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TERNARY ALLOY Ti-Zr-Nb FORMATION BY MEANS OF HIGH-ENERGY COMPRESSION PLASMA FLOWS IMPACT

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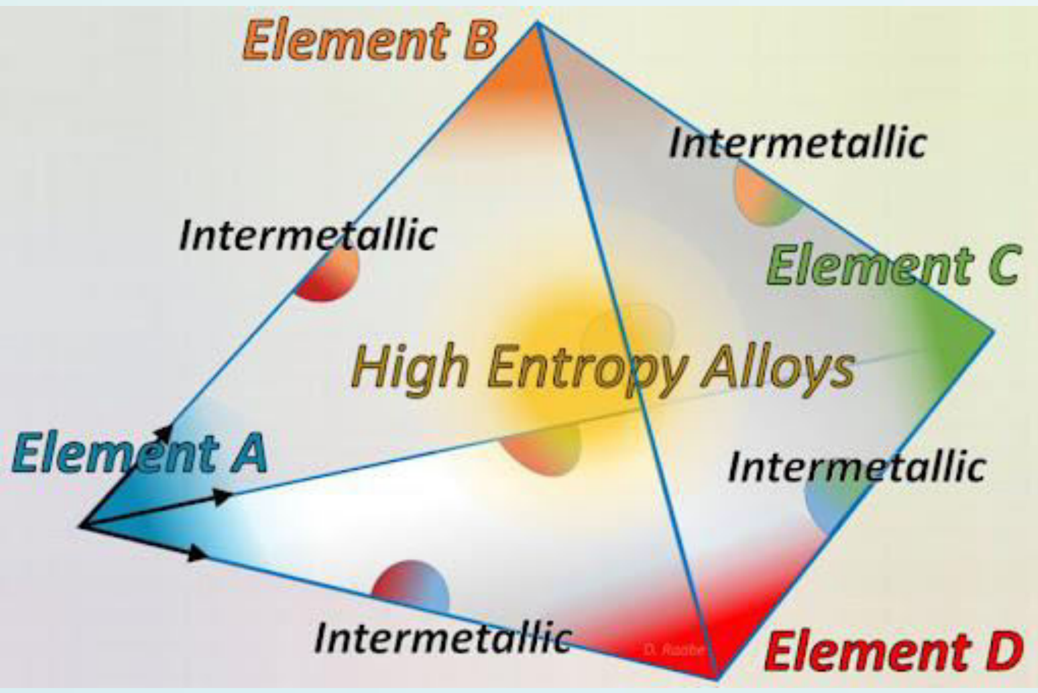
Short introduction



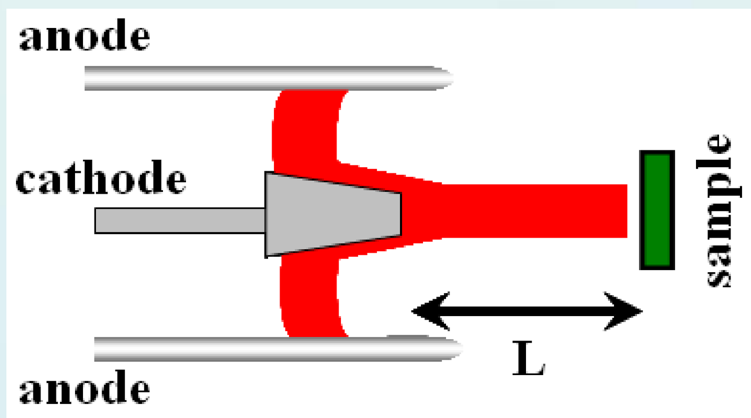
The new paradigm of modern materials science is associated with the approach of forming alloys based on four or more components, all of which have similar crystal lattices and their quantitative content in the alloy is in the range from 5 to 35%. In this case, the concentrations of all elements are comparable with each other and it is not possible to speak about the formation of an alloy based on any of the components. Such alloys are called high-entropy alloys due to the high entropy of mixing of individual components.

