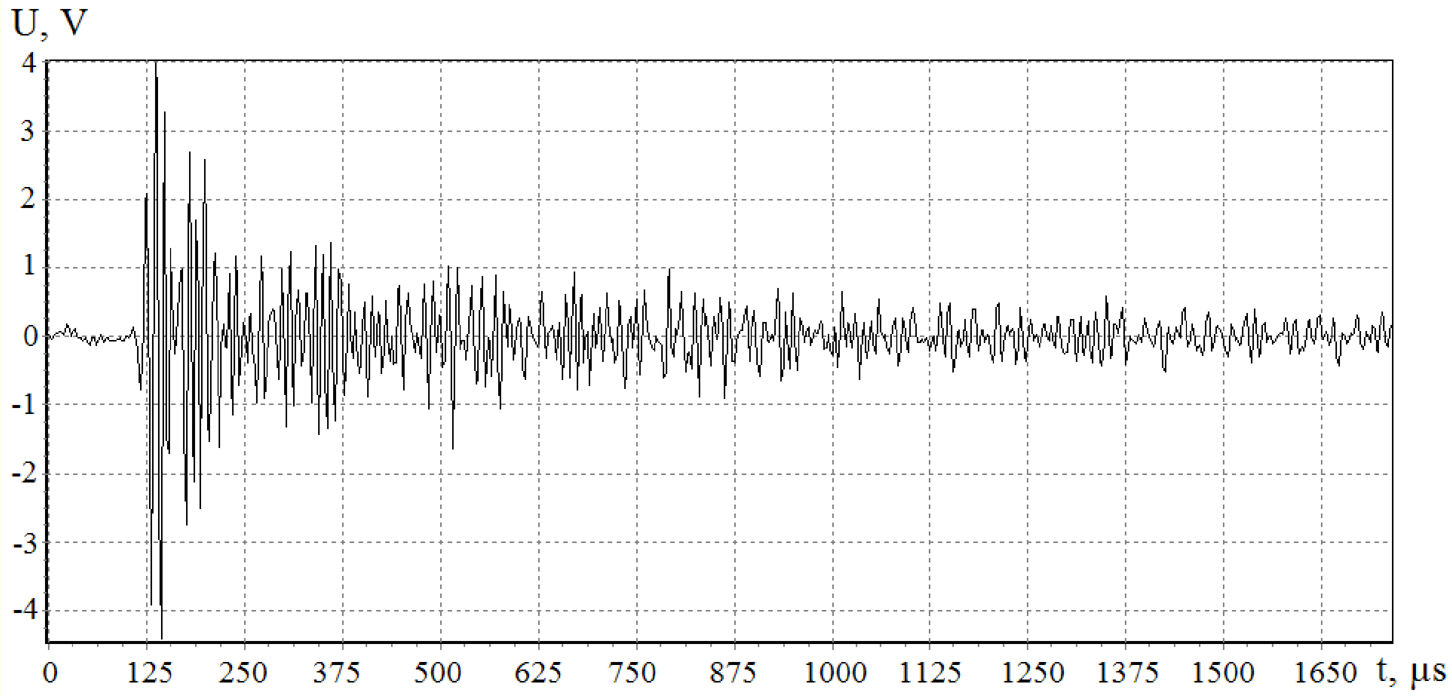
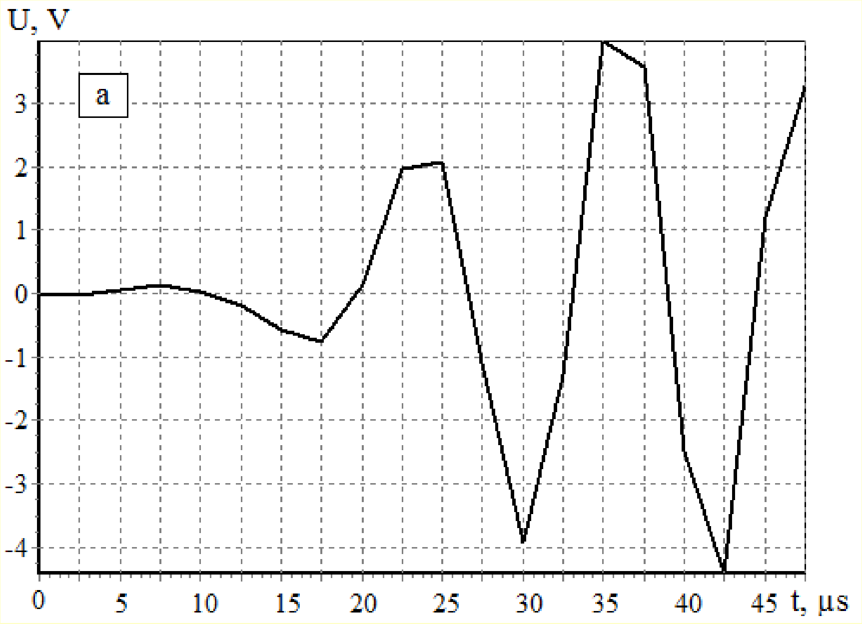


