Analysis of Structure and Microhardness $AlSi_5Cu_2$ and $AlSi_{10}Cu_2$ Cast Alloys Subjected to Electron Beam Surface Melting

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INTRODUCTION

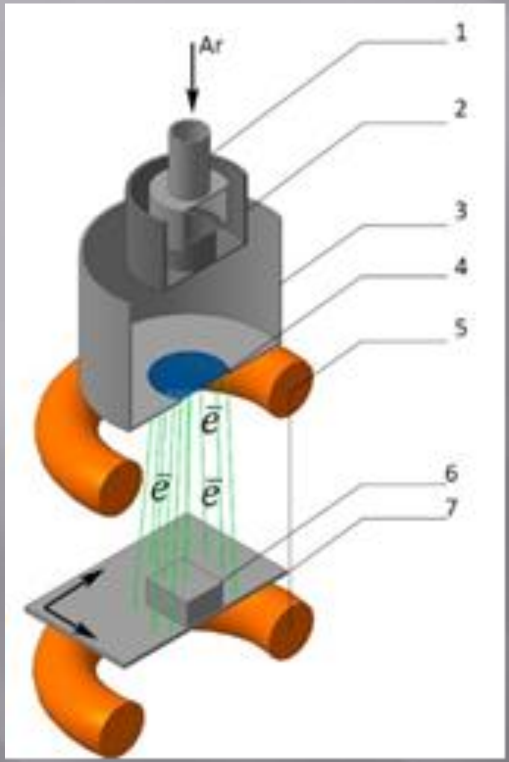
Nowadays the larger part of mechanical energy is generated by internal-combustion engines (ICE) being the main powerful units used generally in many spheres of man’s life.

Now it is a sound practice to introduce the technologies optimizing the process of mechanical energy generation by internal combustion engines and decrease gradually the number of exhausts into atmosphere unless the necessary requirements of competitive converters are reached. One of the optimization methods is a deposition of coatings. However, the methods used nowadays prevent the universal introduction of some technologies by reason of height risk of negative effect on environment and insufficient service life.

The situation being formed stimulates to look for the new ways of solving the problem. The authors consider the process of $AlSi_5Cu_2$ and $AlSi_{10}Cu_2$ alloy modification by the method of surface processing with intense electron beam permitting one to increase the quality of surface and its mechanical characteristics.

MATERIALS AND METHODS

The setup SOLO designed at the Institute of High-Current Electronics SD RAS being used for surface modification of various materials was used to modify the surface layer of the alloys by electron beam processing, its basic diagram is shown in slide



1 - hollow anode of igniting discharge;

2 – hollow cathode;

3 – hollow anode of basic discharge;

4 – emission mesh;

5 – magnetic field coil;

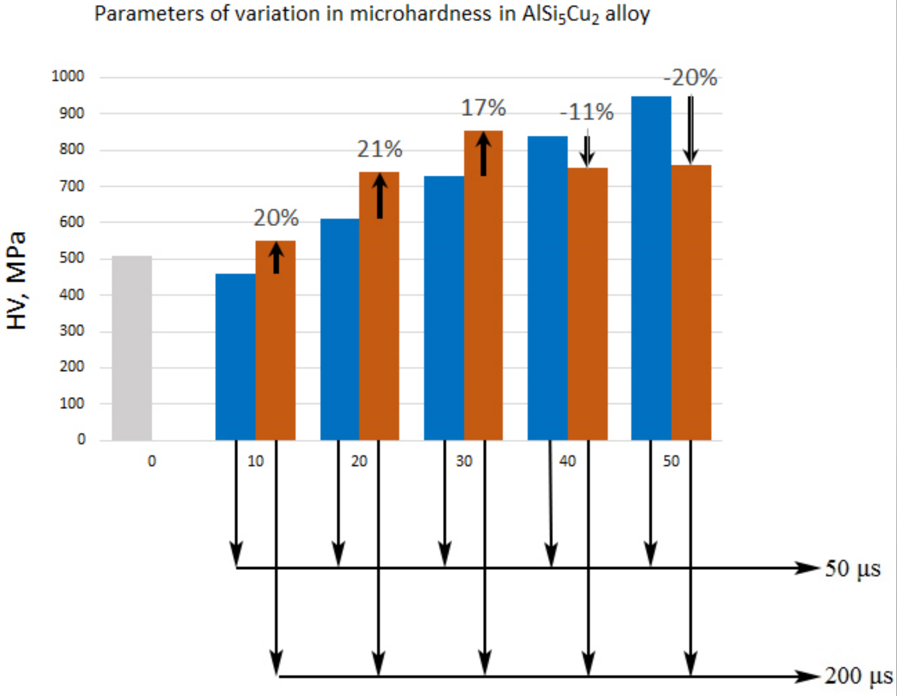
6 – sample being processed;

