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SYNTHESIS OF WZrCu TERNARY ALLOY OF THE TUNGSTEN SURFACE BY PULSED PLASMA IMPACT

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Tungsten and its alloys are considered as promising materials for the first wall of a thermonuclear reactor; however, due to instabilities in the plasma, it interacts with the wall, which leads to structural transformations in the surface layer of tungsten and degrades its physical and mechanical properties. To improve the physical and mechanical characteristics of tungsten, the method of forming alloys based on it is used. However, due to the large difference between the melting points of tungsten and alloying components, traditional methods of forming alloys, for example, using casting technologies, are of little use for it.

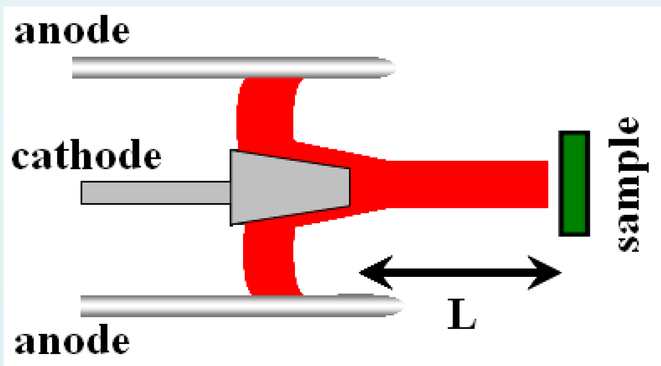
In this work, it is proposed to form a W-Zr-Cu alloy using a pulsed high-energy plasma impact, which allows melting of the alloy components. The choice of copper and zirconium as alloying elements is due to the higher thermal conductivity of copper in comparison with tungsten, which will increase the efficiency of heat removal during the "breakdown" of the plasma in the chamber of a thermonuclear reactor and reduce the level of thermal stresses in the near-surface layer. Zirconium has a greater solubility with copper that provides increasing their concentration in tungsten surface layer.

Experimental procedure

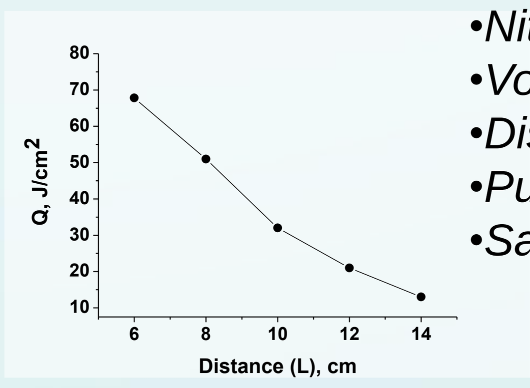
Sample formation

At the initial stage, a copper and zirconium coatings with a thickness of 2 μm was deposited on tungsten samples with a size of 10x10 mm and a thickness of 1 mm. The formation of the coating was carried out by the method of vacuum arc deposition. Then, the samples obtained in this way were processed by compression plasma flows.

