RESEARCH

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PREPARATION AND ABRASIVE PROPERTIES OF EUTECTIC COMPOSITIONS IN THE SYSTEM $B_4C - SiC - TiB_2$

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A diagram of the meltability of the system $B_4C - SiC - TiB_2$ is constructed by calculation. The compositions of binary and ternary eutectics melted in an arc furnace are described. The microstructure, microhardness, and strength of an individual grain are investigated. The prospects for using eutectic compositions as abrasives and in structural ceramics are shown.

Individual compounds of the system $B_4C - SiC - TiB_2$ are widely used as abrasives and bases for wear-resistant materials and structural ceramics due to their high hardness and elasticity modulus and low temperature coefficient of linear expansion. Data published in recent years give grounds to believe that these materials can be used more rationally in solving of the problem of their brittle fracture. It is necessary to improve such parameters as crack resistance and impact strength, which are very important in the operation of abrasives and structural ceramics. In most cases these requirements exceed known characteristics of materials based on the individual substances discussed. At the same time it is known [1, 2] that eutectics of covalent compounds and their models exhibit elevated resistance to brittle fracture. Similar information on the substantial increase in the critical stress intensity factor in directed crystallized eutectics is available [3].

As applied to the system $B_4C - SiC - TiB_2$ all boundary quasibinary systems are constructed as eutectics [4 – 6]. We can say that the triple system considered is also a simple eutectic and can serve as a base for materials of different purposes, including abrasives and structural ceramics.

Our experiments and thermodynamic calculations by the algorithm of [7] have shown that in the range 1000 – 2500 K the components of the system $B_4C - SiC - TiB_2$ are stable and give no intermediate compounds. We calculated the meltability diagram of the triple system by the model of regular solutions using the method of [8] and data on the melting temperature T_{melt} of the pure components and the composition and temperature T_{eut} of binary eutectics: $T_{melt\,B_4C} = 2730$ K, $T_{melt\,TiB_2} = 3490$ K, $T_{melt\,SiC} = 3070$ K (hypothetical value derived from the position of the liquidus line over the compound SiC in the binary system Si – C); for the 74%[2] B_4C – 26% TiB_2 eutectic $T_{eut} = 2470$ K, for the 68% SiC – 32% TiB_2 eutectic $T_{eut} = 2460$ K, for the 63% B_4C – 37% SiC eutectic $T_{eut} = 2570$ K. The calculated results are presented in Fig. 1.

The calculated composition of the ternary eutectic of the system $B_4C - SiC - TiB_2$ contains 43% B_4C, 27% SiC, and 30% TiB_2. According to our estimates its melting temperature is (2320 ± 20) K.

Using initial powders of B_4C, SiC, and TiB_2 we prepared mixtures corresponding to binary eutectics of the boundary systems and the calculated triple eutectic. Compressed specimens were subjected to arc melting with natural cooling of the melt in the furnace. Polished sections of these specimens and samples of them were chosen for investigating their abrasive characteristics and x-ray phase analysis. Metallographic and x-ray analyses demonstrated that the melts contained the initial components only. The microstructures of the specimens were characterized by the formation of comparatively coarse-grained phase components, especially TiB_2 grains, which indicates that the melts cooled comparatively slowly under the chosen melting conditions. This did not promote crystallization of typical eutectics determined earlier in [4, 6] at substantially higher cooling (hardening) rates.

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[2] Here and below in mole fractions.

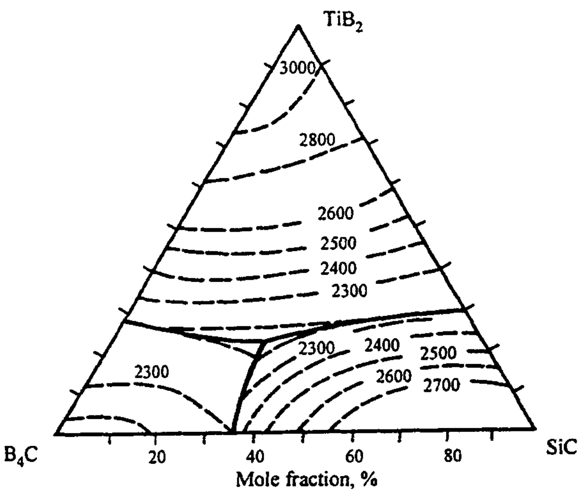

Fig. 1. Calculated meltability of the system $B_4C - SiC - TiB_2$; the numbers at the curves indicate the temperature, °C.

Such a coarse-grained structure affects substantially the physicomechanical properties (including the abrasive ones, namely, grain strength, abrasiveness, etc.). Therefore we were not able to investigate the properties of the eutectics proper by the methods of micromechanics on arc-melted and slowly cooled specimens, because the size of the phase components (for example, the size of TiB_2 grains) was considerably greater than the size of the diagonal d_{diag} of the impression of a diamond indenter at all admissible loads on the PMT-3 microhardness gauge. The determined microhardnesses of the phase components correspond to data on the microhardness of the individual compounds.

As an example, we will consider the microhardness H_m of binary eutectics obtained under conditions of melt quenching that ensure crystallization of the phase components (in an approximately 1 μm scale). This allowed us to determine the resistance of the heterophase volume in the indentation ($d_{diag} \approx 10 - 20$ μm), namely, $H_{m\,B_4C-TiB_2} = 36 - 38$ GPa, $H_{m\,SiC-TiB_2} = 25 - 28$ GPa.

A special feature of these data on the microhardness of the eutectics is that with decrease in the size of the phase components the value of H_m becomes much less than the additive value. The resistance to brittle fracture and the crack resistance grow in this direction [1, 3].

The investigated ternary eutectic $B_4C - SiC - TiB_2$ has a structure that can be characterized as a "coarse conglomerate" in which the effect of the structural parameters on the regularities of brittle fracture is not defined strongly [9]. However, tests of the abrasiveness of eutectic powders by the method of VNIIASh have shown that this characteristic is not inferior to that of powders of pure SiC. At the same time, the investigated material has a higher strength of individual grains and a better crack resistance (by a factor of 5 or more).

Thus, the results obtained show that the ternary system $B_4C - SiC - TiB_2$ can be a base for creating ceramic materials for different purposes, and the relatively high-melting ternary eutectic makes it possible to form new composite abrasive materials in the liquid state. The properties of these materials can be regulated by changing the structural and technological parameters.

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