As recent studies show, high-entropy alloys have thermal stability, high strength properties, wear resistance, and can also exhibit stability of the structural-phase state under the action of high-energy ions irradiation.

The formation of multicomponent alloys can be carried out in the traditional way by mixing several components in a molten state with their subsequent crystallization. However, if it is necessary to synthesize a high-entropy alloy, the components of which differ significantly in melting temperatures, the most promising methods may be those associated with high-energy pulsed exposure, in which high-speed heating and crystallization occur. In this work, it is proposed to obtain a three-component alloy containing titanium, zirconium and niobium using compression plasma flows.

Experimental procedure

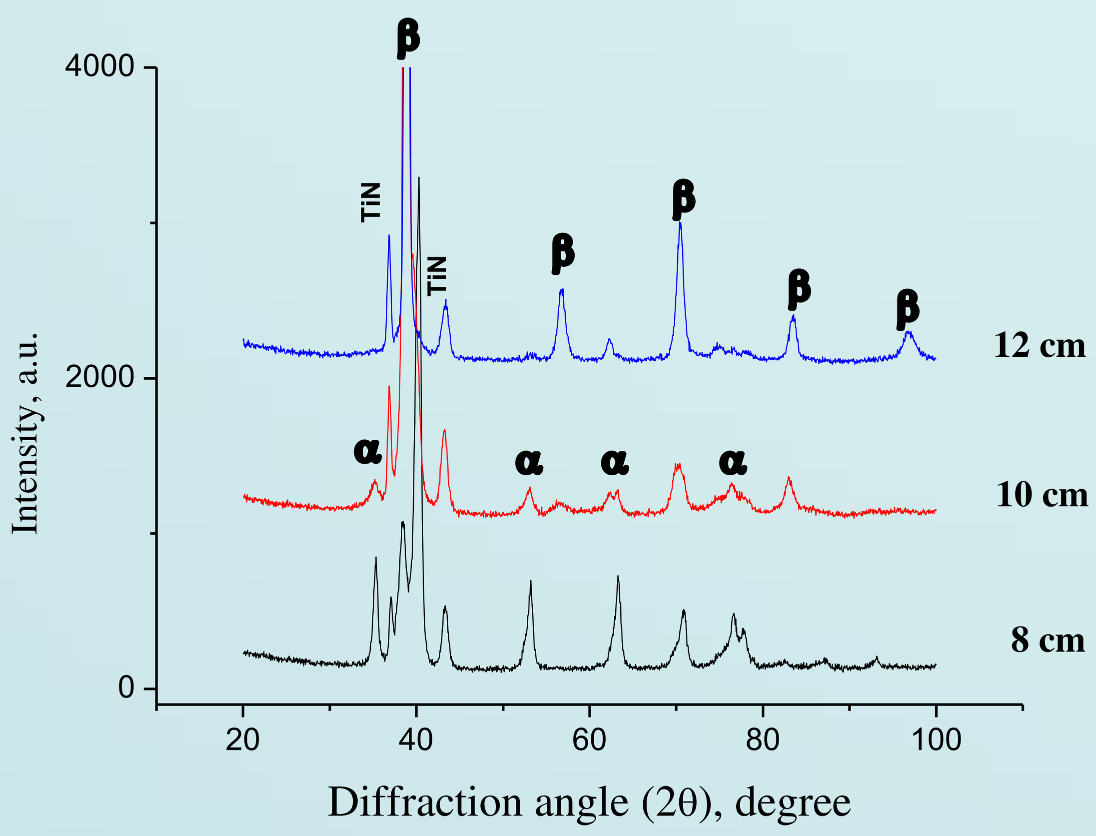
The titanium plates were used as substrates. On the titanium surface two-component (bi-layered) coating consisting of Nb and Zr layers of 2 μm each was deposited. The "coating / titanium plate" system was undergone to compression plasma flows impact with a high absorbed energy density.



