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Modification of the structure of the layers of superficial soda - calcium - silicon glasses nano molecules inorganic compounds

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Properties

ABSTRACT

Purpose: Finding a new surface treatment of glass.
Design/methodology/approach: Testing results of the glass operational properties, such as bending strength, scratching resistance, micro-hardness, chemical resistance and optical properties have been presented. Nano-molecules were spread onto the heated glass surface, or onto cold glass surface and then heated up to temperatures close to the glass transformation, when nano-molecules penetrate into the glass surface.
Findings: Refining method of soda - calcium - silicon glassy surfaces with inorganic compounds nano-molecules assures profitable operational properties of the glass, such as increased bending strength, scratching resistance, micro-hardness and chemical resistance without deterioration of the optical properties.
Research limitations/implications: Structural definition of inorganic compounds nano-powders exposed to thermal processing, including grain-size analysis has been discussed.
Practical implications: Optimal technical and technological parameters of the refining process have been selected.
Originality/value: The presented method undoubtedly develops new possibilities not only in case of container glass, float glass and glass fibres but also in the field of glass processing.
Keywords: Ceramics and glasses; Electron microscopy; Thin and thick coatings; Surface treatment; Nano-particles; Glass surface; Aluminum compounds

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1. Introduction

Glass is a kind of material having relatively high compressive strength but very low tensile, bending and striking strength. Insufficient mechanical resistance of glass and its brittleness restrict broad use of the glass used as construction material. That is why numerous trials of improving the glass resistance have been made. The glass resistance depends first of all on the condition of its surface, and secondary on its chemical

composition, annealing degree, uniformity, environment and temperature. Presence of the glass surface defects developed numerous methods aimed at the improvement of glass strength directed to elimination of micro-fractures, protection of the glass against secondary defects or exposing the glass surface to the action of compressive strengths eliminating such defects [1].

Modification of the glass surface with use of the mentioned methods considerably improves mechanical strength of the glass. One of the mentioned glass refining methods comprises thermal processing, so called glass hardening. The glass is heated up to such temperature that from one side the glass could reach suitable rigidity not being deformed during industrial processes, and from the other side had suitably low viscosity to assure fast relaxation of the internal strengths. In result of air cooling the surface is schrinkaged and rigid, while its internal zones are fluid. During cooling process internal shrinkage of the glass is limited by rigid external layers what in consequence leads to the fact that after final cooling, compressive strengths compensated by internal tensile forces act on the glass surface. In the final phase of the process temperature distribution fades and only strength distribution is left. Thermal hardening enables production of glasses of considerably higher mechanical resistance than was observed in case of traditionally annealed glasses.

Improvement of the strength properties can also be obtained by chemical etching of the glass in hydrofluoric acid solutions. In the initial phase of the process etching fluid penetrates into fractures rounding their originally sharp ending what results in qualitative change of the defect-making strength concentrator of lower damage degree. Final resistance depends not only on the thickness of the liquidated layer but also on the quality of the glass surface after etching process, what is related to the composition of the etching liquid, its temperature and mode of the process realization.

The next method comprises surface ion exchange. The exchange allows considerable increase of the glass bending strength compared to glass not exposed to such process, and also increase of the impact resistance and hardness. Based on the available theoretical and practical data we can suppose that the best results in soda - calcium glass are obtained with use of melted potassium nitrate KNO_3, under glass processing temperature being about 100°C lower than the transformation temperature [2].

The glass surface can also be refined by the „hot" method, where glass of temperature 450-600°C is exposed to action of $SnCl_4$, which when contacted with the hot glass surface is chemically decomposed forming oxygen film on the glass surface. Moreover, diffusion of the tin oxide into near-surface glass zone takes place. Structural bonding with the glass is formed and considerable changes of the glass surface take place, i.e. glass surface smoothness is increased thus scratching resistance and glass hardness increase what results in improvement of the mechanical impact resistance with about 30%. The spread film is resistant to action of hot water, vapor and lye, including variable atmospheric conditions [3].

Development of the nano-technology, being a technology of new generation, is commonly used in various branches. Technology of ultra-thin layers is the best example. Nano-technology also comprises use of very fine-grained powders [4,5].

Nano-powders considerably improve mechanical, thermal, electrical and magnetic properties of ceramic materials and glass, as well as composites. Such material parameters as strength, ductility, brittleness, light transmittance, or dielectric transmittance can be modified by intervention into material microstructure resulting from change of the particle dimension or addition of nano-powders.

2. Experimental

The investigations of the propriety of physics-chemical glasses were conducted in the work after thermal processing, ion exchange in KNO_3 and the refined nano-molecules aluminum compounds. The test of the qualification of the hydrolytic resistance of glasses was undertaken.

