COMBUSTION SYNTHESIS AND PROPERTIES OF SIALON–BASED HETERO-MODULUS CERAMIC COMPOSITES*

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Hetero-modulus ceramic composites (HMCCs) represent a ceramic matrix with a high Young's modulus (300–800 GPa) with inclusions of a phase with a markedly lower Young's modulus (15–20 GPa) such as sp^2-structured carbon or h-BN. Generally low fracture toughness and thermal-shock resistance of these materials with high elastic modulus can be greatly improved upon addition of low modulus phases. Unusually high tolerance of HMCCs to impact and thermal shock is caused by their inherent ability to absorb and dissipate the elastic energy released during crack propagation and their capacity to blunt and divert a propagating crack [1, 2]. Another advantage of HMCCs is their remarkable machinability [3]. The HMCCs formed by SiAlON and h-BN are recognized as promising multifunctional materials for high-temperature applications. SiAlON ceramics have high hardness, good strength, and excellent wear/corrosion resistance [4]. The ceramics containing h-BN possess excellent properties such as low wettability with molten metals, low friction coefficient, high thermal shock resistance, high thermal conductivity, low thermal expansion, and high electric resistance [5]. SiAlON–BN composites are capable of combining these properties in desirable proportions. Up to now, the development of new simple and efficient methods for production of SiAlON–BN HMCCs is a hot subject of research. Infiltration-assisted combustion synthesis (CS) under high nitrogen pressure is successfully used for obtaining wide range of nitride-based ceramics [6]. In the present communication, the specific features, potentials, and limitations for combustion synthesis of SiAlON–BN composites are reported.

SiAlON–BN HMCCs were prepared by CS under high pressure of nitrogen gas according to the following reaction scheme:

$$3.45Si + 1.7Al + 0.85SiO_2 + N_2 \rightarrow \beta\text{-}Si_{4.3}Al_{1.7}O_{1.7}N_{6.3} \qquad (1)$$

$$B + 0.5\ N_2 \rightarrow BN \qquad (2)$$

The diluents like β-$Si_{4.3}Al_{1.7}O_{1.7}N_{6.3}$ or other refractory compounds (SiC, BN, TiN, TiB_2) were added to starting reactive mixture in order to prevent high-temperature dissociation of end product and to suppress coagulation of low-melting combustible components (Si, Al) into large nonreactive formations. Starting mixtures were intermixed in a laboratory-scale attritor with silicon nitride grinding bodies in air, pressed (cold isostatic pressing, 50 MPa) into cylindrical pellets with a relative density of 0.62–0.64, placed first in a special graphite crucible and then installed in a 4-l reaction chamber equipped with water cooling system and double-stage hydraulic gaseous compressor to provide conditions for infiltration-assisted CS under nitrogen pressures up to 150 MPa. The combustion reaction was ignited with an electrically heated tungsten coil.

The main factors that defined structural characteristics (relative density, phase and elemental composition) of SiAlON-based HMCCs obtained by infiltration-assisted CS were revealed experimentally: (a) pressure of gas reagent, (b) amount of combustible components in starting mixture, (c) BN content of product, (d) diluent wettability with low-melting components, and (e) sample diameter. Direct relationships between structural characteristics and such properties of synthesized HMCCs as bending/compressive strength, thermal-shock resistance, corrosion resistance to metallurgical melts, friction and wear behavior, and specific resistance have been studied. The synthesized HMCCs exhibit excellent resistance to thermal shock and metallurgical melts along with good tribological characteristics and machinability.

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