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The Replacement of Quartz Sand with Microsilica for Obtaining Glass Materials

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ABSTRACT: The article presents the physicochemical and technological characteristics of amorphous silica fume. According to the results of experimental studies, it can be established that the replacement of natural quartz sand with ferrosilicon waste–microsilica in the glass charge does not reduce its main physical, chemical and technological characteristics. It is shown that the replacement of quartz sand with microsilica in the raw material composition of the glass charge leads to a decrease in the temperature of smooth formation, in particular, glass melting, as a result of which it helps to save natural raw materials and energy resources, while solving the problems of improving the environmental situation in the industrial region of the Republic.

KEYWORDS: energy resources, environmental situation, ferrosilicon, glass charge, glass materials, microsilica, natural quartz sand, raw material composition, temperature, glass melting, natural raw materials.

INTRODUCTION

It is known [1, 3] that the development of the production of glassy materials in the Republic of Uzbekistan is inextricably linked with the intensive development of the construction complex, the increase in the needs of glass products for household and technical purposes, as well as for the needs of other industries. In addition, the production of glass and glassware has its own special significance in the building materials industry. Since the development of new highly efficient and energy–saving compositions also remains an urgent task set for researchers working in the field of glass production technology [4, 6]. In this regard, it is of interest to use microsilica, which is formed during the production of ferroalloy at Uzmetkombinat JSC instead of natural quartz sand [7, 8].

At the same time, it should be noted that micro–silicon accumulates in most enterprises that currently produce high–silicon ferroalloys containing a large amount of silicon dioxide, which on the one hand leads to economic losses due to non–use, on the other on the one hand, it increases the cost of their production.

In addition, microsilica is a pulverized waste, as a result of disorderly accumulation, it usually loses its value as a secondary raw material for processing. In this regard, the recycling and use of dust emissions should be considered as an important direction for improving the environmental situation in the production of ferroalloys in metallurgical enterprises.

Microsilica is a silicate dust that is formed as a by–product of the production of silicon alloys. During the smelting of silicon alloys, some of the silicon oxide passes into a gaseous state and, subjected to oxidation and condensation, forms an extremely fine product in the form of spherical particles with a high content of amorphous silica [9, 10].

To date, microsilica has begun to be widely used as an additive in order to improve the physical–mechanical and construction–technical properties of cement, concrete, wall and lightweight ceramic materials, in the production of glass and glassware, as well as dinas refractory materials.

Based on the foregoing, hypotheses were made to develop glassy materials based on high–silica raw materials with full and partial replacement of natural quartz sand with microsilica.

MATERIALS AND METHODS

Quartz sands of Tomdi, dolomites of Dekhkanabad deposits, soda ash of Kungrad soda plant and microsilica formed in the production of Uzmetkombinat JSC were used as initial raw materials for the production of glass materials.

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The material composition of the initial components of the glass charge was determined by the methods of silicate rational chemical analysis. The mineralogical phase composition of quartz sand from the Tomdi deposit and fired prototypes was determined by X–ray diffraction analysis. X–ray phase analysis was carried out by the powder method on a LABX XRD–6100 SHIMADZU X–ray diffractometer in the range of 2θ, 10–80 using CuKα radiation with a wavelength of 1.5418 Å. X–ray photographs were taken with a step of 0.02 deg, voltage 30 kV, current 30 mA. Published reference data and an international card index [11–13] were used in calculations and in the identification of crystalline phases.

The degree of light transmission of the synthesized glass samples was determined on a Shimadzu brand spectrophotometer.

Obtaining glass samples was carried out according to the classical technology of glass production. The developed mass compositions for obtaining glass in a stoichiometric ratio were ground in a ball mill to a fineness of grinding passing through a No. The firing was carried out in a bath furnace at a firing temperature of 1200°C. It should be noted that the production compositions of container glass based on traditional compositions are melted in the temperature range of 1400–1450°C, depending on the chemical composition of the glass charge [14, 15].