Parameters of the plasma impact

- *Number of pulses – **3***
- *Nitrogen residual atmosphere (**pressure 400 Pa**)*
- *Voltage on the capacitor battery – **4.0 kV***
- *Distance between the electrodes and the sample **8-12 cm***
- *Pulse duration **100 μs***
- *Interval between the pulses **20 s***
- *Samples dimensions: **10×10 mm**, thickness **2 mm***

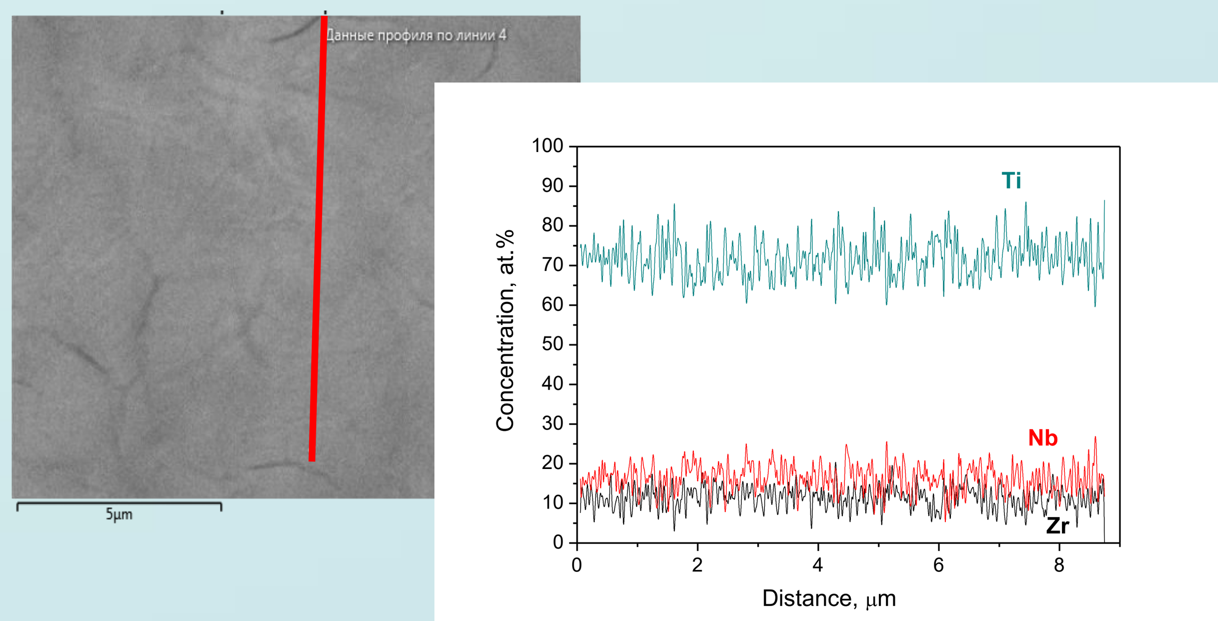
Structure and phase composition of the Ti-Nb-Zr alloys



Elemental composition (at. %) of the alloys after compression plasma flows impact