The strengthening of the surface through the chemical processing was made on the flat glass in melted salts the nitrate of potassium (KNO_3), during the process of the ion exchange i.e. below the temperature of the glass transformation (490°C). Refining the surface of glass nano-molecules aluminum compounds was made on flat glass on which nano-molecules in close temperature of the glass transformation. The modification of the surface of the glass was got in this way through the ions of aluminum.

3. Results and discussion

The investigation of the resistance of the surface of glass products on the working of water was conducted according to the norm of ISO 4802-1. Micro-hardness tests were made by Vickers method with use of PMT-3 micro-hardness-meter according to the norm PN-70/B-13150 and was checked transverse bending strength, which he is the size folded, because they step out in the object curving from one the side tensions squeezing and from second spreading. Tensions spreading decide about the destruction of the glass near curving, because the glass curved will crack under the influence of tensions spreading more quickly than squeezing. The method defining mechanical transverse bending strength to the norm PN-82/B-13151 according.

The samples also proved considerable improvement of the transverse bending mechanical properties and micro-hardness. The examinations were made for various glass types and heir results are shown in Figures 1, 2 [7,8].

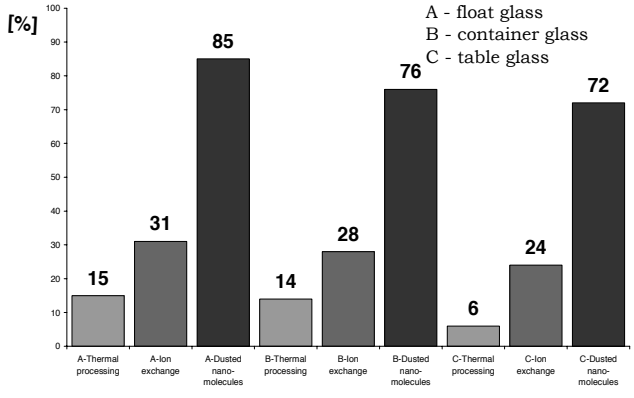

Fig. 1. Increase of micro-hardness of float glass , container glass and table glass

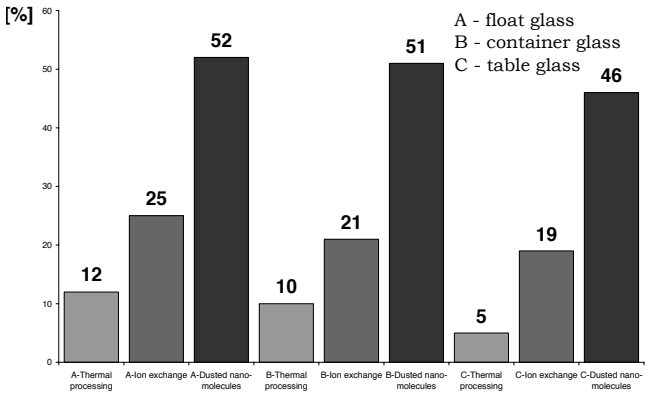

Fig. 2. Increase of transverse bending strength of float glass, container glass and table glass

Samples tested for transverse bending strength shown considerable increase of strength, even by 52% in case of float glass. Micro-hardness tests were made for samples spread with aluminum compounds nano-molecules in temperatures close to transformation temperature (hot spreading) and in room temperature (cold spreading). Samples spread in room temperature were heated up to temperatures close to transformation temperature. The best results were obtained for hot spread float glass samples, which shown micro-hardness increment of about 110%.

Method of the glass surface refining with nano-molecules of aluminum compounds comprises use of previously prepared nano-molecules of aluminum compounds. Nano-powders have been prepared in ball-vibrating mill, by milling particles together with enveloping substance. The powder was then defined on the basis of the material structure and grain-size. Grain-size of the obtained grains is shown in Figures 3, 4.

