The article establishes a correlation between the level of structural defectiveness, transverse bending strength, microhardness, and microbrittleness of industrial cordierite pyroceram AS-380. The increased size of microcracks, connected with the increase in size of microcrystals, is accompanied by an increase of microhardness of the pyroceram. Conversely, transverse bending strength and microbrittleness of pyroceram are reduced with increase in size of structural microcracks. The obtained regularities can prove to be useful in practice for predicting the estimating the level of the mechanical properties of pyroceram according to the results of the methodologically simple determination of their structural defectiveness.

One of the principal factors affecting the mechanical properties of pyroceramic materials is defectiveness. The microscopic defectiveness of pyrocerams, revealed by the method of luminescence flaw detection, can be divided into surface defectiveness and bulk (structural) defectiveness. The level of surface defectiveness of pyroceram depends largely on the method of obtaining specimens or structural elements from it (e.g., on the machining parameters), and in their turn they have a decisive effect on the strength properties of such elements or specimens.

The cause of structural microcracks in pyroceram are bulk microstresses arising during crystallization in consequence of differences between the coefficients of linear thermal expansion (CLTE) of the crystalline phases and the residual vitreous phase, the anisotropy of the CLTE of the crystals and of phase transformations occurring on account of changes of the specific volume of the phases. In distinction to surface defectiveness, structural defectiveness does not depend on the machining conditions; it remains constant on machined and on freely cooling surfaces and on fractures of pyrocerams. The development level (dimensions) of structural microcracks also has a substantial effect on the mechanical properties of pyrocerams, especially when their surface defectiveness is reduced or blocked by some method of increasing their strength (it should be emphasized that the dimensions of structural microcracks also determine the very possibility of enhancing the strength of pyrocerams). In this connection it is of interest to study the effect of structural defectiveness on the micromechanical properties of pyrocerams which by their nature do not depend on surface defects.

The aim of the present work is to study the phenomenological correlation of structural defectiveness, microhardness, and microbrittleness of the industrial cordierite pyroceramic material AS-380 (the system of the initial glass is MgO-MnO-Al2O3-SiO2-TiO2). Cordierite pyrocerams are a suitable object of such a study because their structural defectiveness can change with broad limits when the temperature-time parameters of crystallization change.

The Vickers microhardness of pyroceram ($H_v$) was determined on an instrument PMT-3 with a load of 0.98 N on the indentor. For its determination we used flat specimens of pyroceram, 25 x 25 x 10 mm, polished to class 12 of surface roughness. Indentation of each surface lasted 180 sec. (Preliminary investigations showed that temporal stabilization of the size of the diagonals of microindentations on the surface of the pyroceram AS-380 in dependence on the level of structural defectiveness is attained when indentation lasts 120-180 sec.) Microhardness was calculated by the expression

$$ H_v = 1.854 \frac{P}{d^2}, $$

where $P$ is the load on the indentor, N; $d$ is the length of the diagonal of the microindent, m.
The radial microcracks propagating from the apexes of the microindents were detected and measured by the method of luminescence flaw detection [1] with the use of the luminescent liquid LZh-6A and a luminescence microscope "Lyumam-IZ" provided with an eyepiece micrometer MOV-1-15x, with total magnification 660.

Microbrittleness was calculated by Dertev's formula [2]:

\[
R_d = \frac{4.8(1 + 2\mu)P}{[4d^2 + (d + 2)^2]}
\]

where \( l \) is the length of the microcrack, m; \( d \) is the length of the diagonal of the microindent, m; \( P \) is the load on the indentor, N; \( \mu \) is the Poisson ratio of the pyroceram.

The theoretical systematic error of determining microhardness and microbrittleness in accordance with the method of [3] did not exceed 5%.

To study the structural defectiveness of the pyroceram AS-380 we also used luminescence flaw detection. Structural microcracks were identified and measured on a polished and on a ground surface and on fractures of the specimens. The maximal relative error of measuring structural microcracks was 4%.

According to the size of the microcracks the studied pyrocerams were divided into five modifications. To modification A there correspond structural microcracks 5-15 \( \mu \)m in size. An increase of the maximal size of structural microcracks to 20 \( \mu \)m is characteristic of the modification B \( \rightarrow \) A. To the modification of defectiveness B correspond the maximal sizes of structural microcracks up to 40 \( \mu \)m, and to the modification Bp up to 60 \( \mu \)m. A further increase of the maximal size of structural microcracks brings the pyroceram to the uniform defective [1] modification OD. As an example, Fig. 1 shows characteristic photomicrographs of the structural defectiveness of the pyroceram AS-380, modifications A and OD.

The micromechanical properties of pyroceram were determined on three specimens of each modification of defectiveness. On each specimen ten corresponding measurements were carried out, and the distance between neighboring microindentations was in all cases larger than ten diagonals. The mean values and the sample variation coefficients were established by ordinary methods [3] from all the 30 measurements.

Together with the micromechanical properties we determined the transverse bending strength of specimens of pyroceram AS-380 in different modifications of defectiveness. For that we used specimens 60 \( \times \) 7 \( \times \) 7 mm in size. The blanks for specimens were cut out from the same plates as the specimens for determining the microproperties; this was done with a diamond saw, and then the blanks were ground with a carborundum wheel to the specified dimensions. The specimens (30 for each determination) were tested for transverse bending strength on a tensile testing machine R-0.5 with 50 mm distance between fixed supports. The rate of increase of stresses at the place of application of the maximal bending moment was approximately 25 MPa/sec.

The results of the determination of strength, microhardness, and microbrittleness of the pyroceram AS-380 are presented in Table 1. The table shows that an increase of the size of the structural microcracks is accompanied by a monotonic increase of microhardness of the pyroceram AS-380 from \( 8 \times 10^3 \) to \( 9.1 \times 10^3 \) MPa (by 15%). Under the same conditions the transverse bending strength of pyroceram decreases by 20%, and microbrittleness by 22%.

To explain the observed effects we have to examine the causes of the changed level of structural defectiveness of pyrocerams. Parallel flaw-detection, electron-microscope (electron microscope UEMV-100K, carbon-platinum replicas), and x-ray phase (diffractometer DRON-2.0) investigations showed that with unchanged mineralogical composition of pyroceram (in regard to the pyroceram AS-380 that contains crystals of cordierite, rutile, and pyrophanite) the sizes of structural microcracks