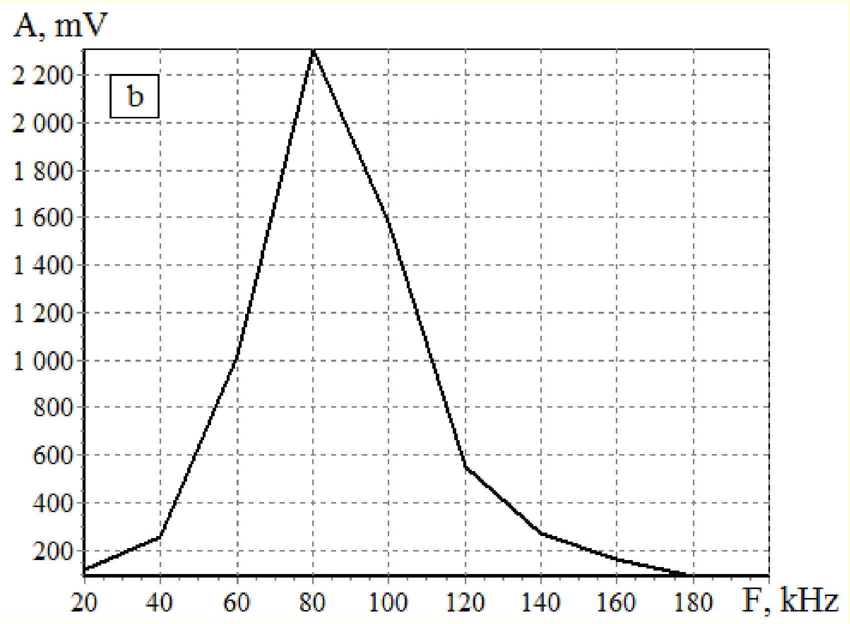
Average acoustic signal type

The acoustic signal from the piezoelectric sensor was detected 0.87 ms after the electromagnetic interference not related to the acoustic emission has passed into the conductor, but which can be used as a marker to time the beginning of the acoustic signal generation process. 7 experiments were made to register acoustic signals under the influence of a pulsed electron beam on steel with Ni-Al coating. For all received implementations of acoustic signals there is a repeatability of their shape and phase-frequency characteristics.

