METAL COATINGS FORMATION BY COMPRESSION EROSION PLASMA FLOWS INTERACTION WITH SURFACES

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In the present work the possibility of metal coatings deposition by erosion compression plasma flows (ECPF) is discussed. The formation of erosion flows occurs due to erosion of the electrodes material in the discharge device. The products of the erosion are accelerated by dense compression plasma flows and reach the surface of a sample placed in the chamber. In the work the coating of tungsten, nickel and copper with synthesized in the air residual atmosphere on the silicon surface. In the work the structure and phase composition of the formed coating are discussed.

The flows of dense (compressed) plasma are widely investigated as effective tool for material structure and properties modification. Such plasma flows are formed by quasi-stationary plasma accelerators during the discharge between two electrodes. These process inevitably followed by the erosion of the electrodes and the products of the erosion are carried away in the plasma stream. So, it can be used for deposition of the eroded material on a substrate. The voltage between the electrodes, residual atmosphere pressure, distance between the electrodes and the substrate are the main factors that determine the effectiveness of the erosion and as a result the structure of the formed coating.

Erosion compression plasma flows were formed in the miniature magnetoplasma compressor in the residual air atmosphere (pressure 1 torr). The radial electrodes in the discharge device were produced from iron, the central electrode was made of copper, tungsten or nickel. So, it allowed to syntheze copper, tungsten and nickel coatings, respectively. The main varied parameters were a voltage between the electrodes which changed from 2.0 to 3.0 kV and distance between the electrodes and the substrate surface changed from 3 to 6 cm. The duration of the discharge in the compressor was about 100 μs. The coating formation was carried out by three pulses. A single crystal of silicon (10×10 mm) with preferred crystallographic orientation (111) or (100) was used as a substrate for the coatings deposition. The structure and phase composition of the formed films were investigated by X-ray diffraction (XRD) with Ultima IV Rigaku diffractometer in the parallel beam geometry using Cu-radiation (λ=0.154178 nm). The thickness of the films was determined by scanning electron microscopy (SEM) in the LEO 1455 VP microscope on the cross-sections of the samples.

After the ECPF influence on the silicon surface the film from the material of inner electrode were formed. The XRD results provided the information about the phase composition of the films and the varied parameters influence on it. Using a copper electrode, copper films were produced (Fig. 1 and 2).

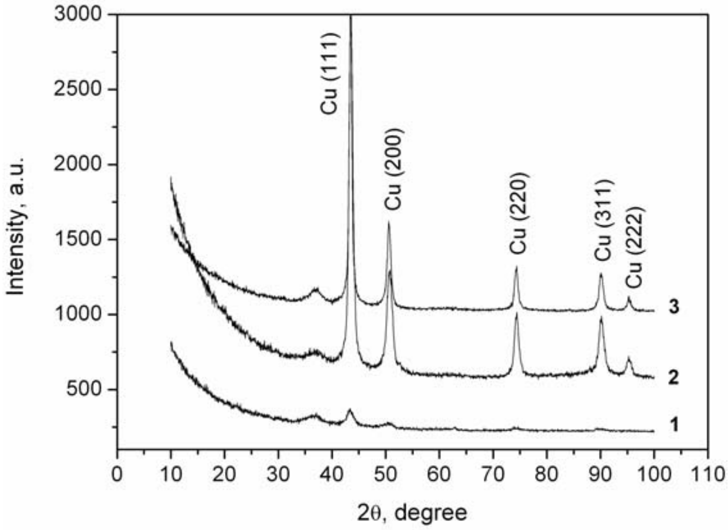


Fig. 1 – XRD patterns of the Cu coatings formed at the voltages 2.0 kV (1), 2.5 kV (2) and 3.0 kV (3)