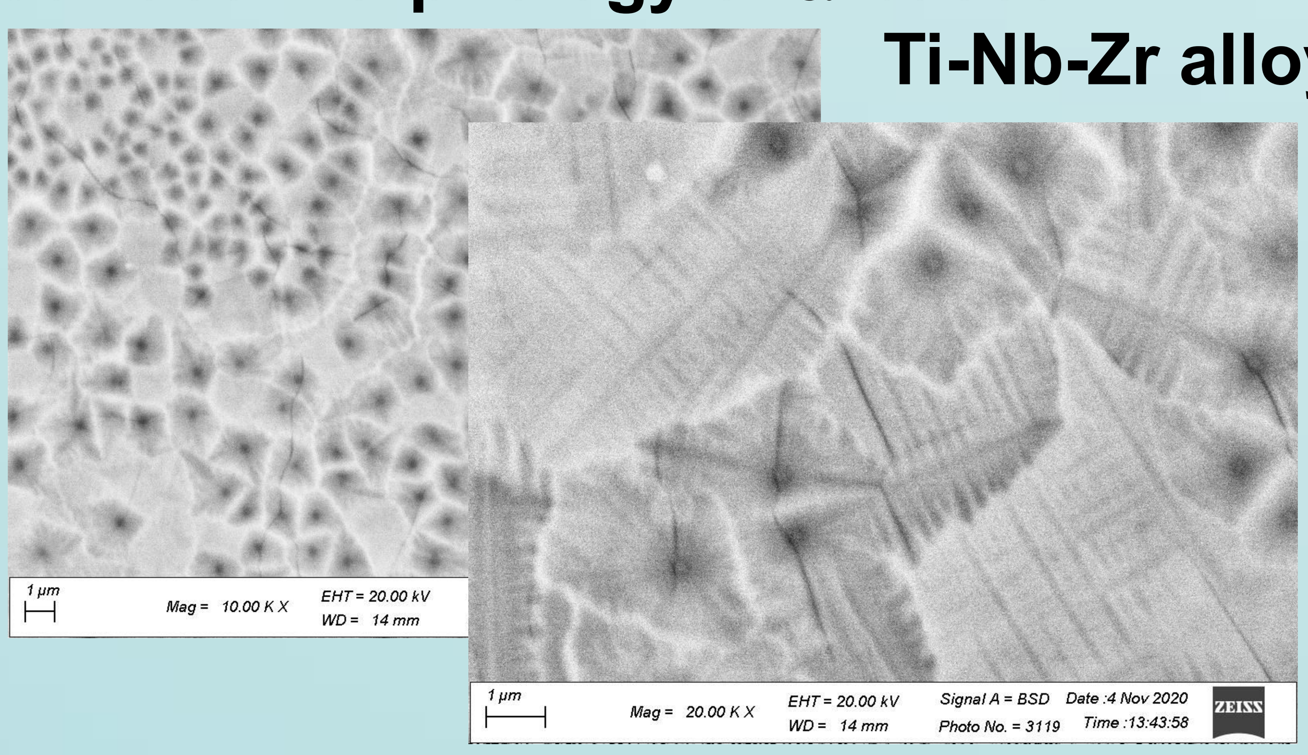
	Ti	Nb	Zr
L = 8 cm	93	2	5
L = 10 cm	83	7	10
L = 12 cm	71	8	21

Exposure to compression plasma flows with the selected energy parameters leads to complete melting of the Zr and Nb coatings, as well as to partial melting of the Ti substrate. The interaction of the plasma flow with the surface of the molten metal layer promotes its mixing and homogenization of the elemental composition, which remains after the rapid crystallization of the melt.



After plasma impact, leading to the melting of the components, a titanium-based three-component solid solution is formed. In the case when the total concentration of zirconium and niobium is 29 at. %, a single-phase alloy based on a β-Ti(Zr,Nb) solid solution with a bcc structure is formed. The lattice parameter of such a solid solution is 0.324 nm, while the lattice parameters of the individual components are 0.331 nm (Ti), 0.354 nm (Zr) and 0.331 nm (Nb), i.e. there is a decrease in the average lattice parameter of the solid solution in comparison with its individual components. With an increase in the absorbed energy density of the plasma flow, when the total concentration of zirconium and niobium is 17 at. %, the modified surface layer is two-phase, which includes both the β-Ti(Zr,Nb) solid solution and the α-Ti(Zr,Nb) solid solution. With a further increase in the absorbed energy density, the total concentration of zirconium and niobium decreases to 7 at.%, which is insufficient to stabilize the high-temperature titanium phase and a single-phase state is formed based on the α-Ti(Zr,Nb) solid solution.

Surface morphology of α-based Ti-Nb-Zr alloy



The surface morphology of three-component Ti-Nb-Zr alloy based on bcc structure (with high concentration of elements) is characterized by uniform distribution. When producing the Ti-Nb-Zr alloy with small concentration of elements, a lot of dendritic and cell peculiarities were found. The center of the cells possesses low concentration of Nb and Zr, these areas are the nucleation points after crystallization.

Surface morphology of β-based Ti-Nb-Zr alloy