PROPERTIES OF MICRO- AND NANOCRYSTALLINE MATERIALS BASED ON SiC, OBTAINED BY HIGH ENERGY CONSOLIDATION

V.S. Urbanovich[1], A.M. Makei[1,] P. Klimczyk[2], L. Jaworska[2], B. Matovic[3], S. Boskovic[3], V.S. Niss[4] and L.V. Sudnik[5]

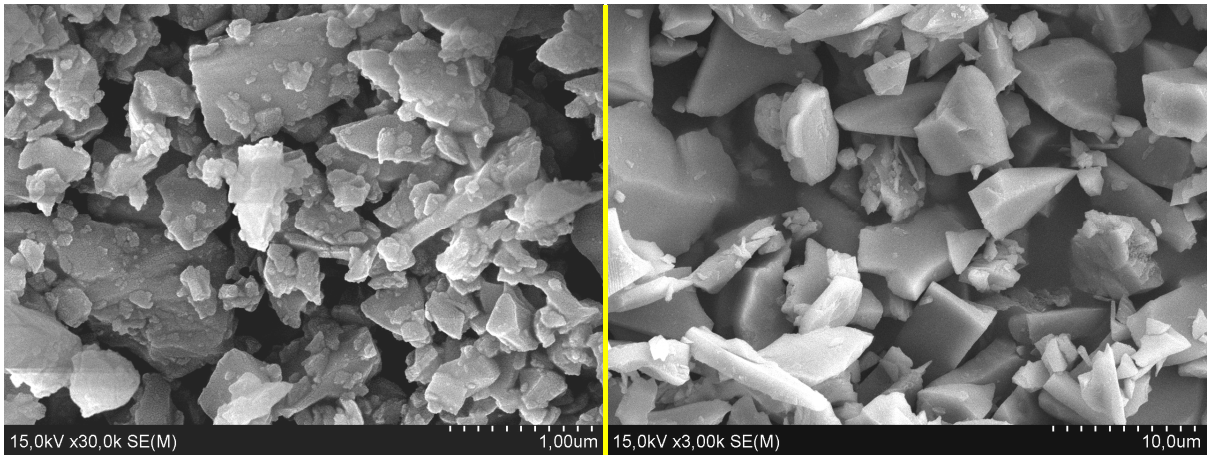
[1]Scientific-Practical Materials Research Centre NAS of Belarus, Minsk, Belarus
[2]The Institute of Advanced Manufacturing Technology, Krakow, Poland
[3]Vinča Institute of Nuclear Sciences, 11001 Belgrade, Serbia
[4]Belarusian National Technical University, 220013 Minsk, Belarus
[5]Research Institute of Impulse Processes with Pilot Factory, Minsk, Belarus

Ceramics based on silicon carbide has a high of mechanical strength at high temperatures and wear resistance, low coefficient of thermal expansion, high resistance to oxidation at temperatures up to 1500 ° C, high chemical inertness, corrosion resistance, high hardness and thermal conductivity [1]. The most dense ceramic materials based on it can be obtained by hot pressing of SiC powder with binders and activating additives [2], spark plasma sintering [3], or high pressure sintering without any additives [4].

Recently there is a growing interest in nanocrystalline ceramic materials and methods for their preparation, which is associated with the expectation of higher physical and mechanical properties and thermal stability of such materials. Therefore, nanocrystalline materials based on silicon carbide are of great interest. The most promising methods of obtaining of nanocrystalline ceramic materials based on refractory compounds are high-energy methods of consolidation. One such method is sintering at high pressures [5]. Efficiency of high pressure sintering for obtaining of high hard nanocrystalline materials has been shown earlier by one of the authors by the example of titanium nitride [6]. Such possibility is not enough studied for silicon carbide. Therefore, investigation of the effect of the initial powder dispersion and the parameters of thermobaric treatment on the structure and physical-mechanical properties of sintered silicon carbide is relevant and of great practical interest.

Silicon carbide powders of various grain used as initial: submicro-α-SiC (Goodfellow, UK) with a particle size of 0.1-1 μm, silicon carbide micropowder F1000 (Boksitogorsk argil plant, Russia) with a particle size of 5-7 μm as well as their mixtures with the addition of 50 vol.% monodisperse α-Si_3N_4 nanopowder (UBE 10, Japan) with a particle size of about 150 nm (Fig. 1).

Sintering was realized in the high-pressure "anvil-type with hollows" apparatus, [7] at pressure of 4 GPa and temperatures of 1500-2000 °C. Sintering time was 60 s.