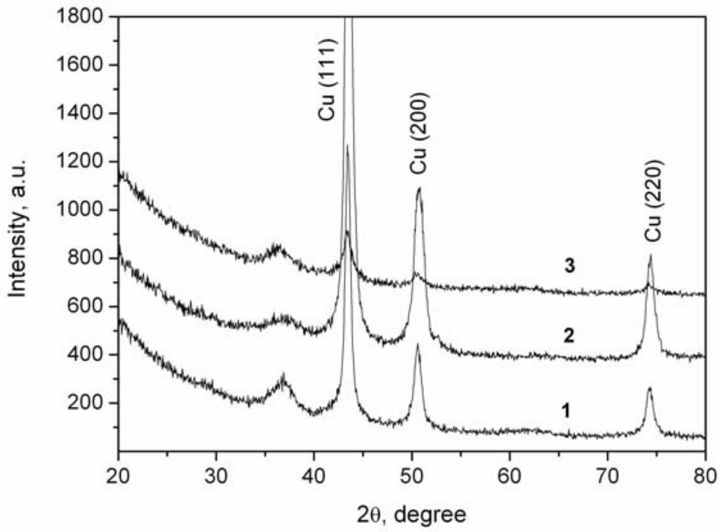


Fig. 2 – XRD patterns of the Cu coatings formed at the voltage 2.5 kV and the electrode-substrate distances 3 cm (1), 4 cm (2) and 6 cm (3)

On the XRD pattern there is a series of the diffraction peaks that indicate the polycrystalline structure of the copper films. The diffraction peaks intensity distribution corresponds to the standard data. Taking into account that the intensity of the peaks depends on the volume fraction of the phase or, in our case, on the thickness of the films, one can see that the films synthesized at the voltage 2.5 – 3.0 kV (the distance between the electrode and Si substrate was 4 cm) possess manifest crystal structure and thickness. The voltage of 2.0 kV on the electrodes is not enough for the film formation. It is a result of less amount of the eroded material from the electrodes.

The distance between the Si surface and electrode as well as voltage on the electrode influence on the thickness and structure of the formed films. Indeed, the results presented in Fig. 2 show that the most appropriate distance between the electrode and Si surface is 4 cm (at the voltage 2.5 kV). In this case the thickness of the film is the highest. An increase in the distance up to 6 cm results in fall in the thickness due to divergence of the plasma stream and the amount of the eroded material is also decreases. The decrease in the thickness at the distance of 3 cm can be explained by the absence of the eroded material in the compressed area near the electrodes.

The films of tungsten and nickel also were formed by the ECPF influence (Fig. 3 and 4). In the XRD patterns of the W films (Fig. 3) a weak diffraction line of the tungsten (110) was found. Besides, some diffraction lines corresponding to the tungsten oxides also were found in the diffraction angles area 30 – 45 degree. The formation of nickel films is also accompanied by the nickel-based compounds formation. In this case the nickel carbide Ni_3C referred also as hexagonal nickel was found. According to the XRD results purer (without additional phases) nickel film was synthesized at the voltage of 3.0 kV (the distance of 4 cm). But the latter regimes allow to form the coating with a small-grained structure since the diffraction line have a very high width.

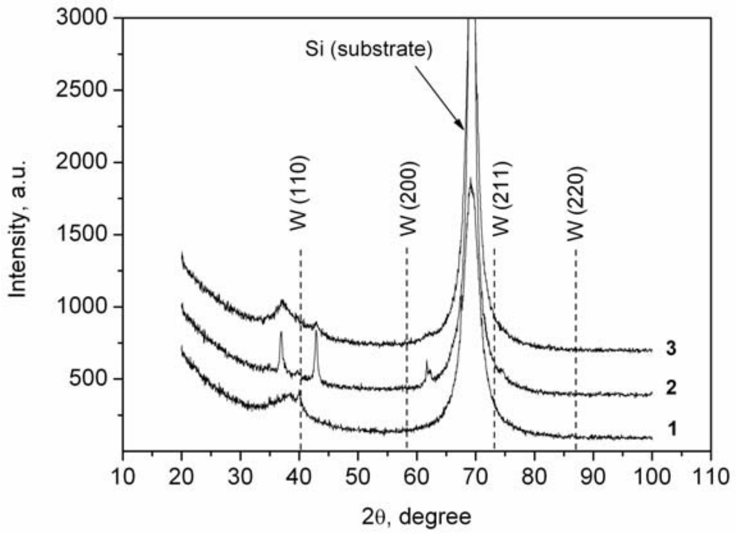


Fig. 3 – XRD patterns of the W coatings formed at the voltages 2.0 kV (1), 2.5 kV (2) and 3.0 kV (3)

