EFRE 2020

TOMSK POLYTECHNIC UNIVERSITY

STUDY OF COATINGS BASED ON CUBIC TUNGSTEN CARBIDE OBTAINED BY PLASMA DYNAMIC METHOD

ARTUR NASSYRBAYEV[1], D.S. NIKITIN[1], I.I.SHANENKOV[1,2]

[1]National research Tomsk Polytechnic University Lenin Avenue 30, Tomsk, 634050, Russia,

[2]College of Communication Engineering, Jilin University, Changchun, PR China

email: arn1@tpu.ru

This work was financially supported by the Russian Science Foundation (Project No. 19-13-00120).

ANNOTATION

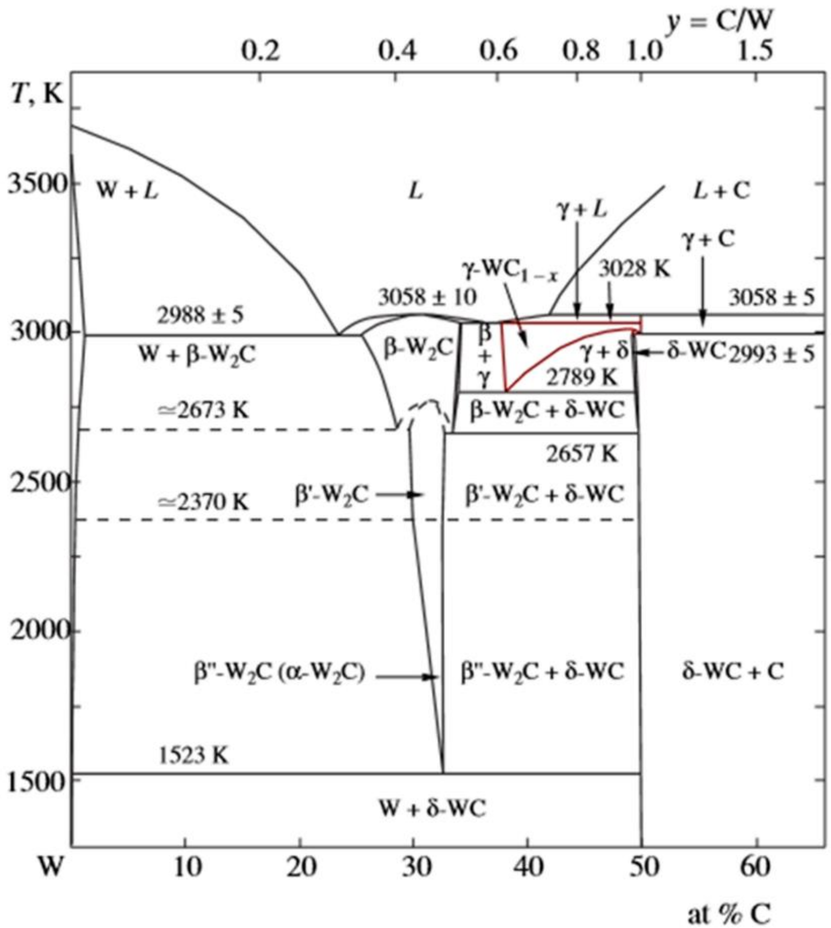

Fig. 1 – Phase diagram of the W–C system [1]

Cubic tungsten carbide WC_{1-x} is still the most poorly studied crystalline phase of the W-C system, since, according to the known phase diagram [1], it can be synthesized only in an extremely narrow range of parameters (pressure and temperature). This makes it difficult to obtain WC_{1-x} in bulk form and measure its physical and mechanical properties [2].

In this work, cubic tungsten carbide was synthesized in the form of a coating by the plasma dynamic method [3]. The process was implemented under high-speed spraying of an electric discharge W-C plasma on copper and titanium substrates. As a result, the coating has a sandwich structure Cu+WC1-x-WC1-x-Cu (substrate) or ($TiC+WC_{1-x}$)-Ti- ($WC_{1-x}+TiC$)-Ti(substrate) with a thickness of the WC_{1-x} layer up to ~10 μm. Direct measurements of WC_{1-x} mechanical properties were carried out for the first time. The maximum values of nanohardness and Young's modulus of the WC_{1-x} layer are $H_v = 31.0 \pm 0.8$ and $E = 310 \pm 12$ GPa respectively.

