Superhard ceramic material from B_4C and $TiSi_2$ powders

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Ceramic composites based on boron carbide are promising materials for use in the defense industry due to their extremely high hardness, low density, and thermal stability. The introduction of additional components into the ceramic may further improve its mechanical properties. Such modified materials are well-suited for application in modern armor protection systems, impact-resistant elements, and structures capable of withstanding ultra-high loads.

The ceramic material studied here was synthesized from high-purity B_4C and $TiSi_2$ powders by spark plasma sintering at a maximum temperature of 1900°C and a pressure of 70 GPa in argon atmosphere. The initial content of $TiSi_2$ in the powder mixture B_4C+$TiSi_2$ was 30 wt.%. X-ray powder diffraction patterns collected from the surface of the synthesized pellet, showed four phases: B_4C, TiB_2, SiC, and Si. Results of the refinement of the crystal structures are shown in Table 1. The crystal structure of B_4C synthesized by spark plasma sintering is reported in [1].

The initial powders for the synthesis and the ceramic material were analyzed by scanning electron microscopy. The grain size was evaluated using ImageJ software. The average size of the B_4C grains before sintering was 1.2 μm, $TiSi_2$ – 1.8 μm; after sintering TiB_2 – 11.2 μm. A SEM-image of the B_4C+$TiSi_2$ ceramic material and the TiB_2 grain distribution in the B_4C+$TiSi_2$ ceramic material are shown in Fig. 1.

By optimizing the synthesis conditions, it was possible to achieve a relative density of 99.5 % and a hardness (measured using the Vickers method) of 43.9 GPa.

Table 1. Results of the refinement of the crystal structure of the ceramic material (R_p = 6.01 %, R_{wp} = 7.65 %).

Phase	$B_{13.174(11)}C_{1.65(3)}$	TiB_2	SiC	Si
Structure type	$B_{13}C_2$	AlB_2	ZnS	C
Pearson symbol	*hR*51	*hP*3	*cF*8	*cF*8
Space group	*R*-3*m*	*P*6/*mmm*	*F*-43m	*Fd*-3*m*
Cell parameters, Å	*a* = 5.6159(6), *c* = 12.156(2)	*a* = 3.03358(13), *c* = 3.22856(15)	*a* = 4.3552(3)	*a* = 5.419(2)
Cell volume *V*, Å^3	332.01(7)	25.731(2)	82.611(8)	159.11(11)
Formula units per cell *Z*	3	1	4	8
Density D_X, g·cm^{-3}	2.441	4.487	3.224	2.345
Mass fraction, %	75(3)	14.7(4)	9.5(4)	0.53(6)
Reliability factor R_B, %	10.8	4.01	2.87	11.8

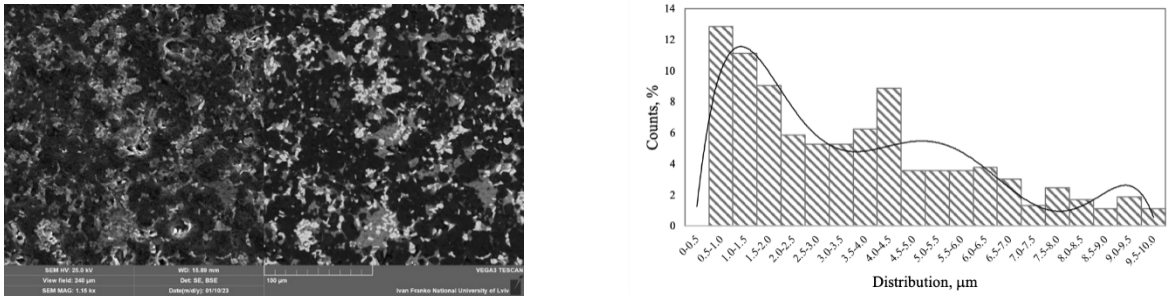

Figure 1. (a) SEM-image (left – SE, right – BSE) for the B_4C+$TiSi_2$ ceramic material and (b) TiB_2 grain distribution.

[1] Ivanushko A. & Gladyshevskii R. (2024) *Visn. Lviv Univ., Ser. Khim.* **65**, 102.