INTERNATIONAL MULTIDISCIPLINARY SCIENTIFIC GEOCONFERENCES SGEM 2015

16-25 JUNE 2015, Albena Co., Bulgaria

IMPROVING ENERGY EFFICIENCY OF SILICON CARBIDE CERAMICS PRODUCTION BY BATCH REGULATION

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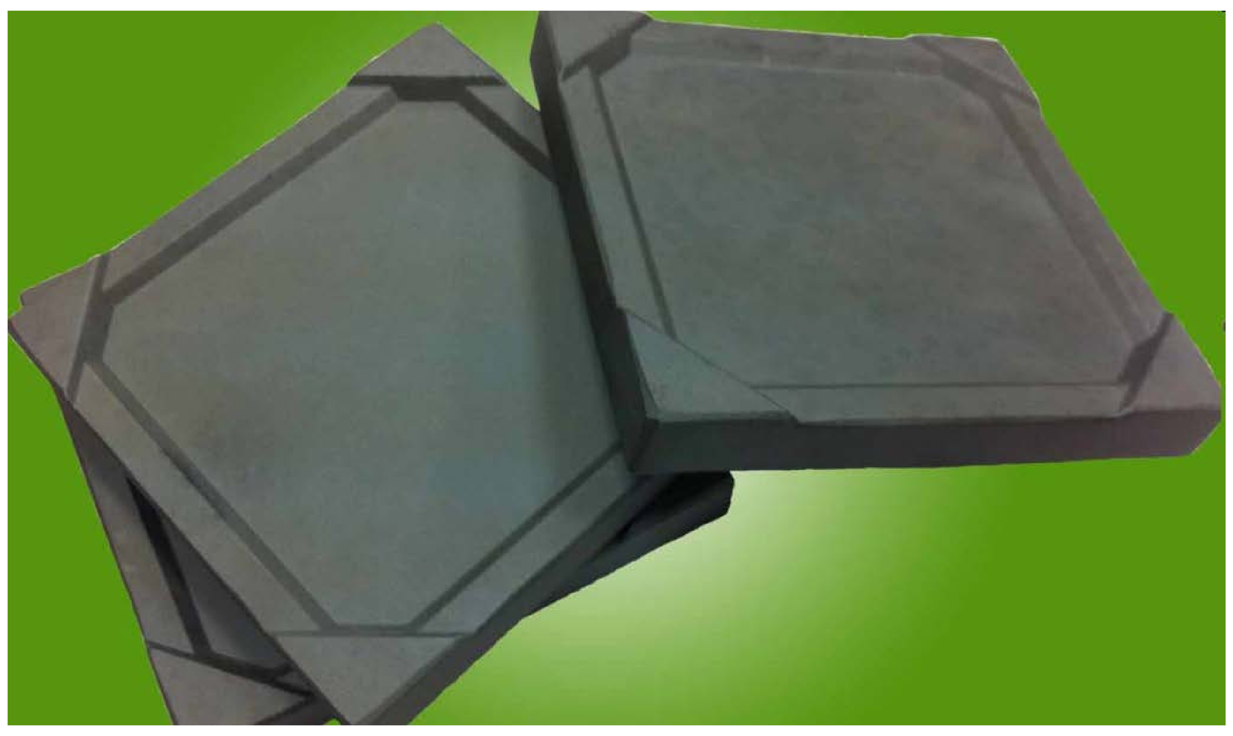
Introduction

Silicon carbide is a non-oxide compound that exhibits excellent toughness, wear resistance, heat conductivity, refractoryness, strength, low thermal expansion coefficient, significant oxidation resistance up to 1500 °C, chemical and corrosion resistance, its density being 2.5 times lower than that of steel. Yet, processing of silicon carbide invokes temperatures up to 2150 – 2200 °C. So, matters of energy- and resource efficiency as well as constant demand for more reliable media stimulate a search for novel materials with improved physico-mechanical properties and reduced sintering temperature. One of the possible solutions here becomes doping SiC with eutectic sintering aids.

