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**MODEL OF THE EFFECT OF STRESS STATE ON THE GROWTH OF ELONGATED
GRAINS β - Si_3N_4 DURING HIGH-TEMPERATURE DEFORMATION OF SILICON
NITRIDE-BASED CERAMICS**

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Abstract. *The structures of ceramic materials of known compositions based on silicon nitride with high (Si_3N_4 -5wt.% Y_2O_3 -5wt.% Al_2O_3), medium (Si_3N_4 -5wt.% Y_2O_3 -2wt.% Al_2O_3) and low (Si_3N_4 -2wt.% Y_2O_3 -1wt.% Al_2O_3) content of sintering activators after high-temperature deformation according to the direct extrusion scheme were analyzed. An increase in grain size and an increase in the number of anisometric grains in the structure of the deformed material were recorded, with the vast majority of anisometric grains being located coaxially with the longitudinal axis of symmetry of the matrix. The stress state in the deformation zone is considered. The influence of the stress gradient in the deformation zone on mass transfer processes is shown. The mathematical model of the influence of the stress state on the growth of elongated β - Si_3N_4 grains in an inhomogeneous stress field in the transition cone of the matrix is considered.*

Keywords: *silicon nitride, deformation, stress state, deformation mechanism, growth of elongated grains.*

During high-temperature extrusion of silicon nitride materials, an increase in grain size and an increase in the number of anisometric grains are observed, with the vast majority of anisometric grains being located coaxially with the longitudinal axis of symmetry of the matrix. Some of these elongated grains are grains of the initial structure that have reoriented (rotated along the axis) in the stress field. The formation of the other part of the hexagonal elongated grains of the β -phase, located in the deformed structure parallel to the extrusion direction, must occur during the high-temperature deformation process due to the dissolution of other grains. Supersaturation in the liquid phase is determined by the size and shape of the β -grains. Planes with an equilibrium concentration higher than the concentration in the liquid dissolve and thus ensure the transition of a certain number of atoms of the base material into the liquid intergranular phase.

The flow of atoms of a material into a particular region depends on the chemical potential of the atoms. The transfer of material from one region to another will occur only if it leads to a decrease in the total free energy. For this, there must be a gradient of one of the factors between different regions that affects the energy of the atoms. If we assume that in the material of the initial sample grains of different sizes and the intergranular phase are evenly distributed over the volume, and also that the composition of the intergranular phase at all points is approximately the same, then such influencing factors can be temperature and stress state in different volumes of the material. In [1], an assessment of the temperature field in the volume of a silicon nitride billet was carried out during hot pressing with radial induction heating up to 1800 °C at a speed of 10 °C/min. This assessment shows that, firstly, the inhomogeneity of the temperature field in the axial direction is much smaller than in the radial direction, and secondly, the inhomogeneity will be significant in the case of pressings with a diameter of more than 100 mm. Judging by the images of temperature fields presented in this work, when deforming billets with a diameter of 30 mm, the maximum temperature non-uniformity will not exceed 100 °C. Therefore, it can be assumed that during high-temperature extrusion, temperature non-uniformity will not have a significant impact on mass transfer processes.

Based on the diagram of the stress state of the material during high-temperature extrusion, let us present the stress state in which an individual grain of material is during high-temperature deformation (Figure 1).

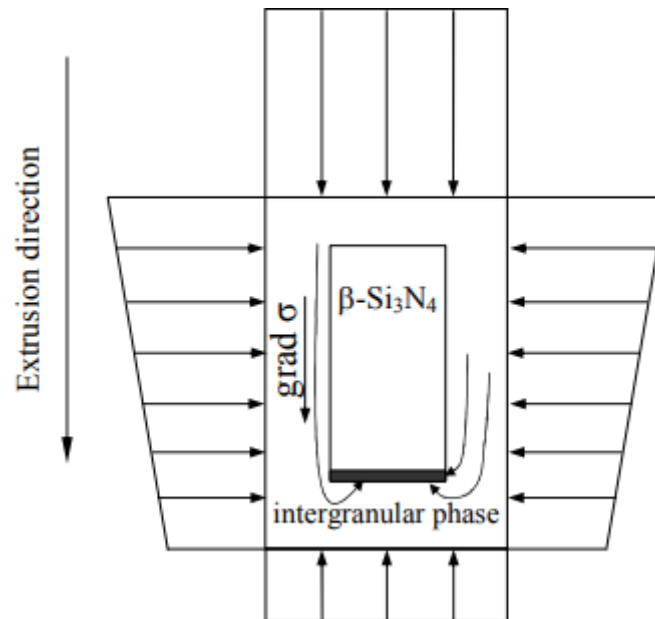


Figure 1 – Growth of elongated grains under conditions of a gradient stress field

Each grain of the material and the volume of the intergranular phase surrounding it are in conditions of non-uniform compression. Compressive stresses are maximum on the side of load application, i.e. on the side of the punch, decrease as they move along the axis to the output channel of the matrix, and, if we talk about a certain elementary volume, are the smallest in its lower part. Thus, in the intergranular phase surrounding the grain, there is a stress gradient that causes the movement of dissolved atoms of the base material to the lower part of the elementary volume, where they participate in the completion of the hexagonal lattice of the elongated grain of the β -phase.

At the stage of stable deformation, when there is much less uncrystallized intergranular phase between the grains, the transition of dissolved atoms to the sites of completion of the hexagonal lattices of elongated grains of the β -phase will occur through this uncrystallized phase and by grain boundary diffusion along the grains of the base material or diffusion in the crystallized intergranular phase.

Conclusions

The influence of the stress gradient in the deformation zone on mass transfer processes is shown. The stress gradient in the high-temperature deformation zone promotes the growth of elongated grains β - Si_3N_4

ЛІТЕРАТУРА / REFERENCE

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МОДЕЛЬ ВПЛИВУ НАПРУЖЕНОГО СТАНУ НА РІСТ ВИДОВЖЕНИХ ЗЕРЕН β - Si_3N_4 ПРИ ВИСОКОТЕМПЕРАТУРНІЙ ДЕФОРМАЦІЇ КЕРАМІКИ НА ОСНОВІ НІТРИДУ КРЕМНІЮ

І.Д. Гнилиця

Анотація. Проаналізовано структури керамічних матеріалів відомих складів на основі нітриду кремнію з високим (Si_3N_4 -5мас.% Y_2O_3 -5мас.% Al_2O_3), середнім (Si_3N_4 -5мас.% Y_2O_3 -2мас.% Al_2O_3) і низьким (Si_3N_4 -2мас.% Y_2O_3 -1мас.% Al_2O_3) вмістом активаторів спікання після високотемпературного деформування по схемі прямої екструзії. Зафіксовано збільшення розмірів зерен і збільшення кількості анізометричних зерен в структурі деформованого матеріалу, причому переважна більшість анізометричних зерен розміщені співвісно з поздовжньою віссю симетрії матриці. Розглянуто напружений стан в зоні деформації. Показано вплив градієнту напружень в зоні деформації на процеси масо переносу. Розглянуто математичну модель впливу напруженого стану на ріст видовжених зерен β - Si_3N_4 в неоднорідному полі напружень у перехідному конусі матриці.

Ключові слова: нітрид кремнію, деформація, напружений стан, механізм деформації, ріст видовжених зерен.