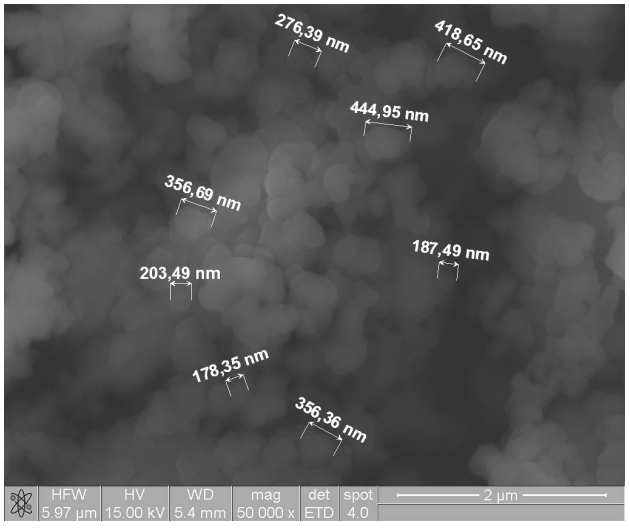

Fig. 3. Nano-powder of aluminum compounds - SEM photo

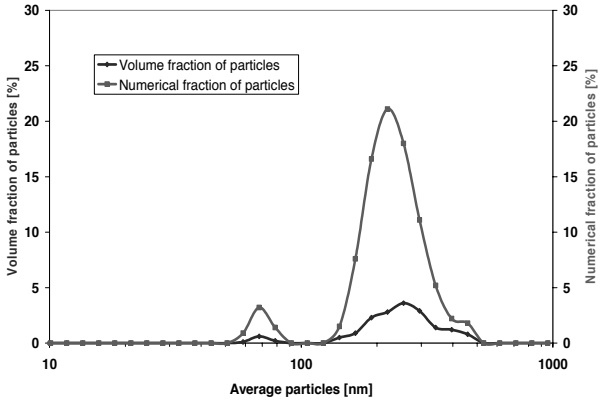

Fig. 4. Volume and numerical fraction of particles

The results of measurements of thermal conductivity coefficient as a function of temperature for nano-molecules aluminum compounds by using one of the most modern experimental sets LFA 427 (Laser Flash Apparatus) produced by Netzsch Company. Results of LFA examinations are shown in Figures 5-7.

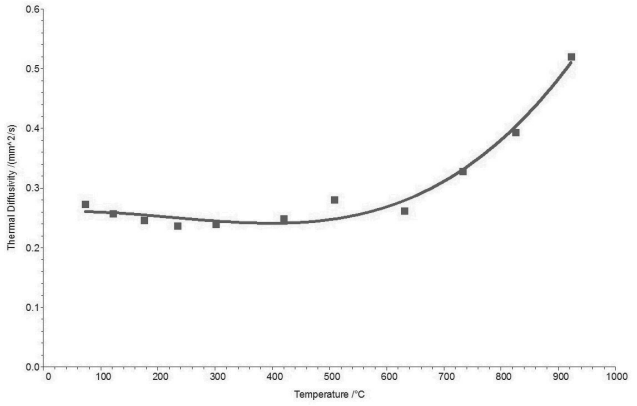

Fig. 5. Thermal difusivity of nano-molecules aluminum compounds

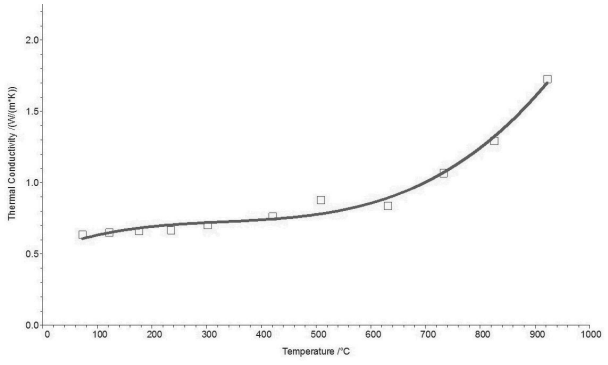

Fig. 6. Thermal conductivity of nano-molecules aluminum compounds

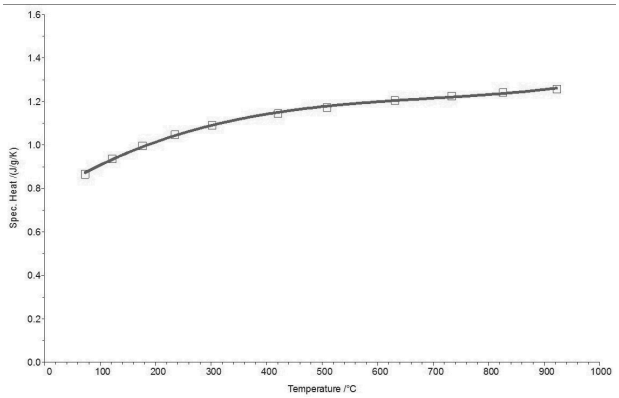

Fig. 7. Specific heat of nano-molecules aliminum compounds

Nano-powders the aluminum compounds are disposed on the whole surface of the studied glass evenly. The layer is homogeneous and uniform that is show in Figures 8, 9 which confirmed of AFM results. Based on the results of examinations, including visual observation, the samples did not show any deterioration of optical effects, what is illustrated in Figure 10 [7,8].