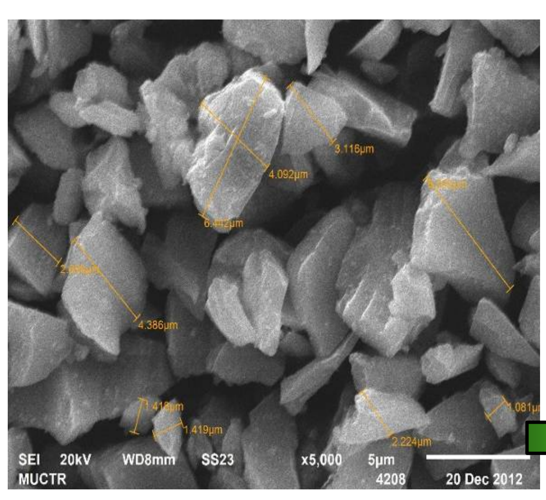


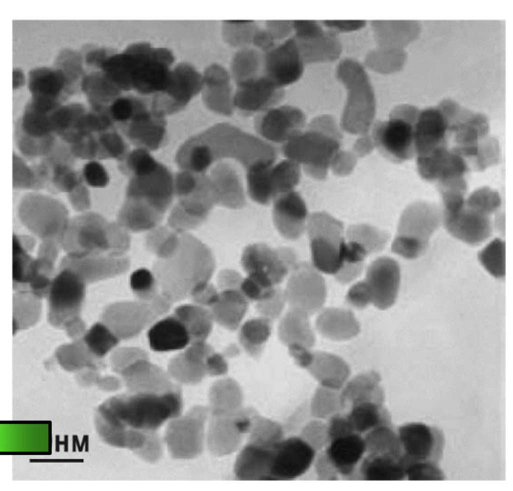
Research

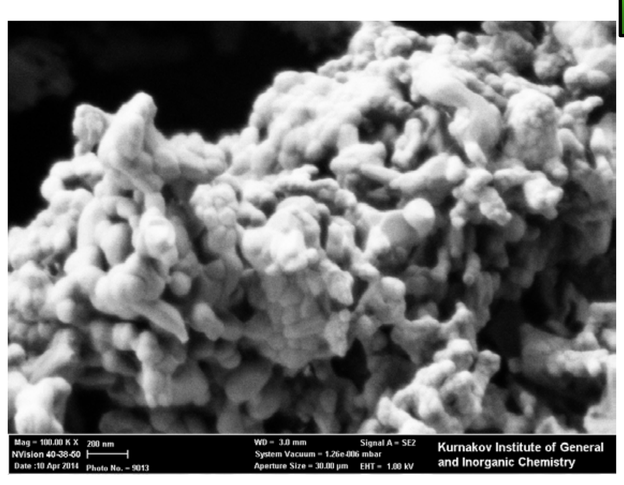
The purpose of this study was to suggest an energy-saving and easily implementational technique for manufacturing dense silicon carbide ceramics with tailored properties.

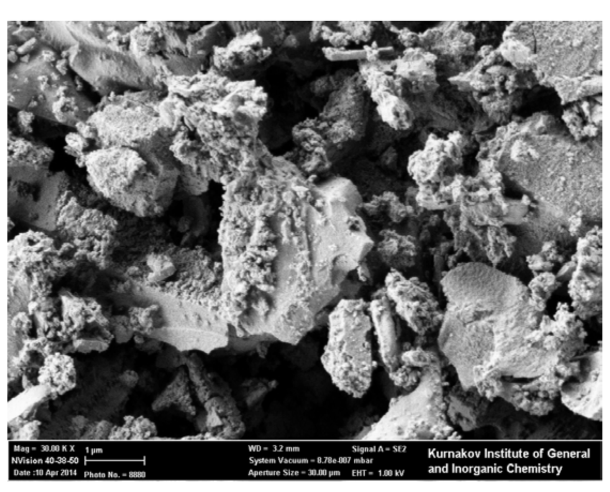
The sample batch consisted primarily of silicon carbide powder with mean grain size of 3 – 4 µm. Mean particle size in silicon carbide nanopowder comprised 45 – 55 nm. Candidate oxide eutectic systems for the present research included $CaO – Al_2O_3 – Y_2O_3$, $Al_2O_3 – ZrO_2$ and $MgO – Al_2O_3 – Y_2O_3$.