7 – two rectilinear manipulator.

The following characteristics were varied within the frame works of the experiment: at electron energy of 17 keV the energy density of electron beam (10, 20, 30, 40 end 50) J/cm^2, the pulse duration (50 and 200 μs).
The number of pulses–3, the pulse repetition rate–0,3s^{-1}, the pressure of residual gas (argon) in working chamber of setup– $-2 \cdot 10^{-2}$ Pa.

RESEARCH RESULTS AND DISCUSSION

a



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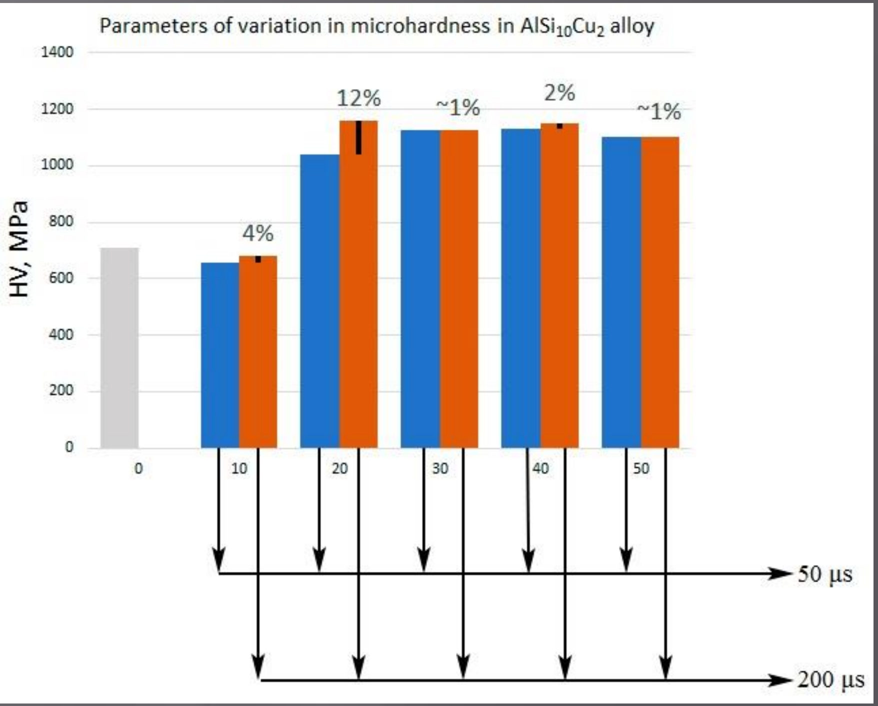
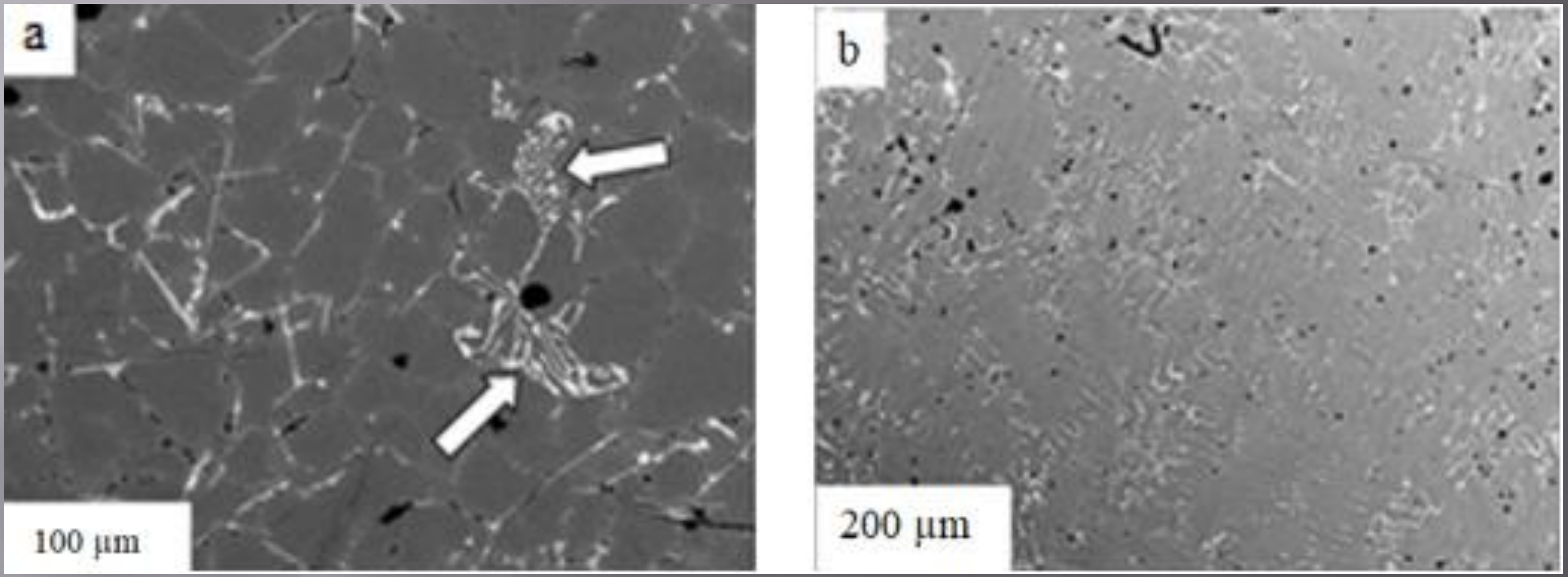