Spectral analysis



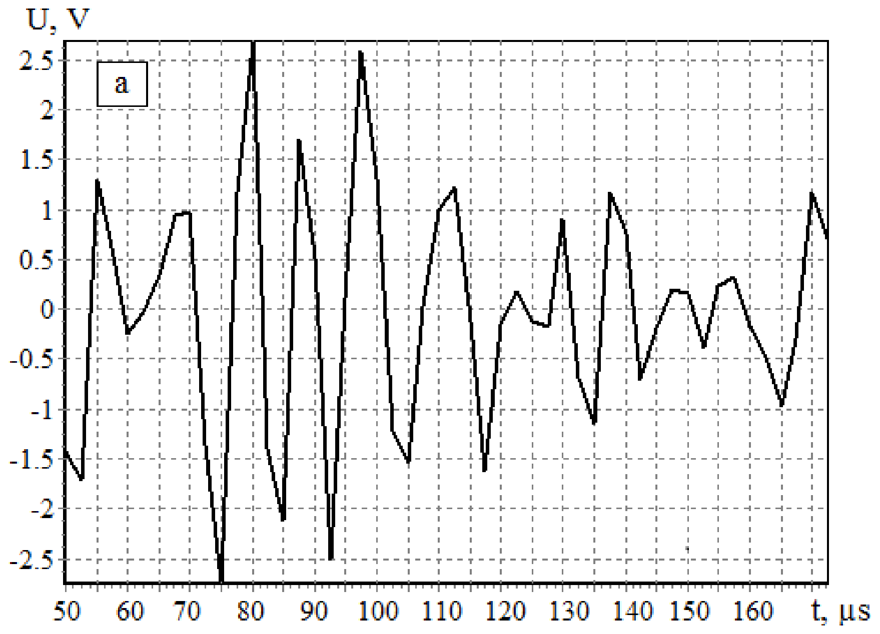
Acoustic signal form



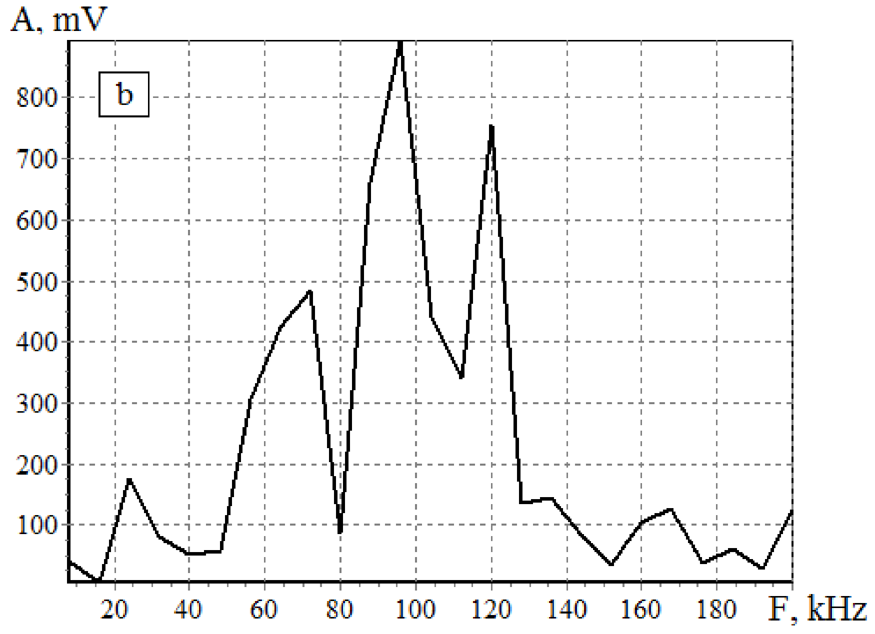
Spectrum

The first 50 μs after exposure by an LEHCEB an acoustic signal with a frequency of 80 kHz is excited in the sample. This type of signal is associated with thermal and shock-wave processes when the beam energy is absorbed into the target. It is coincides in the form with the signal received earlier for the similar exposure by an LEHCEB on a copper target.