Pre-fabricated additives were mixed together with SiC powder in calculated proportions. A hot solution of paraffin in CCl_4 (5 % wt.) was used as binder, whereat mineral component was added portion wise and heated till complete solvent evaporation. Samples of different shape (disks, blocks) were uniaxially cold-pressed at 100 MPa and fired at 1900 °C in argon.





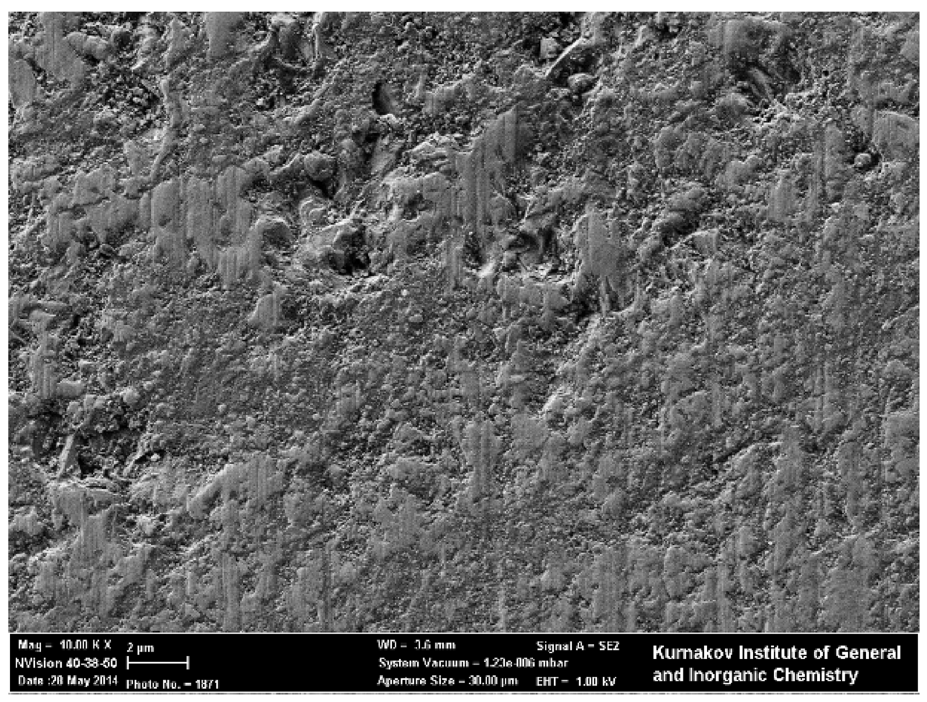




Results

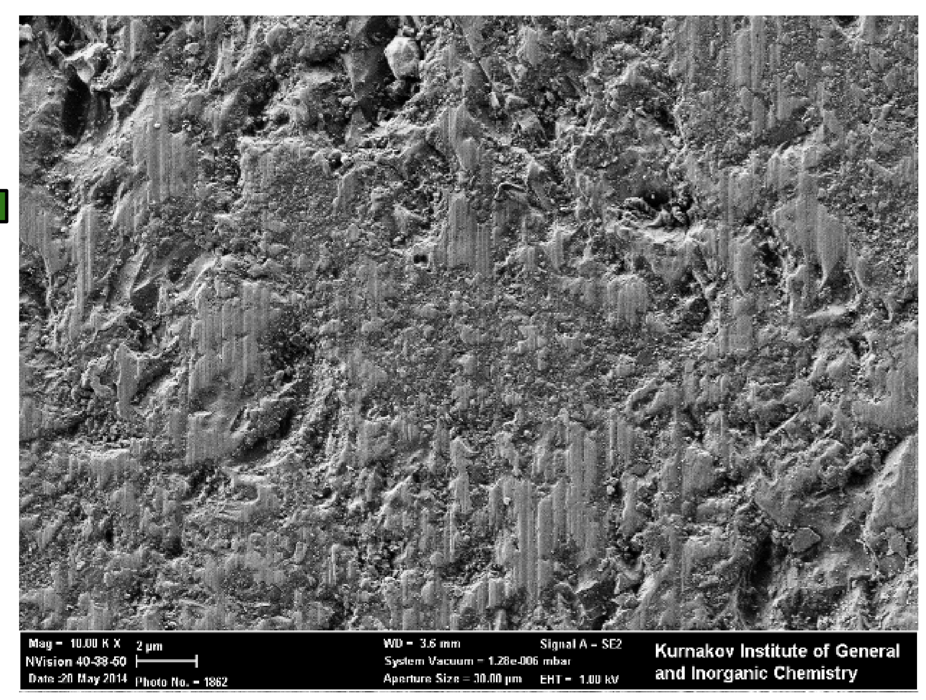
The influence of batch granulometry on physico-mechanical properties of ceramics was studied, and fractions ratio was determined that allowed to obtain a dense material with improved strength and fracture toughness. Candidate eutectics in binary and ternary oxide systems were examined and additives were suggested that could find use in producing ceramics for armour applications. Such ceramics showed excellent mechanical behaviour and holds much promise as a structural and armour material.

Parameters	Sample properties		
	SiSiC	**LPSSiC**	RBBC
Mean density, g/cm^3	3,00 ÷ 3,05	**3,40 ÷ 3,55**	2,70 ÷ 2,75
Open porosity, %	≤ 0,5	**≤ 0,5**	≤ 0,5
Elasticity modulus E, MPa	320 ÷ 340	**340 ÷ 380**	350 ÷ 400
Bending strength (20 °C), MPa	280 ÷ 320	**450 ÷ 500**	320 ÷ 380
Microhardness K1C, MPa·m$^{1/2}$	3,0 ÷ 3,5	**3,5 ÷ 4,0**	3,5 ÷ 4,0
