Rational Usage of Amorphous Varieties of Silicon Dioxide in Dry Mixtures of Glass with Specific Light Transmittance

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Abstract. The paper studied high-silicon amorphous rocks from the perspective of their application for glass production of different purpose. The results contained data of calculation of dry mixtures for producing heat-protective glass using amorphous varieties of silicon dioxide. The obtained glass specimens were melted and studied for spectral characteristics.

Keywords: Amorphous silicon dioxide · Light transmittance · Dry mixture · Heat-protection glass

1 Introduction

High-silicon amorphous rocks as raw materials have a wide range of valuable features. Primarily, this is the amorphous (metastable) state of silicon dioxide (Kondrashov and Kondrashov 2013). Moreover, one can distinguish some peculiarities of amorphous varieties that can be regarded as drawbacks (Manevich et al. 2012):

- instability of chemical composition;
- SiO_2 is accompanied by other components (up to 40%) that can play the role of auxiliary raw materials;
- increased content of aluminum oxides and iron.

One of the main glass spectral characteristics is light transmittance. The main components that affect light transmittance of glass products and that should be strictly controlled are oxides of coloring metals that are encountered in conventional raw materials (dolomite, feldspar concentrate, sands). These compounds include iron oxides; their content in glass is strictly regulated:

- sheet glass – 0.09–0.12%;
- heat-protective – 0.6–0.7%;
- clear container glass – $0.1 \pm 0.01\%$;
- brown container glass – $0.8 \pm 0.1\%$;
- green container glass – not regulated.

The composition of amorphous varieties of silicon dioxide (Distantov 1976) is characterized by increased content of iron oxides (Table 1), which impedes their wide application in production of glass articles.

Table 1. Variation of chemical composition of amorphous silicic raw materials

Rock	Content of oxides [wt.%]							
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	TiO ₂
Diatomites	73.0–90.0	3.3–7.5	2.0–5.2	less than 0.6	0.6–1.7	less than 1.0	less than 0.5	less than 0.3
Opokas	52.1–91.4	2.5–15.4	1.0–5.0	0.43–17.1	less than 2.48	0.6–4.0	0.1–1.0	less than 0.2
Pearlites	68.5–75.3	11.2–16.3	less than 3.0	0.5–2.0	less than 1.0	1.5–4.0	2.0–6.2	0.1–0.5
Tripolites	35.3–86.7	2.5–11.6	0.3–3.4	0.4–31.2	0.2–1.6	0.85–2.1	less than 0.5	less than 0.2

Taking into account increased content of iron and aluminum oxides, these rocks can be used as aluminum- or iron-containing raw materials in production of heat-protection glass or dark-glass containers.

2 Methods and Approaches

Current work assesses amorphous silicon dioxide (ASD) as aluminum-containing raw material that can partially replace quartz sand and other conventional raw materials (Table 2).

Table 2. Composition of average samples of amorphous silicon dioxide varieties

Rock	Content of oxides [wt.%]							
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	TiO ₂
Diatomite	87.22	6.79	2.22	0.431	1.25	1.08	0.245	0.265
Opoka	92.47	3.38	1.32	0.506	0.712	0.88	–	0.174
Pearlite	72.0	16.45	1.06	0.863	0.422	4.30	4.21	0.145
Tripolite	79.93	10.99	3.17	0.838	1.81	1.99	0.273	0.687

To conduct experimental studies, the dry mixtures for heat protective glass with ASD were calculated. The glass was melted from the dry mixtures using pearlite. The content of iron oxides in pearlite is insufficient for production of heat-protective glass, which necessitates the introduction of iron containing material such as magnetite.

The glass was melted in an electric kiln with silicon carbide heating elements at maximum melting temperature of 1420 °C. Another batch of glass was melted without pearlite.

Spectral light transmittance in the visible range was measured automatically on SF-56 spectrophotometer (Russia). The specimens were prepared by mechanical grinding and polishing on laboratory setups.

3 Results

The results showed that the application of ASD for preparation of dry mixtures allowed reducing number of conventional materials for glass melting (Table 3).

Table 3. Economy of conventional raw materials after replacement by ASD, %

Rock	Raw material			
	Sand	Soda	Creta	Dolomite
Opoka	72.7	2.44	1.61	19.71
Pearlite	43.8	20.15	38.7	40.38
Diatomite	41.7	6.5	4.08	25.14
Tripolite	27.6	7.79	7.66	27.06

The glass produced in the laboratory differed in color (Fig. 1), which depends on the shift of equilibrium $\text{Fe}^{2+} \leftrightarrow \text{Fe}^{3+}$.

Fig. 1. Specimens of sheet glass: 1 – with pearlite; 2 – with pearlite and magnetite; 3 – with pearlite and magnetite (+ coal)

We studied spectral characteristics of the glass specimens: sheet glass melted from conventional components; sheet glass with addition of pearlite as aluminum-containing raw material; sheet glass with addition of magnetite (magnetite was reduced by coal) (Fig. 2).

Fig. 2. Spectral light transmittance of sheet glass: 1 – conventional raw materials; 2 – with pearlite; 3 – with pearlite and magnetite; 4 – with pearlite and magnetite (+ coal)

The data from Table 4 demonstrated that in the visible spectrum, the light transmittance of the glass with application of pearlite differed from glass melted with conventional raw materials. The highest light transmittance was shown by sheet glass melted from conventional raw materials, since the content of iron in quartz sand was minimal (0.022 wt%).

Table 4. Light transmittance of sheet glass specimens calculated for the thickness of 10 mm

Specimen	Light transmittance T [%]				Diathermancy index = 10 ⁻¹ T ₁₁₀₀
	λ = 570 nm		λ = 1100 nm		
	As per equation	As per nomogram*	As per equation	As per nomogram*	
1	88.6	88.1	67.4	67.7	6.7
2	48.4	48.8	8.4	8.2	0.8
3	30.8	30.5	5.1	4.8	0.4
4	12.3	12.0	3.7	3.2	0.3

* - Amosov's nomogram

The heat-protective characteristics are assessed by light transmittance at $\lambda = 1100$ nm. In the infrared range of the spectrum, the light transmittance of specimens 2, 3 and 4 reduces due to the presence of impurities of Fe^{2+} , which provisions the heat-protective characteristics.

In IR-range, the light transmittance of studied glasses is different (from 3 to 67%), i.e. high heat-protective properties are possessed by specimens 3 and 4, the IR-light transmittance is 3–5%. However, the production of glass with such content of FeO is unreasonable due to low light transmittance in the visible spectrum. Such dry mixtures can be used for special glass.

4 Conclusions

The calculations allowed determining the amorphous varieties of silicon dioxide that could replace most conventional materials in dry mixtures. They were: opoka (as a replacement for quartz sand) for both aluminum- and iron-containing raw materials, and pearlite capable of replacing the biggest amount of soda, creta and dolomite when using it as an iron-containing material.

Additional studies of glass properties produced from dry mixtures with pearlite were required (spectral characteristics, crystallization capacity and impact of redox conditions of melting). Nevertheless, the work showed that pearlite could be used in the technology of heat-protective glass.

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References

- Distantov AG (1976) Silicon rocks of USSR. Tatar Press, Kazan
- Kondrashov VI, Kondrashov DV (2013) Perspectives of synthesis of industrial compositions of float-glass on the basis of crystalline and amorphous silicon dioxide. *GlassRussia*. 3:31–33
- Manevich VE, Subbotin RK, Nikiforov EA, Senik NA, Meshkov AV (2012) Diatomite as silica-containing material for glass industry. *Glass Ceram* 5:34–39

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