Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering10 (2011) 1463–1466
Engineering Procedia

ICM11

Thermoresistant Nano-filled Glass-ceramics

V.P. Maslov [a]*, Yu. M. Rodichev [b], N.F.Tregubov[a,b]

[a]V.E. Lashkaryov Institute of Semiconductor Physics NASU,41, prosp. Nauki, Kiev,03028, Ukraine
[b] G.S. Pisarenko Institute for Problems of Strength of NASU, 2, Timiryazevskaya str., Kiev,01014, Ukraine
[ab] Konstantinovsky plant "Kvarsit",20, Shmidta str. Konstantinovka,85104, Donetzk reg.,Ukraine

Abstract

It is known that replacing microscopic particles by nano-particles in a composite formulation results in improved physical properties. The authors investigated the possibility adding of nanoparticles SiO_2 and TiO_2 in an amount of 10-30% in the slurry to produce glass-ceramics.

Mechanical strength of the glass-ceramics parts greatly depends on micro-defects of surface and internal structures substantially connected with the factual quality of used production technology, mechanical and heat treatment. There is analyzed a special complex of the destructive and nondestructive methods of strength and quality control of glass-ceramics developed to guarantee the durability of structures used in the usual and extreme service conditions with the temperature up to 1000 ˚C. The methods based on the precise preproduction tests of specimens and real structural elements such as plates and shells were supplemented with the additional non-standard methods for effective use in the working environment which is typical for line production of super thermal-resistant glass-ceramic. As a result of the research found that the adding of nanoparticles in the slurry increases the density of the structure, improves the physical properties and provides high stability of glass-ceramics.

Selection and peer-review under responsibility of ICM11

Keywords: glass-ceramics; strength; nanoparticles

1. Main text

Mechanical strength of the glass-ceramics parts greatly depends on micro-defects of surface and internal structures substantially connected with the factual quality of used production technology, mechanical and heat treatment [1, 2]. Thermoresistant nano-filled glass-ceramics was developed using the

* Corresponding author. Tel.: +38044 525-05-55; fax: +38044 525-05-55.
E-mail address: maslov@isp.kiev.ua.

1877-7058
Selection and peer-review under responsibility of ICM11 doi:10.1016/j.proeng.2011.04.243

slurry ceramic technology and nano-sized additives to improve the internal and surface structure and increase strength of the shells for extreme operation conditions. The authors investigated the possibility of the adding of nanoparticles SiO_2 and TiO_2 in an amount of 10-30% in the slurry to produce glass-ceramics ware with operation temperature up to 1000 ^oC.

Next shortcomings are typical for water slurries based on lithium-silica-alumina glass:

- high humidity of the suspensions is need to guarantee the required fluidity;
- tendency to sedimentation and inhomogeneous densification;
- insufficient density and strength of cast products.

It was shown in this study that significant heterogeneity, porosity and technological defects of the sintered blanks decrease the strength and carrying capacity of the glass-ceramics shells under normal and extreme conditions.

There was analyzed a special complex of the destructive and nondestructive methods of strength and quality control of glass-ceramics developed to guarantee the durability of glass-ceramics structures and to improve production technology using the strength and quality criteria [3]. The methods based on the precise preproduction tests of specimens and real structural elements such as plates and shells were supplemented with the additional non-standard methods for effective use in the working environment which is typical for line production of super thermal-resistant glass-ceramic.

The characteristics of nano- and micro-dimensional structure of raw glass and sintered glass-ceramics were studied using the micrographs made with atomic-force microscope. It was shown that homogeneous structure of special raw glass is close to amorphous structure of float glass (Fig. 1). But primary crystallization centers were fond in the fracture surface of the special glass blank.