Vickers hardness HV, GPa	22 ÷ 23	**18 ÷ 19**	27 ÷ 28



Tri-modal ceramics with 30 % vol. $MgO – Al_2O_3 – Y_2O_3$ (polished section, 30000^x)

Tri-modal ceramics with 30 % vol. $Al_2O_3 – ZrO_2$ (polished section, 30000^x)



Conclusion

In the present study patterns of physico-mechanical and structural properties of silicon carbide ceramics were examined. SiC-based compositions with 20 % vol. SiC nanopowder dopant and 30 % vol. eutectic additives in $MgO – Al_2O_3 – Y_2O_3$ and $Al_2O_3 – ZrO_2$ systems were suggested that could find use in producing ceramics for armour applications. Specified ceramic materials had sintering temperature of 1900 °C, a fine-grain structure and depending of the eutectic additive exhibited bending strength of 450 ± 25 and 400 ± 20 MPa, microhardness of 18.8 and 17.0 GPa for magnesia-based and alumina-zirconia systems respectively.

Acknowledgements

This research was carried out under financial support from the Ministry of Education and Science of the Russian Federation within the framework of State order, contract No. 11.2056.2014/K.

Authors would like to express their gratitude to Olga Petrova, Assistant Professor at Chemistry and Technology of Crystals Dept., MUCTR, for assistance in microhardness studies.