Spectral analysis



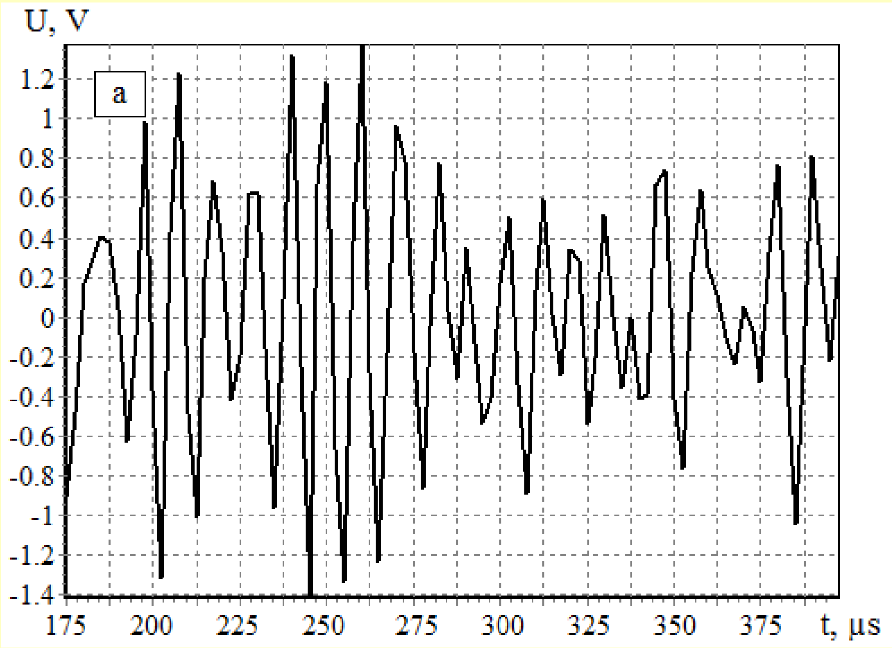
Acoustic signal form



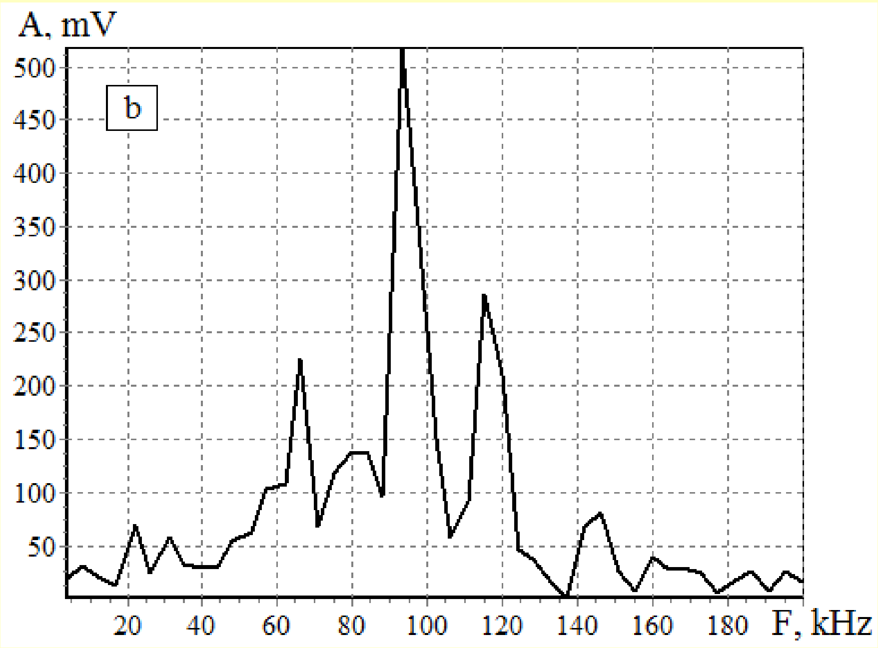
Spectrum

During the subsequent time interval 50-175 μs, the components with a frequency of 22 kHz, 64 kHz, 96 kHz, 120 kHz, 136 kHz and 168 kHz was observed. The components with frequencies 64 kHz, 96 kHz and 120 kHz in the spectrum have the largest amplitudes. Previously it was shown that in a similar time interval after exposure by an LEHCEB in a copper target oscillations with frequencies of 80 kHz and 120 kHz amplitude of which increases in proportion to the charging voltage.

Spectral analysis



Acoustic signal form



Spectrum

During the subsequent time interval 175-400 µs, the components with a frequency of 22 kHz, 31 kHz, 66 kHz, 80 kHz, 93 kHz, 115 kHz and 146 kHz was observed. Oscillations with frequencies of 80 kHz, 100 kHz and 116 kHz were observed in a copper target on a similar time interval.