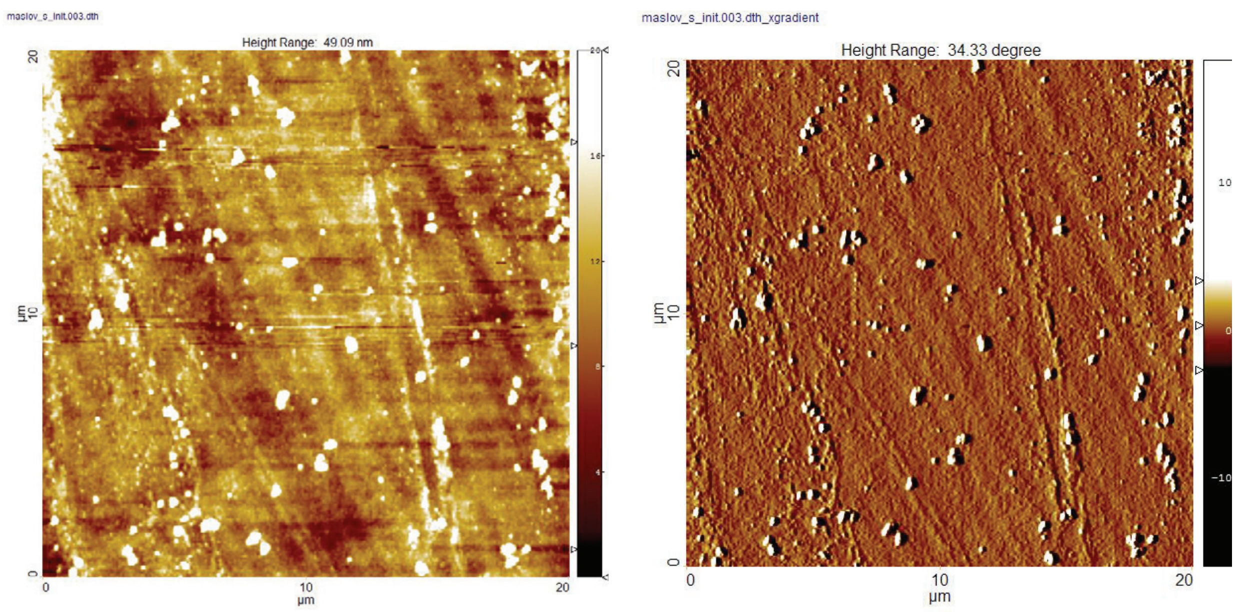

Fig. 1. Structure of fracture surface of raw special glass with primary crystallization centers and linear marks of crack discontinuous motion

The character and large dimensions of internal structure elements and defects for sintered glass-ceramics ware are shown in the Fig. 2. The grain sizes are about 5…10 μm. The sizes of crystalline aggregates were about 20…30 μm. The pores and other internal technological defects together with micro-dimensional defects of glass-ceramics structures are the typical fracture source.

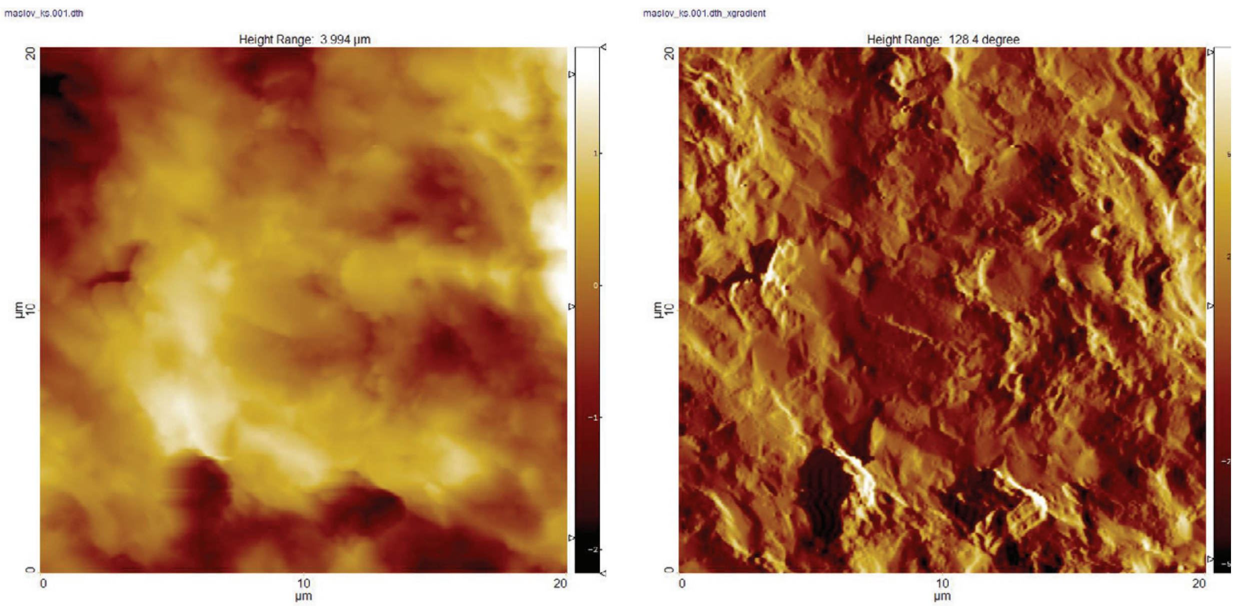

Fig. 2. Character of fracture surface of sintered glass-ceramics with enlarged sizes of polycrystalline structure elements and defects

The crack formation and moving take place in the border of glass-ceramics polycrystalline aggregates. The pores and other technological defects may be controlled by the use of special mechanical tests and technological methods.