[1] A.S. Kurlov, A.I. Gusev, Tungsten carbides and W-C phase diagram, Inorg. Mater. 42 (2006) 121–127

[2] Y. Gao, X. Song, X. Liu, C. Wei, H. Wang, G. Guo, On the formation of WC 1-x in nanocrystalline cemented carbides, Scr. Mater. 68 (2013) 108–110

[3] A. Pak, A. Sivkov, I. Shanenkov, I. Rahmatullin, K. Shatrova, Synthesis of ultrafine cubic tungsten carbide in a discharge plasma jet, Int. J. Refract. Met. Hard Mater. 48 (2015) 51–55

PARAMITERS:

Electrical:

U_c = 3.0 kV, **C** = 6 mF, **W_c**= 27 kJ

Precursors:

W – purity>99.7%, average size ~75 nm

C - carbon black, amorphous

m(W+C) = 1 g.,

Atomic ratio **[C]/[W] = 0.6**

Substrates:

Copper and titanium

Area: **50·50 mm²**,

Thickness: **4 mm**

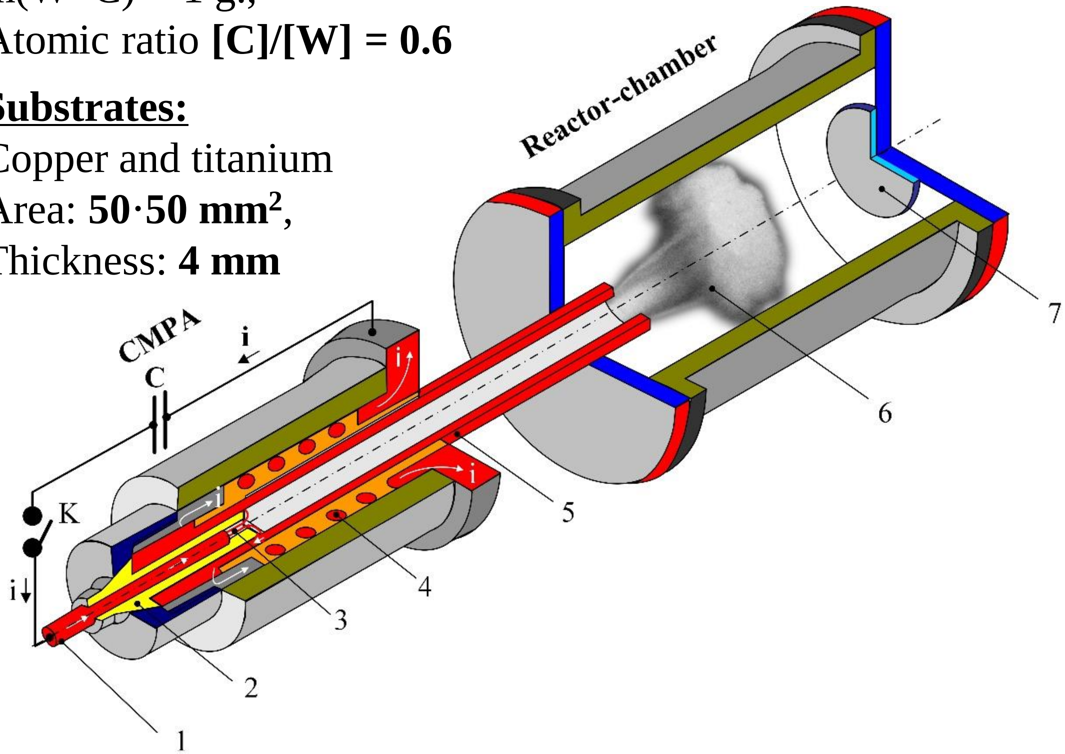

Fig. 2 – A schematic diagram of the installation for a plasma dynamic synthesis: **1** – Central non-magnetic metal electrode, **2** – Insulator, **3** – Plasma formation zone, **4** – Inductor, **5** – Graphite barrel electrode, **6** – Tungsten-carbon plasma jet, **7** – Metal substrate