Spectral analysis

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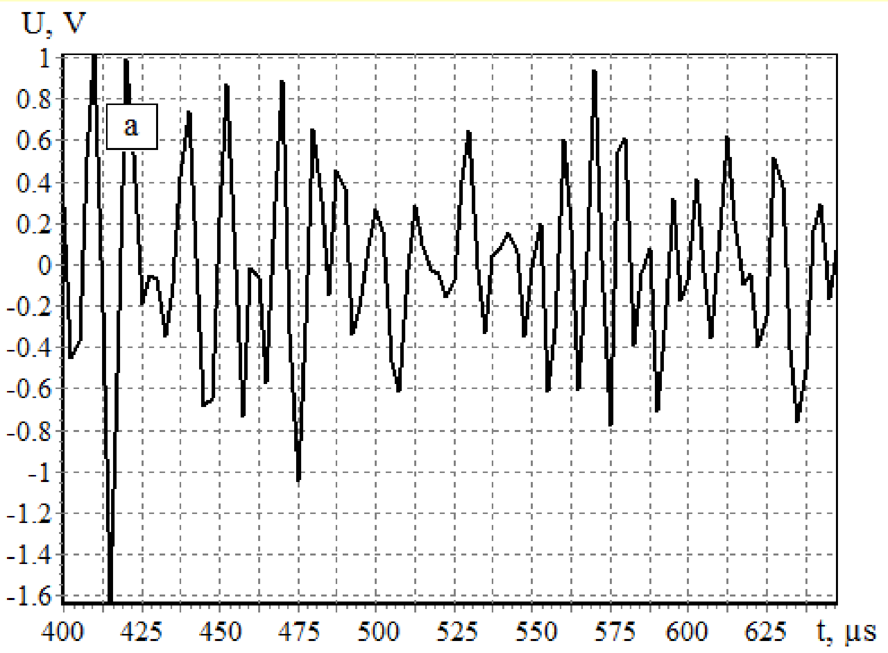
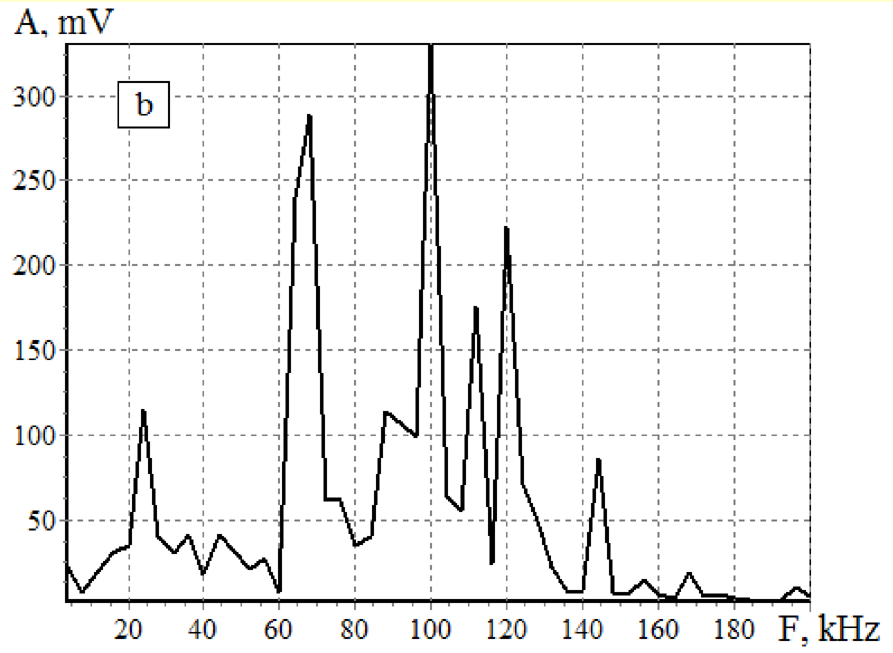


Acoustic signal form



Spectrum

During the subsequent time interval 400-650 µs, the components with a frequency of 24 kHz, 64 kHz, 100 kHz, 120 kHz, 144 kHz was observed. For a copper target, harmonics with frequencies of 11 kHz and 22 kHz were observed in a similar time interval. Then the signal spectrum as a whole saves its form with a monotonic decrease in amplitudes of harmonic components. After 2.5 ms, the spectrum begins to be dominated by a harmonic component with a frequency of 23 kHz whose amplitude decreases over time until the signal disappears completely.

Conclusion

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1. The characteristic forms of acoustic signals at irradiation of NiAl multilayer system on a steel substrate are experimentally received.

2. It is received, that at pulse action at the given charge voltage of a beam of 22 kV for each pulse the qualitative amplitude and phase-frequency structure of acoustic signals in a target is kept.

3. It was found that the acoustic signal with the main frequencies 22-31 kHz, 64-66 kHz, 80 kHz 93-96 kHz, 115-136 kHz and 160-168 kHz is excited under the influence of the pulse electron beam in NiAl multilayer system on the steel substrate.

4. It was obtained that in the acoustic signal spectrum in the investigated sample there are coincident or close harmonics of the acoustic signal spectrum in the copper target.

The end

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Thanks for attention!