In this regard, the melting of glass charge from the developed four composite compositions was carried out in laboratory electric furnaces with silicate heaters in corundum crucibles with a volume of 300 g, with a temperature rise rate of 400 deg/h. The glass melting temperature was 1450–1500°C with an exposure of 1 hour. The synthesized glasses were poured onto a preheated metal plate.

RESULTS AND DISCUSSIONS

The results of the analysis of the material composition of the initial components of the glass charge are given in Table 1. As a result of the chemical analysis of microsilica, it was found that the content of the main phase–silica is about 88.45 wt.%. In addition, the material composition of microsilica also contains oxides of alkaline earth elements. When comparing the chemical composition of Tomda quartz sand and microsilica, it was found that, in addition to alkaline earth oxides, the content of silica and other oxides are similar.

Table 1. The chemical composition of the used components

Name of components	The content of oxides in wt.%									LOI, wt.%
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	H_2O	
Dolomite Dekhkanabad	1,8	1,23	0,04	31,07	18.94	≤ 0,1	≤0,1	≤ 0,1	3,30	43,8
Silica sand Tomdi	95,1	0,47	0,03	0,22	0,14	0,1	0,02	0,05	0,01	0,91
Soda ash of the Kungrad plant	0,06	–	0,01	–	–	43,21	0,03	0,01	0,31	56,37
Microsilica Uzmetkombinat	88,5	0,8	1,3	3,8	2,7	≤ 0,1	≤0,1	0,5	0,01	5,2

Where: Loss on ignition (LOI) includes: water, organic and volatile impurities, and carbon dioxide (CO_2).

The results of X–ray phase analysis showed that on the X–ray pattern of the waste from the production of ferroalloy JSC “Uzmetkombinat” – microsilica, there is mainly an amorphous glass phase, which is not fixed by X–ray phase analysis. Only in the presence of diffraction lines related to the mineral tridymite (d=1.36; 0.430; 0.409 nm), which is a high–temperature form of β–quartz, was found. In addition, the radiograph shows low–intensity diffraction lines related to the carbonate mineral.

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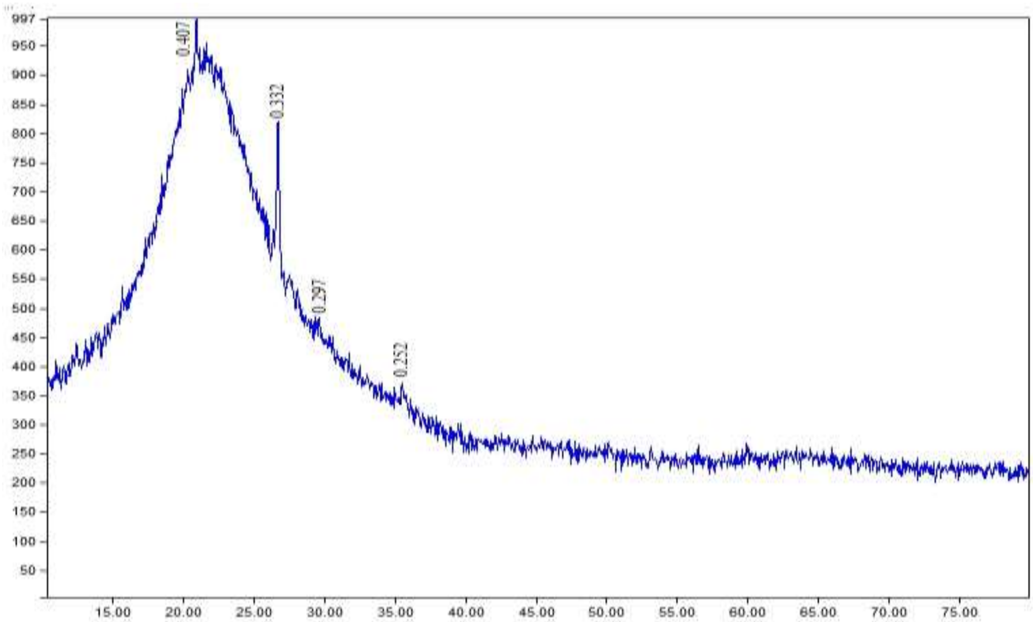

Figure 1. X–ray pattern of microsilica–a waste product of the production of ferroalloy JSC "Uzmetkombinat"

For the preparation of glass charge, various charge mixtures were developed based on the composition "quartz sand–dolomite–microsilica" using soda ash from the Kungrad soda plant, the compositions of which are given in Table 2.