New engineering approach was developed to increase the manufacturability and to limit the negative influence of typical shortcomings of the slurry ceramic method. This approach foresees the use of new nano-components in the slurry composition, slurry production method and technology of glass-ceramics ware forming. The main idea considered that replacing microscopic particles of SiO_2 by nano-particles in a composite formulation results in improved physical properties.

The results of the study show that adding nano-components limits the sedimentation of coarse fractions slurry, stimulates the suspension homogeneity increasing and compaction of sintered glass-ceramics structure. The bending strength 120 MPa is guaranteed and fracture toughness minimal values increase on 15…20%.

Technological control of glass-ceramics ware quality and strength included complex assessment the values of bending strength and hardness of the specimens made of real shells, as well as fragments of blanks and shells at the different stages of manufacture production.

The correlation curves for these data were established and used widely in real working environment. The correlation curves for dynamic hardness data and temperature of the glass-ceramics heat treatment are given in the Fig. 3. The optimal heat treatment conditions were selected using these experimental regularities for different slurry compositions.

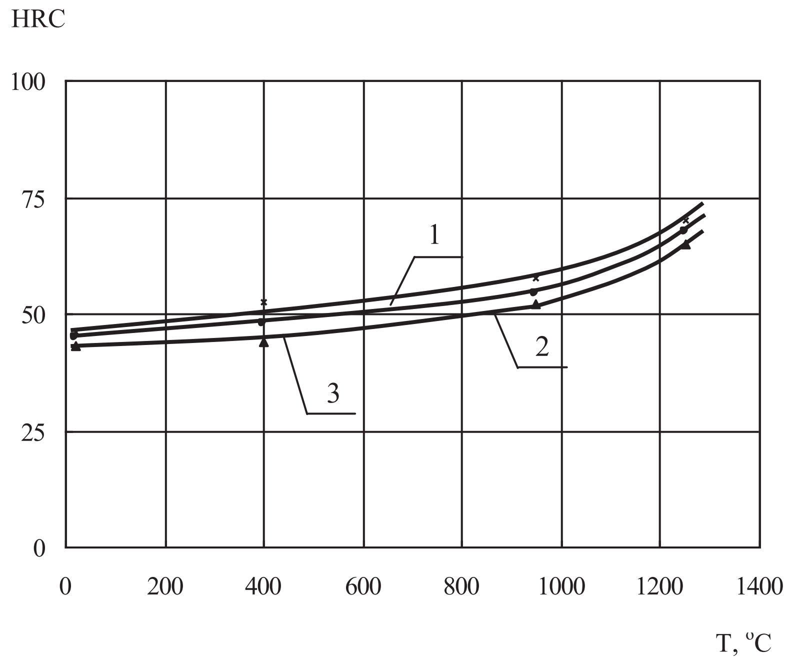

Fig. 3. The dynamic hardness data against to temperature of heat treatment of glass-ceramics ware
1 – minimal values; 2 – maximal values; 3 – mean values.

As a result of the research found that the adding of nanoparticles in the slurry increases the density of the internal structure and strength of the ware, improves the physical properties and provides high stability of glass-ceramics. It was shown high efficiency of complex engineering approach based on the use of quality and strength test results together with new technological decisions.

The results of this investigation were implemented in the main stages of production of the thermoresistant nano-filled glass-ceramics ware for extreme operation conditions.

References

[1] Rodichev Yu.M., Maslov V.P., Netychuk A.V., Bodunov V.P., Yevplov Yu.N. Bending Strength and Fracture of Glass Materials under the Different Loading Conditions, “Glass Performance Days” Conf. Proc., Tampere, Finland, 2007.-P.P.615-618.

[2] Maslov V.P., Rodichev Yu.M., Demaille D., Zheng Y. , Lacaze E., Roditchev D. Strength and Fracture of Nano-Joints for Glassceramics Materials and Elements.- Proc. Intern. Conf.”Nansis 2007”, Kyiv, 2007, C. 495.

[3] Rodichev Yu.M., Maslov V.P., Bodunov V.P., Yevplov Yu.N. Methods of Composite Glass Materials Quality and Strength Testing, “Glass Performance Days” Conf. Proc., Tampere, Finland, 2007.-P.P.624-625.