alloys, Ti–Al–V (BT6) and Ti–Al–V–Mo (BT14), a two-stage technological cycle to manufacture the desired product is proposed and studied in this work. In the first stage the material specimen is subjected to severe plastic deformation to form submicrocrystalline structure that ensures higher strength. In the second stage a nanocomposite coating is synthesized in order to significantly improve the tribotechnical properties of the surface layer and remain the parameters of sample bulk submicrocrystalline structure unaltered.

The method of gradient nanocomposite coatings formation employing ion-plasma technology and a multicomponent target for magnetron plasma sputtering has been developed. In this method the processes of ion-plasma surface cleaning, ion-plasma coating surface doping and magnetron-plasma spray coating are combined in an overall cycle. The given method and the sputtering target Ti–C–Mo–S application enabled to form a gradient nanocomposite structure with a surface layer containing carbide TiC, silicide $MoS_2$ and an X-ray amorphous phase, each one is less than 100 nm. Such a surface layer presence decreased the friction coefficient by a factor of ten, considerably increased wear resistance and resulted in friction pairs running-in as well.

The results of our work are relevant for the development of submicrocrystalline titanium alloys friction pairs used in dry friction conditions.

*The research was supported by the Ministry of Education and Science of the Russian Federation (objective №2014/223, project code: 727).*

## SPALL FRACTURE GENERAL REGULARITIES AND PATTERNS OF COARSE-GRAINED AND SUBMICROCRISTALLINE Ni–Al ALLOY EXPOSED TO NANOSECOND RELATIVISTIC HIGH-CURRENT ELECTRON BEAM

**Dudarev E.F.[1], Markov A.B.[2], Kashin O.A.[3], Bakach G.P.[1], Tabachenko A.N.[1], Zhorovkov M.F.[1]**

*[1]National Research Tomsk State University, Tomsk, Russia*
*[2]Institute of High Current Electronics, Tomsk, Russia*
*[3]Institute of Strength Physics and Materials Science, Tomsk, Russia,*
*tabachenko@spti.tsu.ru*

According to existing models, spall fracture of metal materials is described as generation, growing and conjunction of micro-pores and cracks, and that caused formation of main crack. As a rule, grains and twins boundaries, accumulations of dislocations and second phase particles are the places of micro-voids arise. It is foundation to propose that sub-micron grain size and un-equilibrium state of grain boundaries in ultra-fine grain alloy may essentially to influence on deformation processes development and on spall fracture characteristics at spall-wave loading. Powerful ($10^{10}$ – $10^{11}$ Wt/cm$^2$) nanosecond relativistic high-current electron beams, which application allows to investigate processes of high velocity deformation and spall occurrences in massive metal specimen, is a perspective source of shock wave.

In this work accelerator of electrons SINUS – 7 with strength of power on irradiated target to $5\times10^{10}\cdot$Wt/cm$^2$ was used to forming shock wave with amplitude, which provides spall fracture of massive targets of alloy Ni–12 at.% Al with velocity of deformation to $10^6$ c$^{-3}$. Submicrocristalline structure, with middle size elements of grain – subgrain structure 240 nm and with theirs distribution in interval from 50 to 1300 nm, was formed by ***abc*** – pressing. It was established that yield stress $\sigma_{0.2}$ increases in 3 times (deformation by tension at the room temperature with the rate $10^{-3}$ s$^{-1}$) at the passage from coarse-grained (middle size of grains 20 μm) to submicrocristalline structure. Fracture tension, calculated from diagram of loading with taking into account the true cross section of specimen in area of fracture increases only on 20% (from 1500 to 1800 MPa) at the transition from coarse-grain to submicrocristalline structure. The fracture of specimens with both grained structures is ductile, with ductile dimple tearing off, not only according deformation, but according structural indication.

Fracture mechanism at influence of electron beams is remained as at quasi-static tension for bath initial grained structures. However fracture surface on mezo-scale level is faceted and consists of combs and cavities; the dimples are observed on the combs. It was shown that the formation of pores and micro-cracks between them goes in front of fracture.

In the specimens with coarse-grain structure not far from split was observed fragmentation of grained structure to submicrocristalline dimensions, but in the specimens with submicrocristalline structure was not observed essential changes in grained structure was not detected. That is in specimens with both initial grained structures, spall fracture in zone with submicrocristalline structure, and spall strength are determines parameters of grain-subgrain structure, which was forming in zone future spall at the wave tension propagating from back surface.

These results of investigations will allow to define more precisely spall fracture mathematical model of submicrocristalline metals and alloys under influence of concentrated energy streams.

*This work has been performed with financial support of Grants RFFE № 10-08-00724-a and № 15-08 04118-a.*