Compression plasma flows impact



Scheme of the compression plasma flows (CPF) treatment

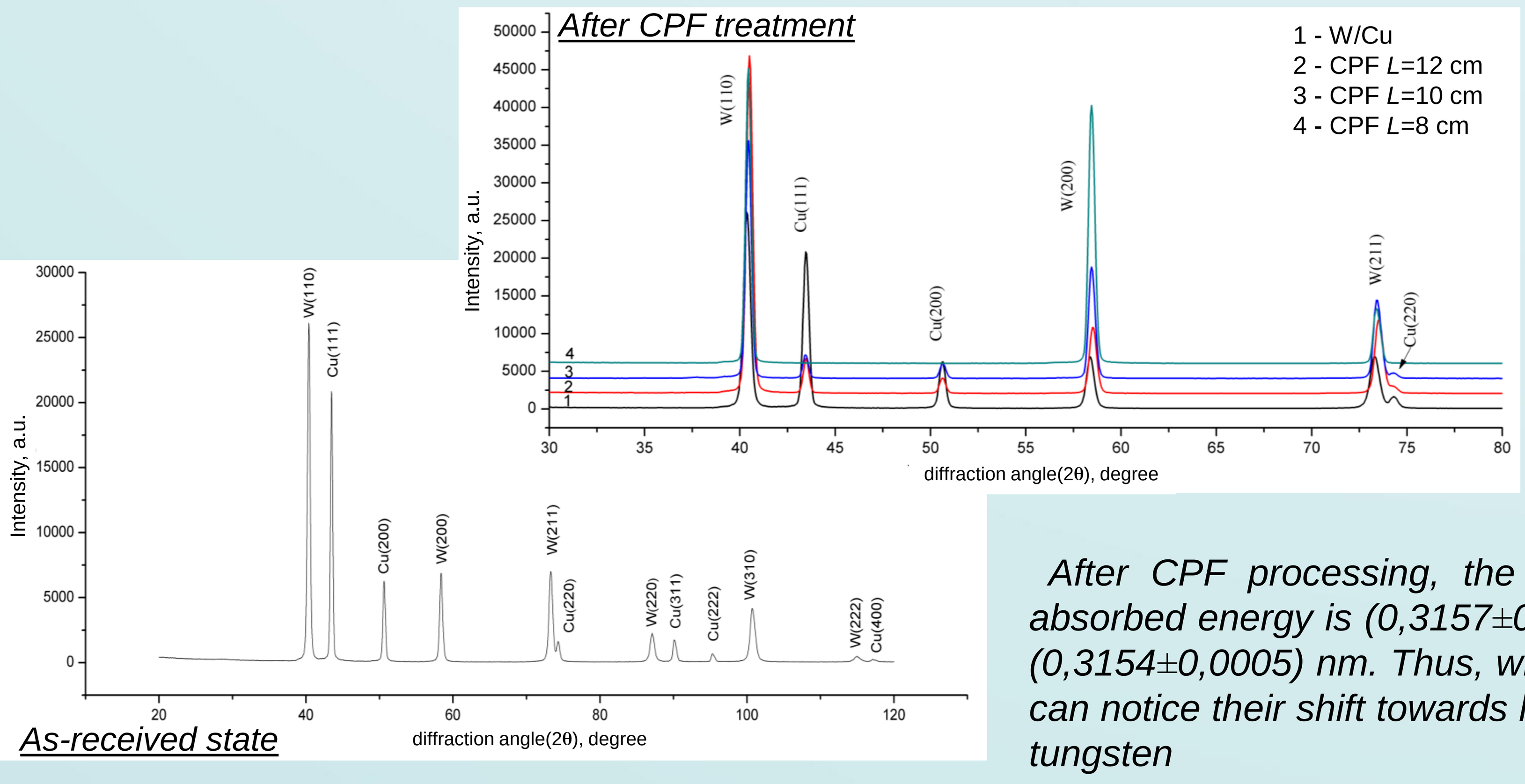


The dependence of the absorbed energy density (Q) on the distance L

Parameters of the CPF treatment:
- *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***
- *Samples dimensions: **10×10 mm***

Phase composition and surface morphology of tungsten and W-Zr-Cu alloy after CPF impact