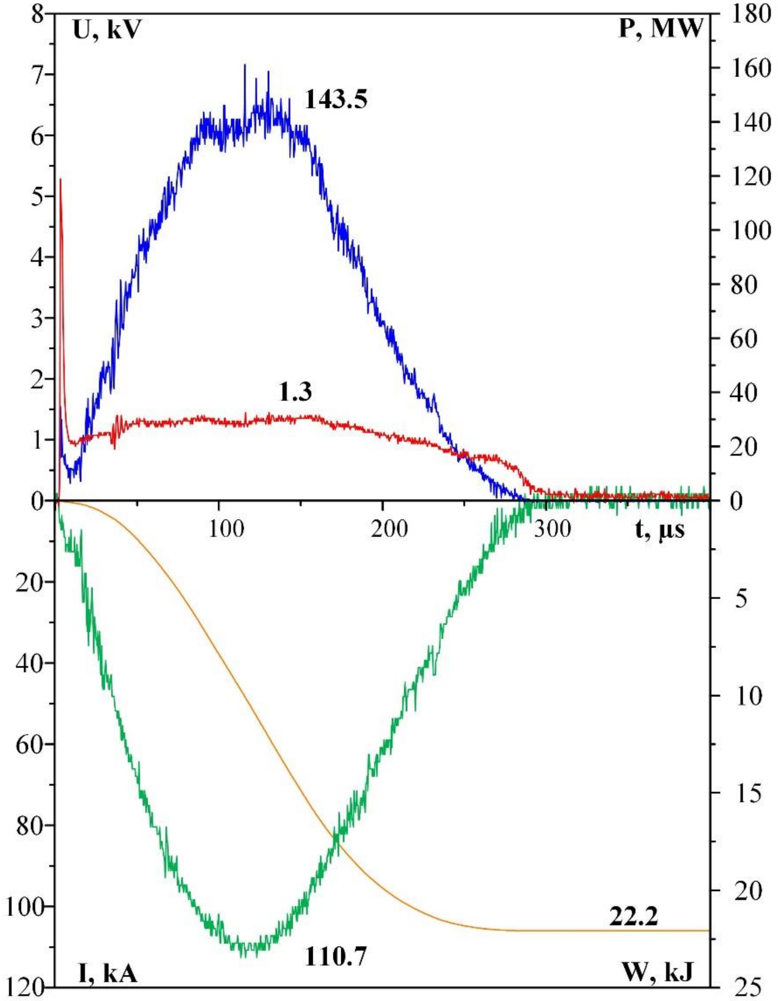

Fig. 3 – Typical oscillograms of current **I(t)** and voltage **U(t)**, plots of discharge power **P(t)** and energy input **W(t)**