Table 2. The developed charge compositions for glass

Name of Nova Sampling	Component composition of the glass mixture, wt.%				Degree of light transmission,%
	Quartz sand of the Tamdinsky deposit	Dolomite of the Dekhkanabad deposit	Soda ash of the Kungrad soda plant	Microsilica Uzmetkombinat	
MC–1	0	15–17	20–22	61–63	65–67
MC–2	60–65	0	17–22	16–20	65–68
MC–3	29–33	16–19	20–23	28–32	64–67
MC–4	55–62	15–19	20–23	1,5–5,0	45–50

The use of microsilica when replacing quartz sand in the raw composition of glass showed that the melting point of the raw mass is reduced by about 80–100 °C, due to the influence of amorphous silica on the process of smooth formation.

It should be noted that when replacing quartz sand with microsilica, the reactions of decomposition of carbonates, silicate formation and melting in a four–component charge begin at a relatively low temperature, proceed more intensively and end at lower temperatures. Therefore, an increase in the number of equivalent components of the glass charge, as a rule, leads to a decrease in the fusibility of glasses.

Further, after melting at heat treatment temperatures of 1400–1450°C, experimental glass batches in a silica furnace, the resulting molten glass mass was poured into metal molds.

The results of determining the physicochemical characteristics of glass samples based on the developed compositions are shown in Table 3.

Table 3. The physicochemical properties of the synthesized glasses

Name of Nova Sampling	TCLE · 10^7 deg^{-1}	Density, kg/m^3	Refractive index	Softening temperature, °C	Thermal durability, °C	Degree of light transmission,%
MC–1	50,14	$2{,}71 \cdot 10^3$	1,521	750	380	65–67
MC–2	47,65	$2{,}74 \cdot 10^3$	1,534	740	420	65–68
MC–3	51,86	$2{,}79 \cdot 10^3$	1,547	735	350	64–67
MC–4	52,44	$2{,}83 \cdot 10^3$	1,553	730	330	45–50

The obtained glass products from experimental compositions 1–3 have transparency with a degree of transmission of a light beam of 65–68%, within the permissible limits established for container glass. The appearance of the prototype glass samples has a slight creamy tint. The glass product obtained from composition No. 4 has a darker color with a degree of transmission of the light beam of 45–50%, due to the influence of residual impurities of iron oxides.

From the data of Table 3 it can be seen that the density indicators of the developed glass samples are in the range of $2.71 \cdot 10^3$–$2.83 \cdot 10^3$ kg/m^3, in which the density of the sample increases with an increase in the content of dolomite in the glass mass. At the same time, the refractive index also increases in parallel and is in the range of 1.521–1.553, and the heat resistance of glass samples decreases.

It should be noted that the value of the thermal coefficient of linear expansion depends on the ratio and nature of the oxides that make up the glass sample. The chemical composition of the glass charge affects the linear change in thermal expansion during their heat treatment. Thus, the value of the thermal coefficient of linear expansion of the synthesized glasses with increasing dolomite content increases from $47.65 \cdot 10^{-7}$ deg^{-1} to $52.44 \cdot 10^{-7}$ deg^{-1}. In general, the main physico–chemical properties determined by the synthesized glass sample significantly depend on the behavior of all constituent components in the composition of the glass mixture.

CONCLUSION

Thus, on the basis of the experimental studies carried out, it can be established that the replacement of natural quartz sand with ferrosilicon waste–microsilica in a glass batch does not reduce its basic physical, chemical and technological characteristics. It is shown that the replacement of quartz sand with microsilica in the raw material composition of the glass charge leads to a decrease in the temperature of smooth formation, in particular, glass melting, as a result of which it helps to save natural raw materials and energy resources, while solving the problems of improving the environmental situation in the industrial region of the Republic.

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