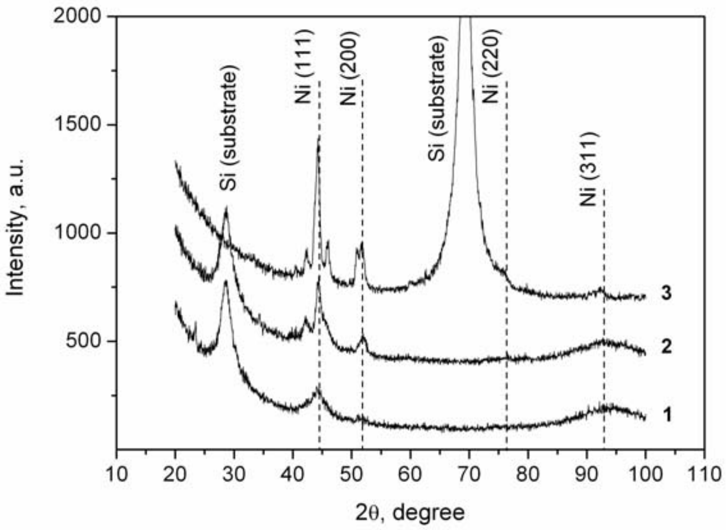
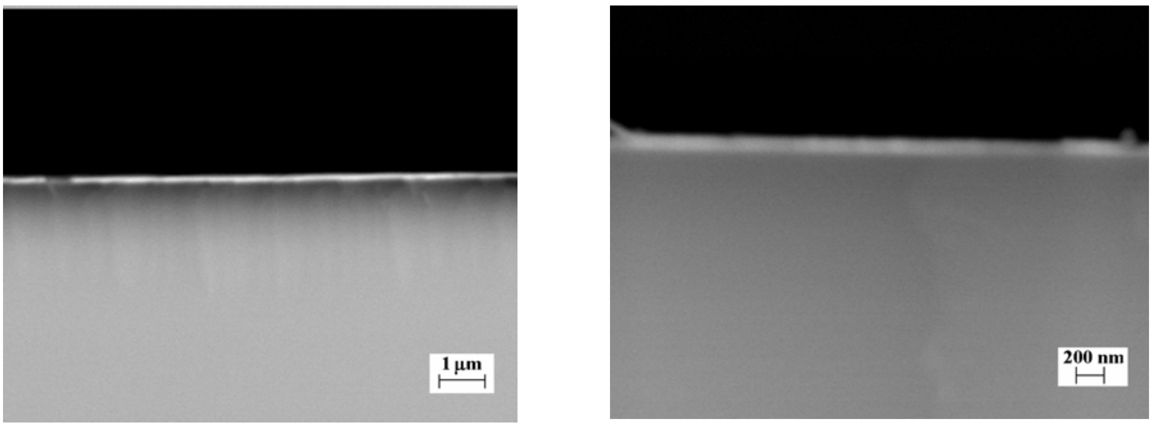


Fig. 4 – XRD patterns of the Ni coatings formed at the voltages
2.0 kV (1), 2.5 kV (2) and 3.0 kV (3)

The SEM results (Fig. 5) showed the thickness of the films formed by the ECPF impact. According to the SEM images the thickness of the tungsten coating is about 130 nm, meanwhile the nickel coating has a thickness of 170 nm (the regimes of the formation are the same). One can see that the coatings have the constant thickness in every section. So, the formed films possess uniform thickness.



a) **b)**

Fig. 5 – SEM-images of the W coating cross-section (a) and Ni coating cross-section (b). The films were formed at the voltage 3.0 kV

So, in the work the possibility of copper, tungsten and nickel thin (130 – 170 nm) films synthesis on the silicon wafer by erosion compression plasma flows impact in the miniature magnetoplasma compressor was demonstrated.