RESULT AND DISCUSSION

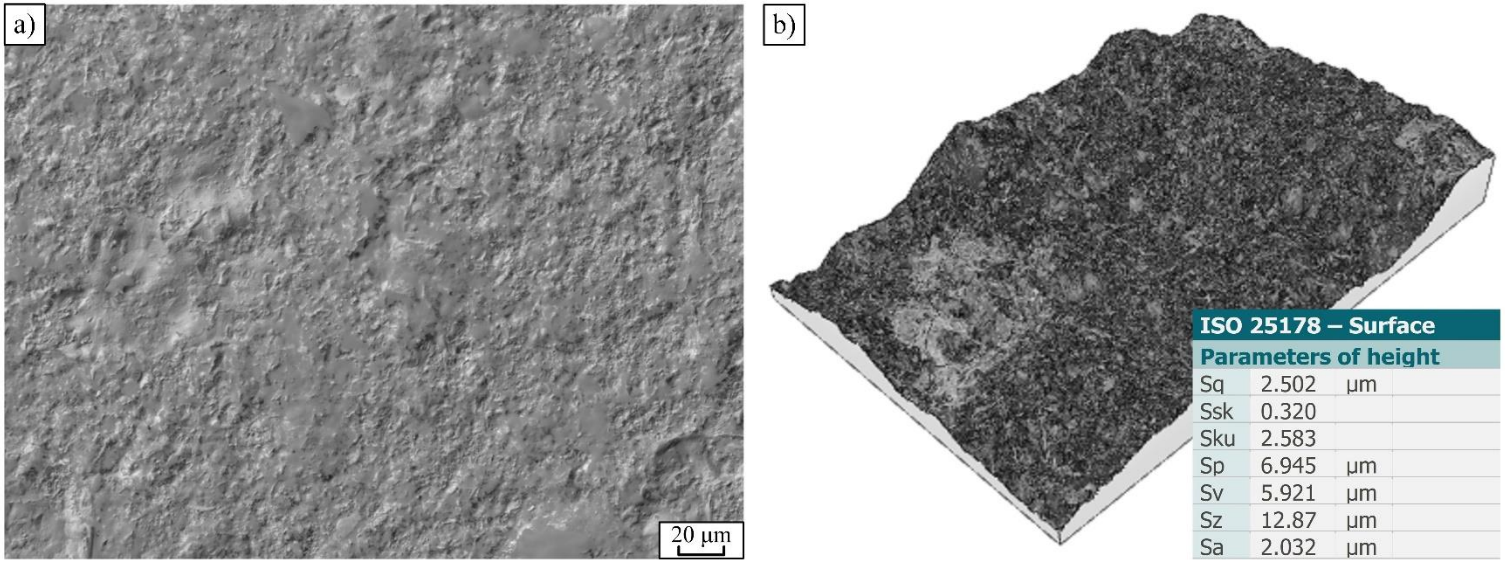

Fig. 4 – SEM image (**a**) and corresponding results of its processing (**b**)

Fig. 5 – Typical view of synthesized coating

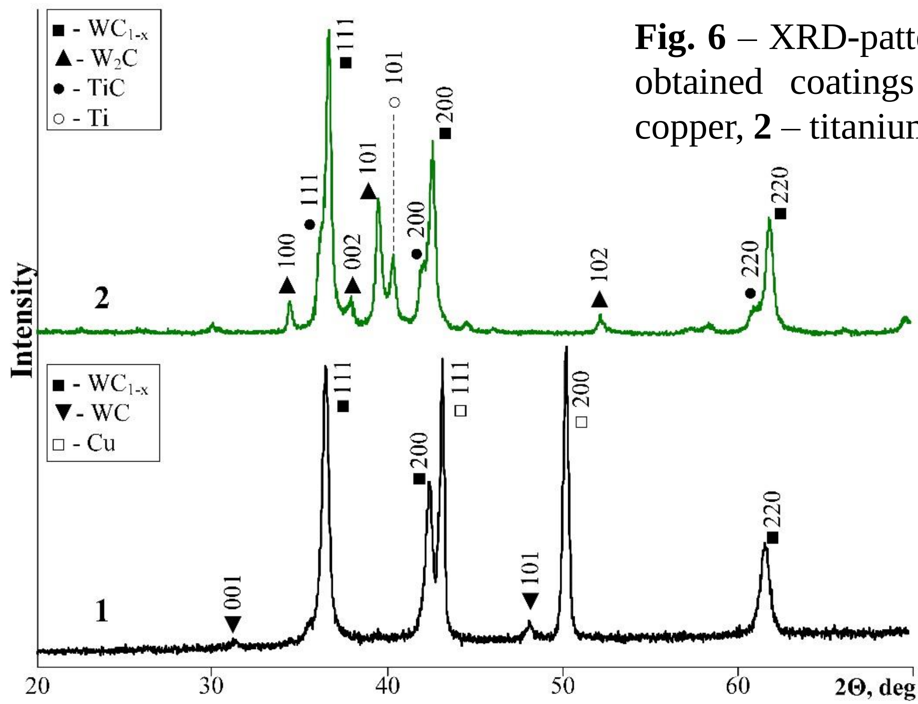

Fig. 6 – XRD-patterns of the obtained coatings on: **1** – copper, **2** – titanium