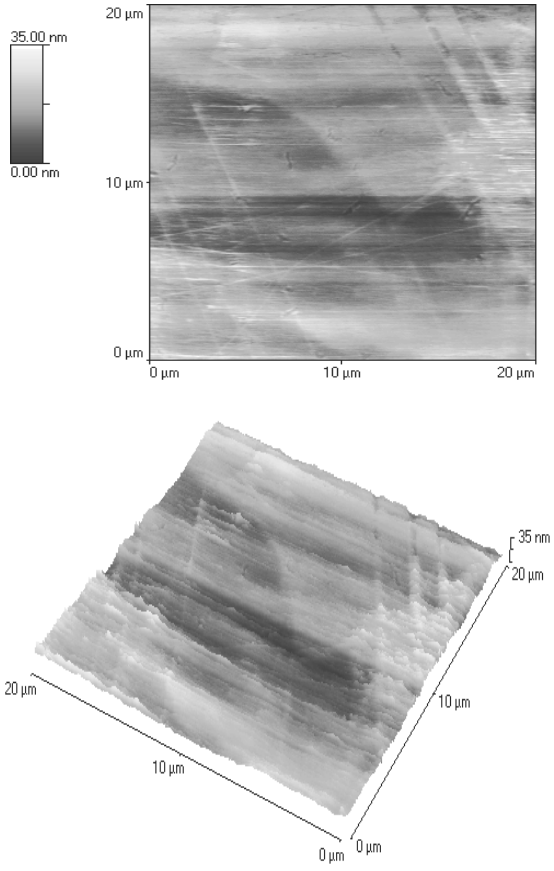

Fig. 8. Base glass surface - AFM photo

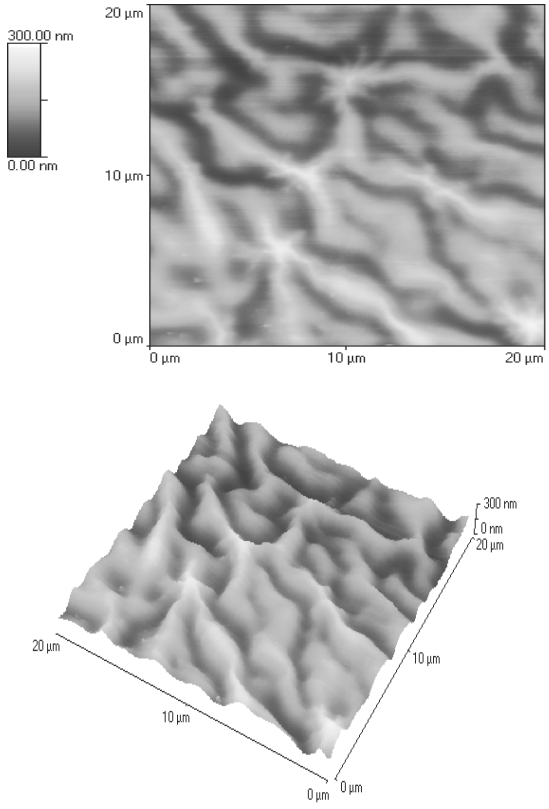

Fig. 9. AFM photo of glass surface after refining with aluminum compounds nano-molecules

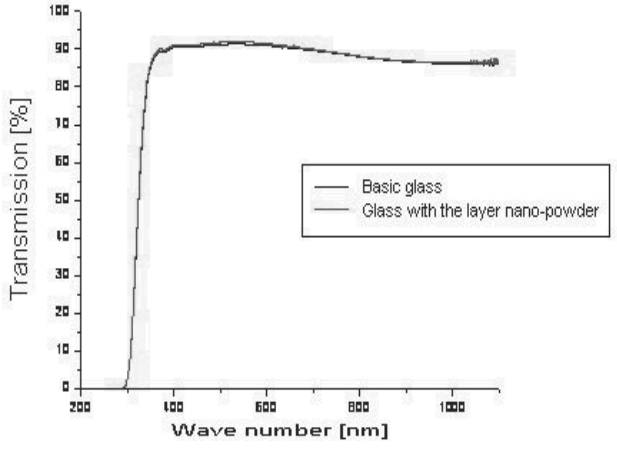

Fig. 10. Light transmittance of the float glass

4. Conclusions

The new technology of refining gives the new possibilities of the use in glass. The results of micro-hardness and bearing bending strength considerably top issue from the ion exchange.

Glasses refined nano-molecules aluminum compounds do not show deterioration of optical proprieties as they not are also harmful for the health.

Acknowledgements

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