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Research paper

Using quartzofeldspathic waste to obtain foamed glass material

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Abstract

The present paper proposes a method for the processing of mine refuse non-ferrous metal ore in the production of foamed glass. The subject of this research is a low-temperature frit synthesis (<900 °C), allowing for the high-temperature glass melting process to be avoided. The technology for the production of frit without complete melting of the batch and without using glass-making units offers a considerable reduction in energy consumption and air pollution. It was found that material samples obtained with a density of up to 250 kg/m^3 are of rigidity (up to 1.7 MPa) in comparison with the conventional foamed glass (1 MPa). This increased rigidity was due to the presence of crystalline phase particles in its interpore partition of less than 2 μm in size. Material with a density of 300 kg/cm^3 is recommended for thermal insulation for the industrial and construction sectors. At densities above 300 kg/cm^3 and a strength of 2.5 MPa, the purpose becomes heat-insulating construction material. The proposed method for obtaining a porous material from waste widens our choice of raw materials for foamed glass, whilst saving resources and energy.

Keywords: Quartzofeldspathic waste; Low-temperature frit; Foamed glass material

1. Introduction

Feldspar is widely used in glass, ceramic and other industries, as well as in the manufacturing of abrasive materials, mastics and as a drilling fluid filler. In addition to deposits, feldspar can also be found in non-ferrous metal ore processing, where it appears in the form of feldspathic waste. The waste from the beneficiation of metal ore can also be used in the manufacturing of construction materials. The given area of application will depend on both the waste composition and the features of other ingredients. Individual cases must be based on research into the preparation of content and processes.

The waste from non-ferrous metal ore beneficiation, whether copper, lead-zinc, molybdenum or other, constitutes large tonnage recoverable waste which, if not used, would pollute the environment. Therefore, the issue of their usage draws considerable attention. For example, the mass of tailings from the production of 1 tonne of copper reaches 5.6 tonnes, while the production of nickel from oxide ore yields almost 100 tonnes. Currently each year, metallurgical slag amounts to hundreds of millions of tonnes all over the world, whereas the worldwide production of mining products and fuels is greater than 150 billion tonnes per year [1–5]. Pollution of the environment with industrial waste is one of the most important problems of the modern world [6–8]. Industrial waste disposal is necessary not only for the reduction of dangerous environmental pollution, but also for the generation of economic benefits. The use of sludge and tailings from various processes as an alternative raw material is regarded as the most promising method of reducing the production costs of various materials [9,10]. The present article considers the issue of obtaining foamed glass from quartzofeldspathic waste, generated by non-ferrous metal ore beneficiation.

The conventional raw material from which foamed glass used to be extracted has been secondary glass waste or other specially melted glass. Glass waste, the potential of which in terms of foamed glass is limited, can now be gradually replaced by industrial or off-grade waste. There are examples of the production of light porous fillers from clay, shale rock, perlite and vermiculite, as well as certain types of waste [11–13]. Research in this area is one of the most rapidly growing fields. Furthermore, the issue of the reduction of energy consumption

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is also attracting growing attention. There is practical interest in obtaining foam glass from other types of man-made materials using low-temperature processes, without relying on conventional high-temperature melting techniques. For the development and application of these materials, it is necessary to bring together the technological and operational properties of materials, as well as their composition.

The objective of this work is to synthesise frit, from waste of non-ferrous metal ore obtained from beneficiation, and use it to produce foamed glass, using the low-temperature process (<900 °C). The technology for the production of frit without complete melting of the batch and without using glass-melting processes offers a considerable reduction in energy consumption and air pollution.

2. Materials and methods

2.1. Materials

The subject of the research is quartzofeldspathic refuse, obtained through beneficiation, in the form of copper-zinc ore from the Zhezkazganskoe mine in Kazakhstan, as well as beneficiation waste from molybdenum ore, from the Sorskoe complex in Russia. The chemical and granulometric composition of the waste is indicated in Table 1.

The chemical composition of the waste differs from that of graded quartz sands, normally used for glass melting, as they contain less glass-forming SiO_2 and more Al_2O_3, Fe_2O_3. Both types of waste are aluminosilicates. According to the results of chemical analysis, the wastes do not correspond to the sand grade [normally] used in the production of foam glass, cans and bottles, half-white glass, insulation or pipes. The elevated levels of oxides contained in glass and the quality of main components, such as CaO, MgO, K_2O, Na_2O, must be taken into account when calculating the batch composition. The chemical composition of the waste indicates possible suitability for producing foamed glass from frit.

In addition to the chemical composition, another important requirement for raw materials suitable for low-temperature synthesis of frit is its dispersiveness, where the average particle size must not be lower than 100 μm. The assessment of granulometric composition of quartzofeldspathic waste indicated that the material obtained from beneficiation of the ores originating from Zhezkazganskoe deposits are a fine grain material, which could be used in frit synthesis. The waste from the beneficiation of ore originating from Sorskoe deposits, on the other hand, must undergo additional pulverisation.

2.2. Experimental method

The study of the material's phase composition as well as finished materials was conducted using X-ray diffraction on a DRON-3M in copper radiation, whilst the quantitative X-ray diffraction analysis was performed using Match! software. The physical and chemical processes that occur during the heat treatment of the batch were studied using differential thermal analysis (combined TGA/DSC/DTA analyser SDT Q600). The study of the macro- and microstructures of the porous samples was performed on a digital microscope (USB Digital Microscope) and scanning electron microscope (JCM-6000) with an attachment for energy dispersive analysis.

Radiological measurements, conducted using the "RKS-01-SOLO" radiometer-dosimeter, indicated that the radiation from this material does not exceed the natural background radiation level, constituting 0.07 μSv/h. The effective activity of the radionuclides, measured using the "Progress-2000" gamma spectrometer, amounted to 241 Bq/kg, which also does not exceed the level of safety for construction materials (370 Bq/kg).

3. Results and discussion

The work produced frit at a temperature of 800–900 °C based on a two-stage process developed for this purpose [14]. During the first stage, frit was synthesised by thermal processing of the initial batch from waste. In the second stage, the frit was ground, with the addition of a blowing agent; the mixture was then granulated and foamed. The two-stage technology allows us to gradually optimise the structure and properties of the material. At the first stage, we solve the problem of synthesising frit with certain characteristics, as they can be regulated by certain recipe and technology factors. The main features of material macrostructure are manipulated in the second stage.

When selecting the chemical composition of frit for low-temperature processing, the following factors were taken into

Table 1
Chemical and granulometric composition of ore beneficiation waste.

Chemical composition										
Ore deposits	Content of oxides, %									
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Cr_2O_3	TiO_2	SO_3
Zhezkazganskoe	68.38	17.04	3.81	3.02	1.79	3.49	1.65	0.14	0.50	0.18
Sorskoe	63.58	16.33	4.28	4.83	2.06	4.38	3.85	–	0.59	0.10

Granulometric composition					
Particle size, mm	Fraction content, %				
	<0.056	0.056–0.16	0.16–0.35	0.35–1.63	1.63–3.5
Sorskoe	2.1	11.2	45.3	38.2	3.2
Zhezkazganskoe	87.0	13.0	0	0	0