Fig. 7 (a) shows a micrograph of the material that indicates the formation of a multilayer coating close to a “sandwich” structure. The substrate material **(1)** apparently surrounds the sintered mass of denser material **(2)**. **Structure** – **Cu+WC_{1-x}-WC_{1-x}-Cu (substrate)**

Fig. 7 (b) shows the microstructure of the coating deposited on a titanium substrate. In this case, an even more heterogeneous structure is observed since at least three areas of different density are formed. **Structure** – **(TiC + WC_{1-x}) -Ti- (WC_{1-x} + TiC) -Ti (substrate)**

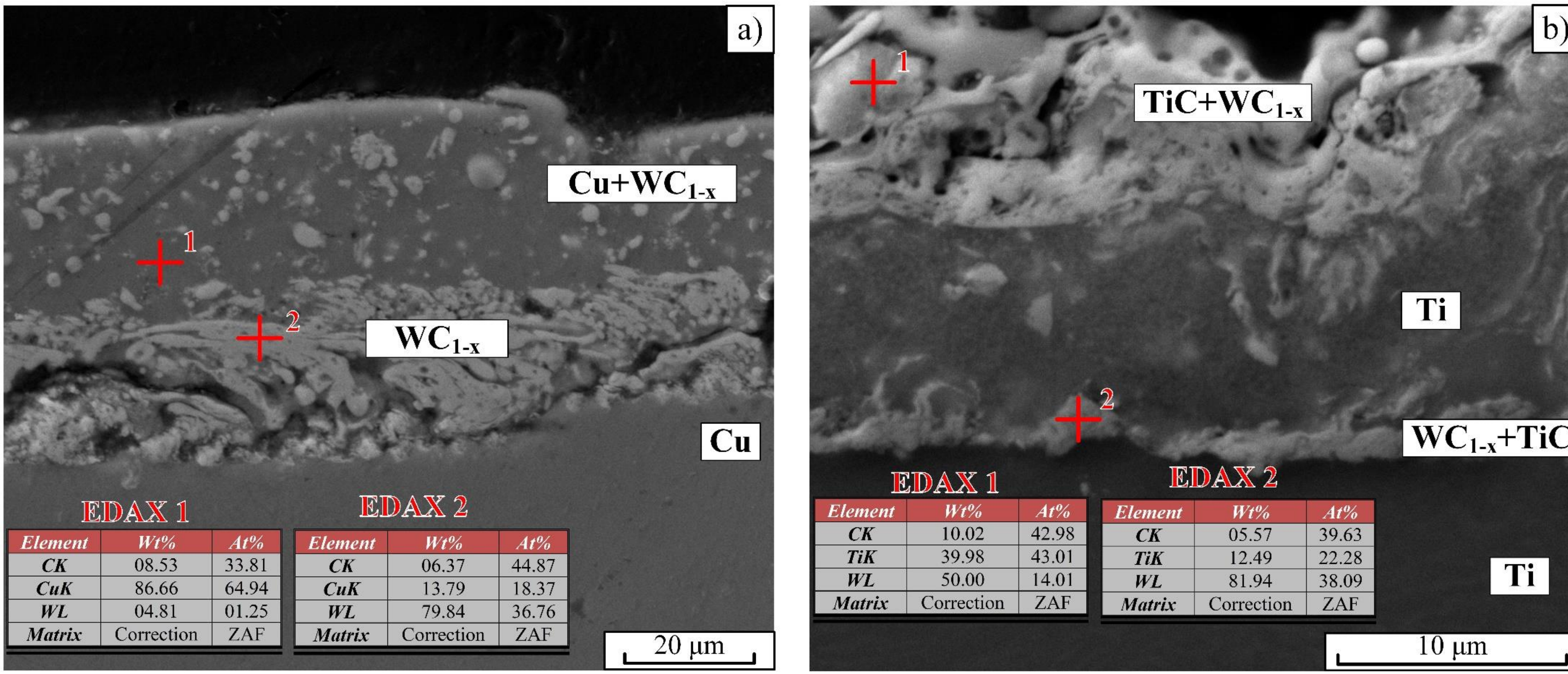

Fig. 7 – SEM-images of cross-sections of coating deposited on **(a)** copper substrate, **(b)** – titanium substrate.