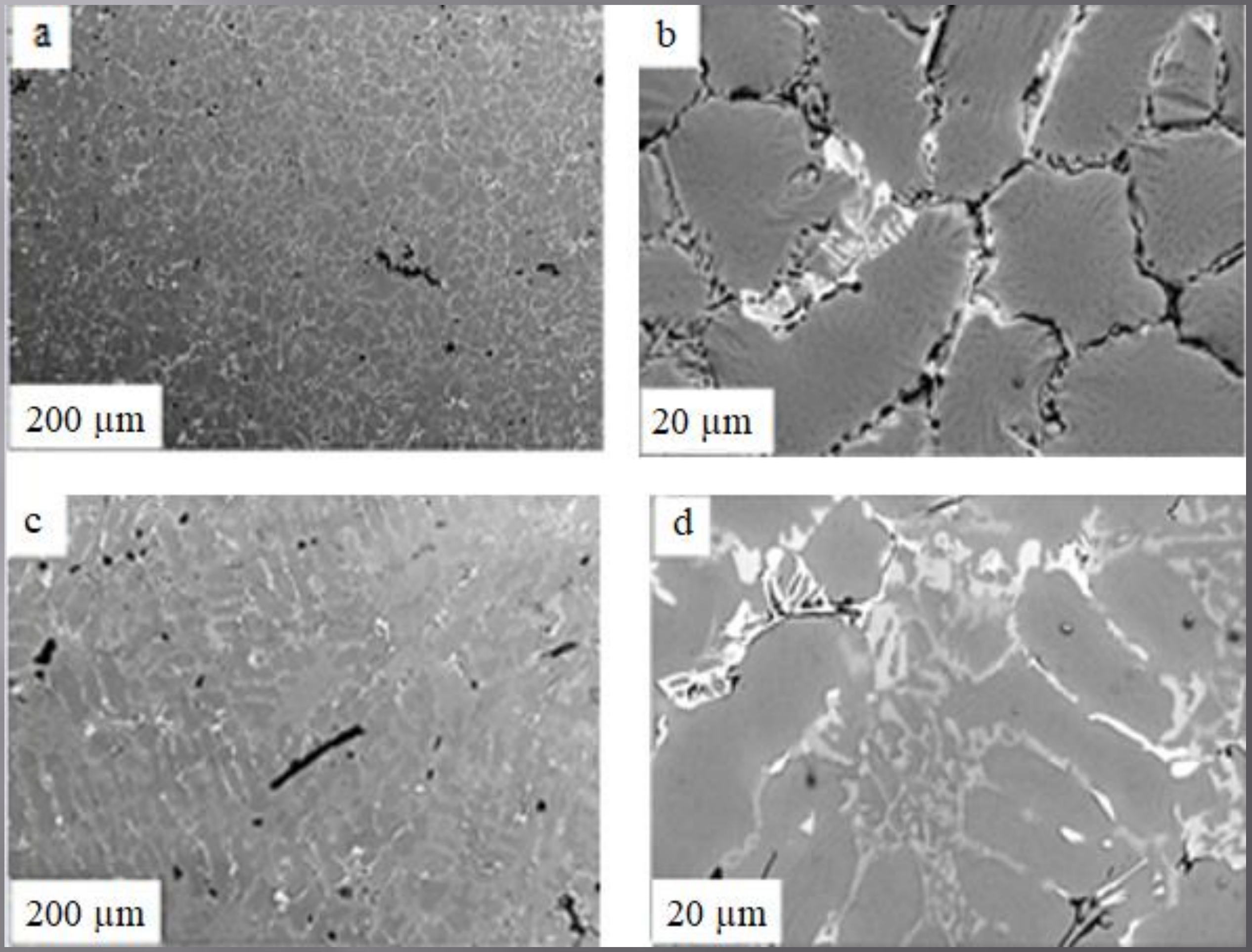
Dependances of microhardess parameter of $AlSi_5Cu_2$ (a) and $AlSi_{10}Cu_2$ (b) alloys on energy density of electrons E_s and pulse duration 50 µs (blue bar) and 200 µs (red bar). Indenter load – 1 H. Grey bar indicates the initial microhardness of $AlSi_5Cu_2$ and $AlSi_{10}Cu_2$ aloys.