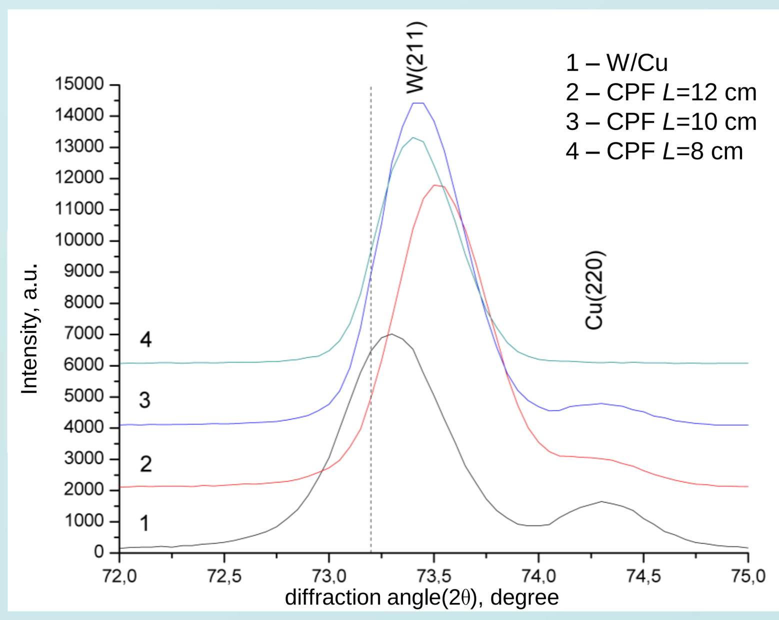
Phase composition



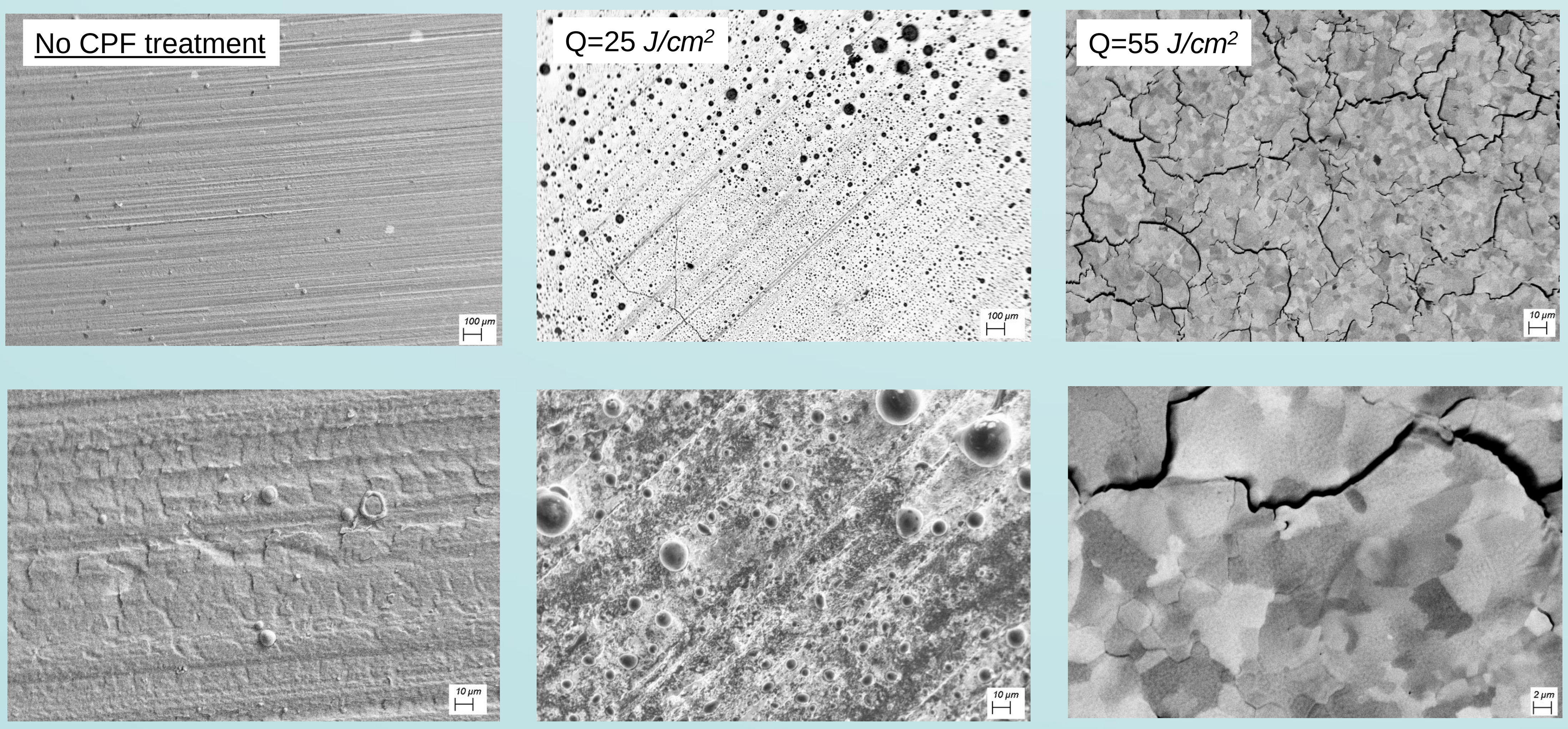
When carrying out X-ray diffraction analysis of the original sample coated with copper, it is possible to detect the presence of two phases of tungsten and copper. The initial value of the lattice parameter W is (3,0161±0,0004) nm. After CPF treatment at different absorbed energy densities, it is possible to notice the preservation of a two-phase system in two cases and a single-phase system in the case of a maximum absorbed energy density Q=55 J/cm^2.

It is also seen that with an increase in the absorbed energy density, the integral intensity of the diffraction lines of copper decreases, which indicates a decrease in its volumetric content in the analyzed layer, and at the maximum density of absorbed energy, diffraction lines of Cu were not detected. So, according to the results of the elemental composition carried out by the method of X-ray spectral analysis, the atomic content of copper in the near-surface layer at the minimum density of absorbed energy is 62.5 at.%, And at the maximum density of absorbed energy it is already 1.3 at.%, Which may indicate evaporation, entrainment, or ablation of copper atoms.

After CPF processing, the lattice parameter of tungsten at the maximum density of the absorbed energy is (0,3157±0,0005) nm, and at the minimum density of the absorbed energy is (0,3154±0,0005) nm. Thus, with a more detailed analysis of the diffraction lines of tungsten, one can notice their shift towards large angles, which indicates a decrease in the lattice parameter of tungsten



Surface morphology



The impact of compressive plasma flows leads to the melting of the surface layer, as evidenced by the change in the surface morphology. Thus, on the obtained SEM image of the initial state, it is possible to detect the presence of a droplet copper phase formed during the deposition of the coating, as well as the features of the surface relief, which coincides with the grinding bands of the tungsten substrate. After the action of the CPF with a minimum absorbed energy density of 25 J/cm^2 the droplet phase can be preserved, which indicates a partial melting of the surface layer. After an increase in the absorbed energy density to 55 J/cm^2 the surface completely melts. On the corresponding SEM image, one can notice a set of misoriented cracks, the appearance of which is caused by the rapid cooling and crystallization process, which contribute to the appearance of a high level of thermoelastic stresses exceeding the ultimate strength of the material.

The detected changes in the structural-phase state of the modified tungsten layer provide a change in its microhardness. In the initial state, the tungsten sample had a hardness of 716 HV, which could be additionally provided by preliminary deformation of the original plate. After processing, with an increase in the density of the absorbed energy, the microhardness decreases, so it falls from 673 HV to 473 HV.