Influence of the ionic radius of the stabilizing oxide on the crystal structure and mechanical characteristics of tetragonal crystals of solid solutions of ZrO2-R2O3 (R- Y, Gd, Sm)

Borik MA[1], ChislovAS[1,2]*, Kulebyakin AV[1], Lomonova EE[1], Milovich FO[2], Myzina VA[1], Tabachkova NY[1,2].
E-mail: chislov.artem@bk.ru
1 Prokhorov General Physics Institute of RAS, Russia
2 National University of Science and Technology «MISIS», Russia

Solid solutions based on partially stabilized zirconia (PSZ) are a promising structural material. They have high hardness and crack resistance, are able to work in aggressive oxidizing environments at elevated temperatures. High strength characteristics are achieved due to the hardening mechanisms inherent in these materials. In turn, the possibility of implementing hardening mechanisms largely depends on their phase composition.

The aim of this work was to study the phase composition and mechanical characteristics of single crystals based on zirconium dioxide depending on the ionic radius of the stabilizing impurity.

PSZ crystals were synthesized by the method of directional crystallization of the melt in a cold container. Three series of crystals stabilized with yttrium oxide, gadolinium oxide, and samarium oxide at comparable concentrations from 2.0 to 6.0 mol % were grown. The results of the study of the phase composition, crystal structure, microhardness and crack resistance of the obtained crystals are presented.

When studying the phase composition, it was shown that all crystals contain two tetragonal phases t and t' with different degrees of tetragonality. The content of Y2O3, Gd2O3, and Sm2O3 in these phases has been estimated. The effect of differences in the phase composition of crystals on the mechanism of transformation hardening is discussed. It is shown that the efficiency of transformation hardening requires the preservation of the maximum amount of the tetragonal phase and the optimal transformation ability of this phase. The value of crack resistance largely depends on the microstructure and phase composition of the material. In turn, the crystal structure strongly depends on the concentration and type of stabilizing oxide.

It is shown that the concentration dependence of the crack resistance of $(ZrO2)_{1-x}(Y2O3)_x$ and $(ZrO2)_{1-x}(Gd2O3)_x$ crystals has a similar character. The maximum values of crack resistance are observed at a Y2O3 or Gd2O3 content of 2.8 mol%. At comparable concentrations, the crack resistance of $(ZrO2)_{1-x}(Gd2O3)_x$ crystals is greater than the crack resistance of $(ZrO2)_{1-x}(Y2O3)_x$ crystals. The concentration dependence of the crack resistance of $(ZrO2)_{1-x}(Sm2O3)_x$ crystals also has a maximum, but it is shifted towards higher concentrations of the stabilizing oxide. The maximum values of crack resistance of $(ZrO2)_{1-x}(Sm2O3)_x$ crystals exceed the similar value of $(ZrO2)_{1-x}(Gd2O3)_x$, which, in turn, exceeds the crack resistance of $(ZrO2)_{1-x}(Y2O3)_x$ crystals. The observed dependence correlates well with an increase in ionic radii in the series $RY_{3+} < RGd_{3+} < RSm_{3+}$.

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