The structure of $AlSi_5Cu_2$ and $AlSi_{10}Cu_2$ alloys before and after processing was studied by the methods of scanning electron microscopy. As a result of analysis, it was detected that $AlSi_5Cu_2$ and $AlSi_{10}Cu_2$ alloys in the initial state are polycrystalline aggregates formed by grains of aluminium and Al-Si eutectic



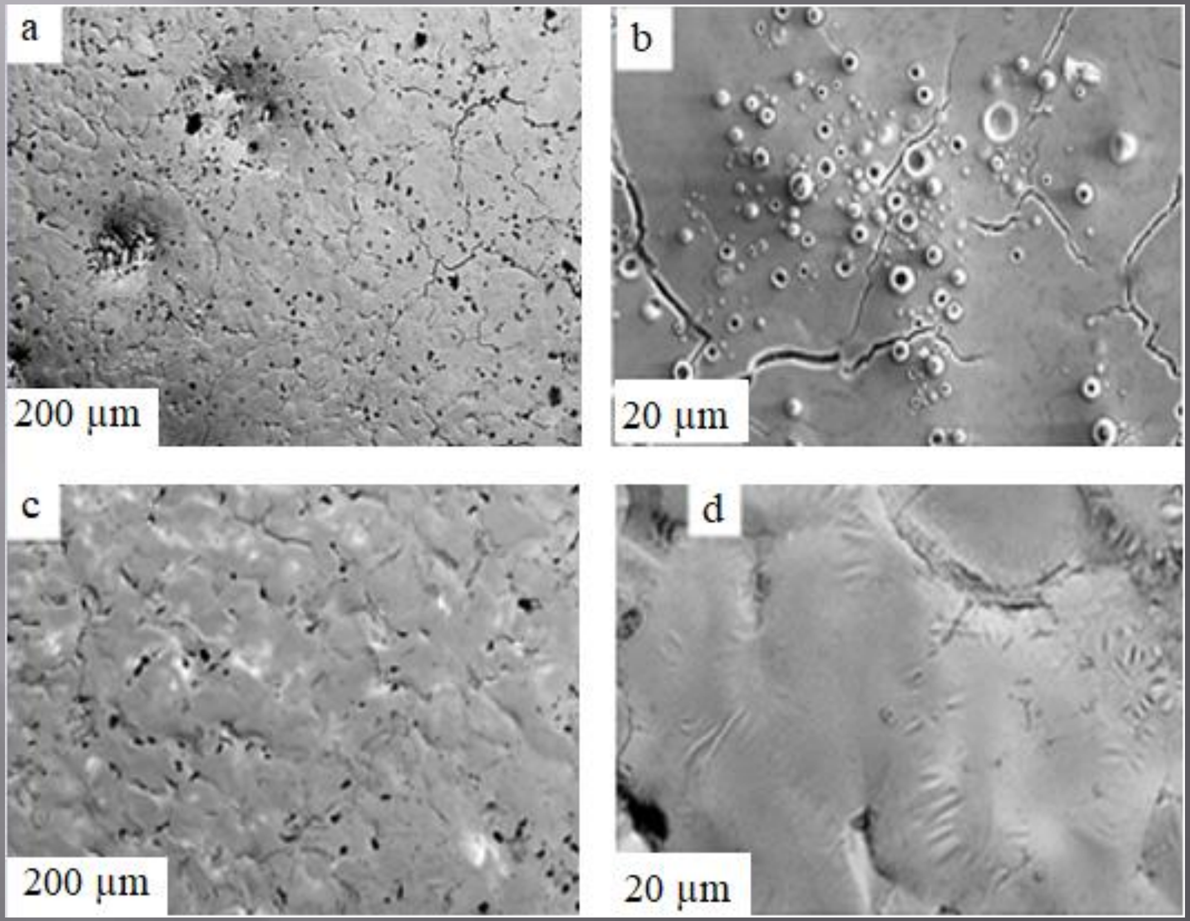
Structure etched surface of $AlSi_5Cu_2$ (a) and $AlSi_{10}Cu_2$ (b) alloys in the initial state (prior to pulsed electron beam irradiation). Arrows indicate the intermetallide inclusions presenting the nuclei crack formation

The electron beam causes the extensive change in sample surface structure. With energy density of electron beam of 10 J/cm^2 the intensive etching and smoothing of the surface are observed, the changes in the number of intermetallide inclusions are absent along the grain boundaries



