Electrodischarged Ti-(B, C, Si)-coating

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Abstract: The possibility of using hyperhigh speed high current electrodischarged Ti-plasma, generated by coaxial magnetoplasma accelerator as a method for Ti-C, Ti-B and Ti-Si coatings is shown. It is estimated that the most ordered microstructure is formed for a sample obtained under $W = 46.7$ kJ and 2.0 g carbon load. The average level of nanohardness for this sample is 15.3 GPa.

1. Introduction
TiC-based coatings are highly wear resistance, superhard, strength, resistant to corrosion and oxidation [1], have high melting point temperature and thermally stable. They have low friction coefficient and high coefficient of electrical and thermal conductivity [2]. TiC-coatings could be synthesized by laser cladding [1], laser-assisted CVD [2] or plasma-assisted CVD [3], ion deposition [4] or PVD [5].

Titanium diboride is highly hard, has low electrical resistance, large cross section for thermal neutron capture, high wettability and high thermal shock tolerance. Due to this TiB-coatings could be used as electrode coatings in aluminum manufacturing, coating for turbine's blade, chemical reactors, crucibles, pump parts, thermocouples and cutting tools. Usually TiB-coatings obtained in solid-phase diffusion reaction of boron into titanium [6] or by laser cladding [7].

Titanium silicide is highly electro conductive and thermally stable material which could be applied as a contact layer between semiconductor and base structure [8].

Low adhesion, residual stress, long duration of coating deposition and preheating necessity of substrate until 1050 °C are still an aim of the search despite a wide spread of methods for Ti-based coatings obtaining [3].

Coaxial magnetoplasma accelerator (CMPA), generating hyperhigh high current electrodischarged plasma jet, could be a way for solving described problems. TiC/Ti-based coating with high adhesion level was deposited on a copper substrate using this CMPA at [9].

2. Experimental
High voltage high current CMPA with titanium electrodes was used for TiC-based coatings deposition [9]. Capacity energy storage was used as a power supply source. Interelectrode gap was filled with necessary precursor (B, C or Si). Electro erosion of titanium was occurred from the surface of electrodes after generation of high current plasma jet. Eroded titanium was reacted with loaded precursor under acceleration from electrode channel and impacting on substrate. The mass of loaded precursors was varied in a range 0.4–2.0 g. The distance between the end of electrode and substrate was 150 mm in all experiments. The level of charged voltage and capacity was 2.8 kV and 14.4 mF respectively.
Obtained samples were researched using X-Ray diffraction method (Shimadzu XRD6000S, CuKα). Microstructure of cross section grinds of samples was obtained using scanning electron microscope Hitachi TM3000 (SEM). Nanohardness of the samples was measured using NANO Hardness Tester NHT-S-AX under 300 mN loads.

3. Results and discussion
The level of TiC in coating increases with increasing of carbon mass load and level of energy allocated in process as shown by XRD. Titanium, iron and iron carbide are presented in coating beside titanium carbide. Carbon absence in coating is shown by XRD-pattern in figure 1. The presence of Ti caused by erosion of Ti-electrodes and loaded carbon deficit. Formation of iron in coating caused by contact of high temperature plasma jet with steel substrate and mixing with eroded material. Wherein the reaction of iron with accelerated carbon occurs with iron carbide formation.

Microstructure of cross section grinds of samples was researched using SEM. Thickness of coatings varies in a range 30–300 μm and increases with carbon load mass and allotted energy. The most ordered microstructure formed for a sample obtained under \( W = 46.7 \text{ kJ} \) and 2.0 g carbon load as shown in figure 1.

Uniform distribution of TiC-grains in Ti-matrix could be seen according to the picture. This allows obtaining the average level of nanohardness for this sample up to 15.3 GPa.

![Figure 1. XRD-pattern for TiC-coating.](image)

XRD-pattern of TiB-coating in figure 2 demonstrates formation of a few crystalline phases: TiB (ICDD #5-0700), TiB₂ (ICDD #7-0275), Ti (ICDD #1-1197), TiO₂ (ICDD #76-0326).

According to XRD-pattern in figure 3 Ti₅Si₃ (ICDD #78-1429) is a dominant phase in Ti-Si coating with small amount of TiSi₂ (ICDD #27-1402) and initial precursors if Ti and Si.

4. Conclusion
The results of the work establish the possibility of using coaxial magnetoplasma accelerator for TiC-coatings deposition on steel substrates in short time cycle up to 500 µs with coating thickness up to 300 µm and hardness level up to 15.3 GPa. The possibility of titanium borides and silicides coating deposition is shown.
Figure 2. XRD-pattern for TiB-coating.

Figure 3. XRD-pattern for TiSi-coating.

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