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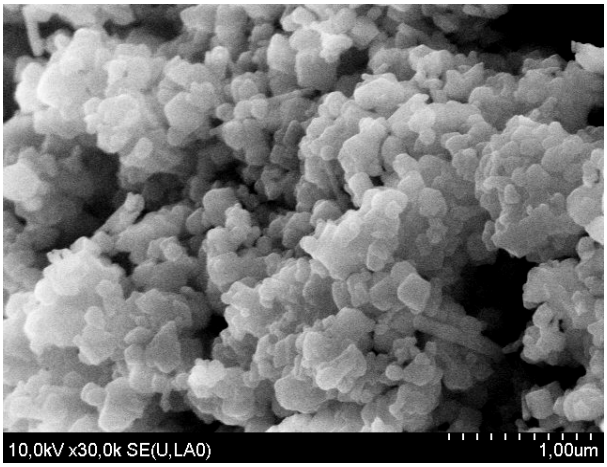

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Figure 1 - The microstructure of initial SiC powders:
a – submicro-SiC (Goodfellow);
b – micro-SiC (Boksitogorsk);
c – submicro-Si_3N_4 (UBE 10)

After machining of the sintered samples their microstructure, density and Vickers microhardness as a function of sintering temperature were investigated. Microhardness was measured with help the device MHT-240 LECO (load 2 N).

It is established that changing the density of the samples of these silicon carbide powders with increasing sintering temperature nonmonotonic (Fig. 2a). The samples obtained from micro-SiC have a higher density, due to the peculiarities of behavior of large particles of the powder under compression at high pressure - their crushing and plastic deformation under the effect of shear stresses. Achieving maximum value of 98.5% densification (3.16 g/cm^3) of these samples occurs at a lower sintering temperature of 1700 °C, than for more dispersed submicro-SiC.

Found that the density of SiC/Si_3N_4 composites is lower than SiC samples for all sintering temperatures. The density of micro-SiC/Si_3N_4 composite is higher than submicro-SiC/Si_3N_4, which is also due to fragmentation and plastic deformation of SiC micropowder large particles at high pressure compression.

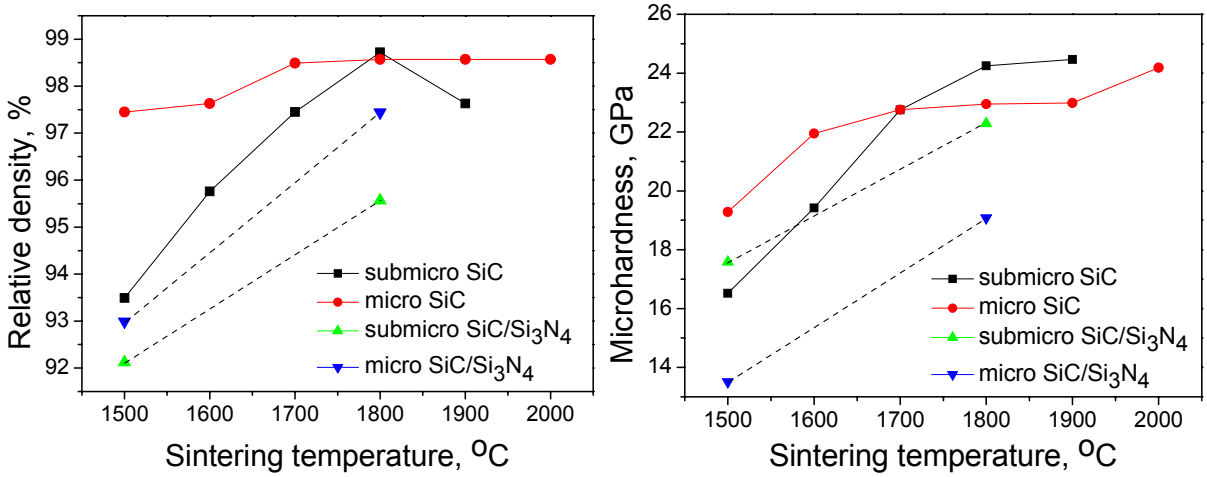

Figure 2 - Relative density (a) and microhardness (b) of ceramic samples from the sintering temperature

In the sintering temperature range up to 1700 °C micro-SiC samples have the higher microhardness (19-22 GPa) due to a higher value of their density (Fig. 2b). However, at higher sintering temperatures, on the contrary, submicro-SiC samples are of higher microhardness (~ 24 GPa), apparently due to the smaller grain size and more homogeneous microstructure (Fig. 3a, b).