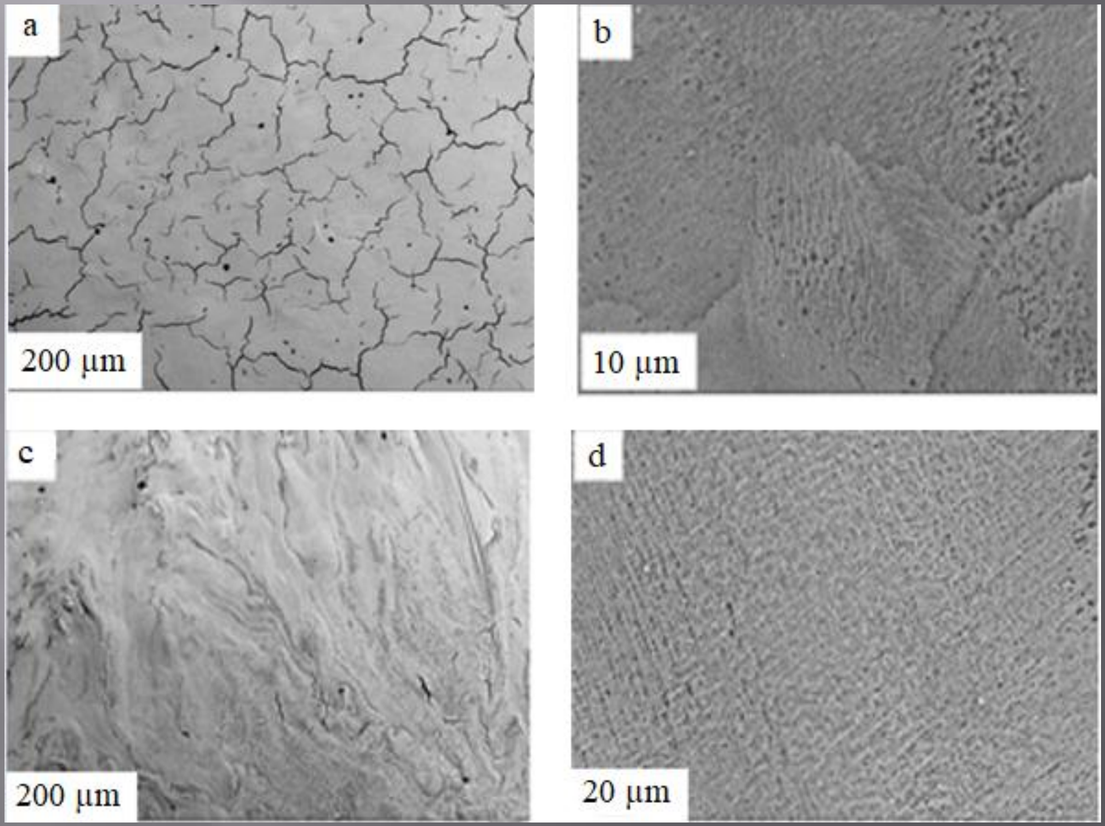
Surface structure of $AlSi_5Cu_2$ and $AlSi_{10}Cu_2$ silumins subjected to pulsed electron beam irradiation. For $AlSi_5Cu_2$ – (a) 10 J/cm^2, 200 µs; (b) 10 J/cm^2, 50 µs and $AlSi_{10}Cu_2$ – (c) 10 J/cm^2, 200 µs; (d) 10 J/cm^2, 50 µs. Scanning electron microscopy

With the increase in energy density of electron beam to 30 J/cm^2 the effect of covering the irregularities and defects on the surface is more noticeable (Figure 5). The degree of surface smoothing is practically independent of pulse time. The shrinkage of the material at its high rate of crystallization caused by superrapid heating and cooling may serve as one of the possible causes of the effect.



Surface structure of $AlSi_5Cu_2$ and $AlSi_{10}Cu_2$ silumins subjected to pulsed electron beam irradiation. For $AlSi_5Cu_2$ – (a) 30 J/cm^2, 200 µs; (b) 30 J/cm^2, 50 µs and $AlSi_{10}Cu_2$ – (c) 30 J/cm^2, 200 µs; (d) 30 J/cm^2, 50 µs. Scanning electron microscopy

The surface defects cover completely at energy density of electron beam of 50 J/cm^2 on irradiation surface independent of pulse duration. It should be noted that the processing mode results in maximum increase in microhardness for $AlSi_5Cu_2$ alloy. It is supposed that the increase in strength characteristics as a result of external effect is caused by the formation of surface layer of high-velocity cellular crystallization with extremely small grain size.



Surface structure of $AlSi_5Cu_2$ and $AlSi_{10}Cu_2$ silumins subjected to pulsed electron beam irradiation. For $AlSi_5Cu_2$ – (a) 30 J/cm^2, 200 µs; (b) 30 J/cm^2, 50 µs and $AlSi_{10}Cu_2$ – (c) 30 J/cm^2, 200 µs; (d) 30 J/cm^2, 50 µs. Scanning electron microscopy

CONCLUSION

It was established that irradiation of $AlSi_5Cu_2$ and $AlSi_{10}Cu_2$ alloys with pulsed electron beam is accompanied by the change in microhardness and covering the surface defects. As a result of concentrated energy flow effect the sample surface melts, during heat effect the tensile stresses arise that contribute to covering the surface defects being formed during sample processing.

The data on surface layer modification of $AlSi_5Cu_2$ and $AlSi_{10}Cu_2$ alloys obtained in the course of the research allow the suggestion that the increase in material surface hardness is caused by the formation of extremely small grains of high velocity cellular crystallization and the repeated precipitation of nanodimensional particles of the strengthening phases (silicon and intrermatalies).