CONCLUSION

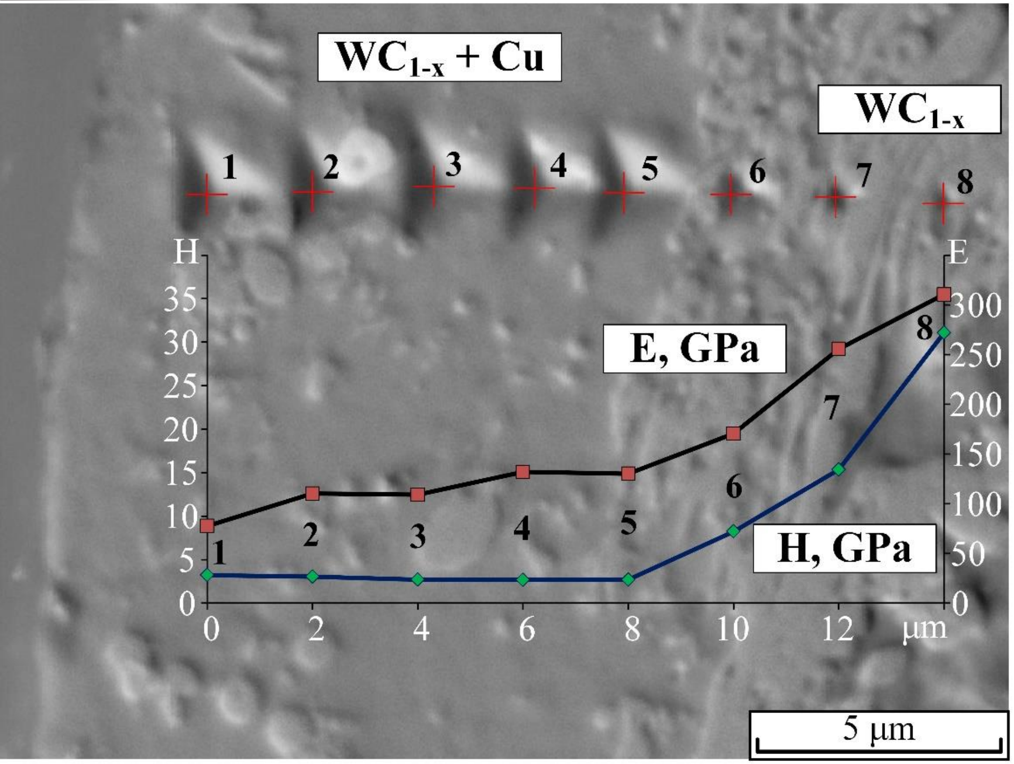

Fig. 7 – SEM-image of areas with the nanoindenter prints along the line “surface layer – intermediate layer” with corresponding values of hardness and Young's modulus for every point

Measurements of the mechanical properties in the region of the large specimen WC_{1-x} gave values of **H = 33.0 ± 0.9, E = 401 ± 14 GPa** and **H = 29.2 ± 0.8 GPa, E = 410 ± 15 GPa** for the coating on **copper** and **titanium** substrate respectively.

Acknowledgment

This work was financially supported by the **Russian Science Foundation (Project No. 19-13-00120).** The development and optimization of the accelerator power supply system (capacitive energy storage) design was carried out at Tomsk Polytechnic University within the framework of Tomsk Polytechnic University Competitiveness Enhancement Program grant.

EFRE 2020

TOMSK POLYTECHNIC UNIVERSITY

STUDY OF COATINGS BASED ON CUBIC TUNGSTEN CARBIDE OBTAINED BY PLASMA DYNAMIC METHOD

ARTUR NASSYRBAYEV[1], D.S. NIKITIN[1], I.I.SHANENKOV[1,2]

[1]National research Tomsk Polytechnic University Lenin Avenue 30, Tomsk, 634050, Russia,

[2]College of Communication Engineering, Jilin University, Changchun, PR China

email: arn1@tpu.ru

This work was financially supported by the Russian Science Foundation (Project No. 19-13-00120).