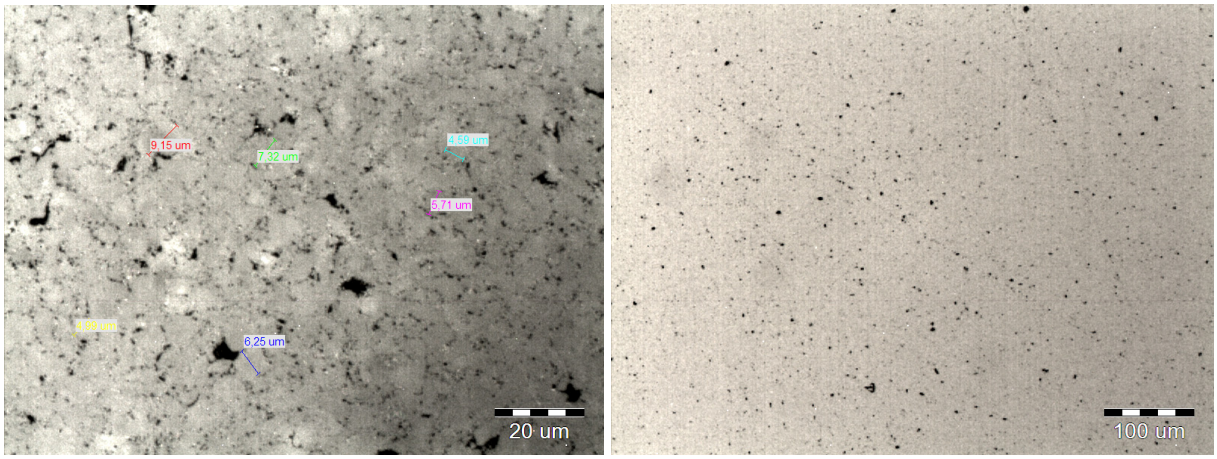

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Figure 3 - Microstructure of samples of silicon carbide:
a – micro-SiC (F1000), Ts=2000 °C; b – submicro-SiC (GW), Ts=1900 °C

As can be seen from Fig. 2 microhardness of submicro-SiC/Si_3N_4 composite is higher than micro-SiC/Si_3N_4 composite, although its density is less than that due to a more homogeneous structure and smaller grain size of SiC (Fig. 4). This may reflect the predominant influence of the microstructure of the composite to its microhardness compared with the density, and may be associated with a higher level of microstresses.

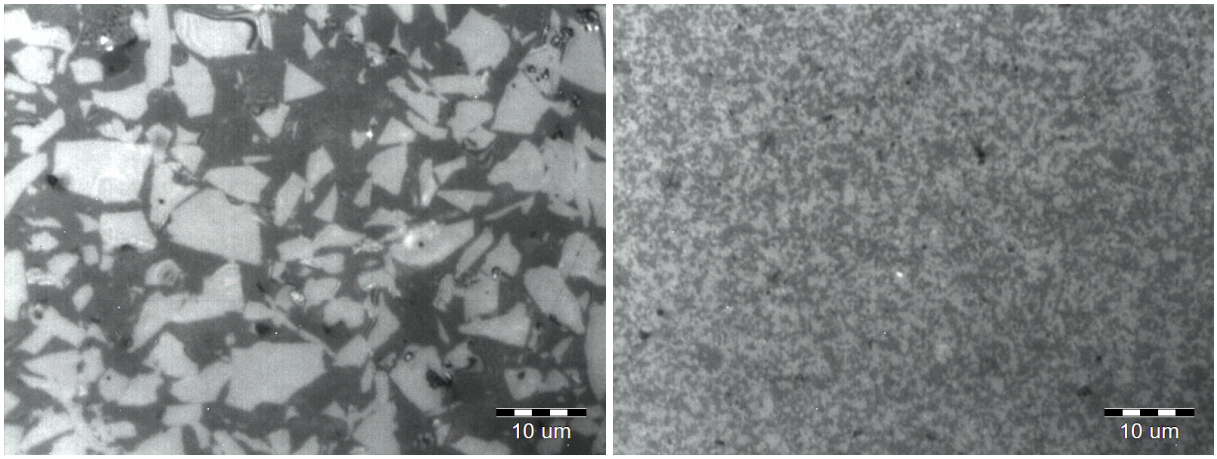

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Figure 4 - Microstructure of composite micro-SiC/Si_3N_4 (a) and submicro-SiC/Si_3N_4 (b) Tsp=1800 °C

Analysis of the microstructure of micro-SiC/Si_3N_4 composite (Fig. 4) shows that the particle size of the carbide phase almost corresponds to particle size of the initial silicon carbide micropowder. This indicates that at the compression of SiC/Si_3N_4 composite under high pressure crushing of large particles of SiC powder does not occur.

Thus, at high pressure sintering the samples of more dispersed silicon carbide submicron powder and the composite of submicro-SiC/Si_3N_4 powder mixture have the most homogeneous microstructure and higher hardness respectively up to 24 GPa and 22 GPa.

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