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Upgrading Silica/Glass Sand Concentrate Applying Cationic Flotation

OKTAY BAYAT*, HUSEYIN VAPUR and VOLKAN I. ARSLAN
Department of Mining Engineering, Cukurova University, Balcali, 01330 Adana, Turkey
Fax: (90)(322)3386126; Tel: (90)(322)3386119
E-mail: obayat@cukurova.edu.tr; hvapur@cukurova.edu.tr; varslan@cukurova.edu.tr

In this study, upgrading of flotation silica/glass sand concentrate (clear flat glass quality), sized 0.600 ± 0.106 mm, from Camis Mining Company (Mersin, Turkey) was investigated applying amine flotation. In the experimental work; Armac-C, Armac-T, Armoflote-64, Armoflote-586, Armoflote-565 and Armoflote-P were used as cationic collectors keeping other flotation conditions constant. Armoflote-565 gave the best results as an effective collector since the Fe_2O_3 content was reduced from 0.098-0.03 % with 70.4 % iron removal efficiency after applying two cleaning stages of amine (Armoflote-565, 800 g/t) flotation onto the glass sand concentrate (clear flat glass quality) treated traditionally in the plant. The upgraded silica concentrate can be utilized as for manufacturing the household white glass ($Fe_2O_3 \leq 0.05$ %). The floated product (the tailings of the amine flotation) can be a raw material for production of some titanium concentrates due to its TiO_2 content.

Key Words: Upgrading of minerals, Froth flotation, Flotation reagents, Mineral processing.

INTRODUCTION

Silica sand is utilized for a variety of commercial purposes. The major consumer of this resource is the foundry or metal casting industry for cores and molds. Other uses include glass, fiberglass and metallurgical industry, traction and blasting sand and filter sand. Although consumption by the glass industry is not as great as use by the foundry industry, strict specifications demanding a high-silica, low-impurity sand make dune sand ideally suited for the industry. Silica sand is the principal ingredient used in the production of glass. It is only acceptable by the manufacturers of both flat and bottle glass if the amount of iron oxide present within the sand is below a certain level.

The glass industry has established different standard specifications for the silica sand for seven types of glass. The requirements for these grades of silica sand are set out in the British standard[1] cover the following applications: Tableware and lead crystal glass, Grade B (max. percentage of iron as ferric oxide, 0.02) and clear flat/float glass, Grade E (max. percentage of iron as ferric oxide, 0.1). In order to meet the iron content specification, suppliers of silica sand to the glass industry have to treat the sand to reduce the inherent iron content. Iron within the sand can be present in a number of forms, including hematite, magnetite, goethite, limonite and pyrite and can exist as either individual particles or surface staining on the sand grains. Upgrading of flat glass concentrate into tableware glass concentrate as a qualified raw material is very important in economical and production purposes at glass industry. The sand deposits that have in the nature state the purity demanded by the consuming industries and especially by the glass industry are very few in the world. Although the SiO_2 content of sand usually exceeds 97-98%, the presence of the iron and titanium oxides (colouring minerals) limits the fields of utilization of the glass/silica sand for production of high quality glass. Therefore, it is necessary to reduce the content of iron-bearing minerals in order to be used in the high quality glass industry ($Fe_2O_3 \leq 0.02\%$)[2]. The processing steps used in producing high quality industrial silica sand may include a variety of combinations involving drying, screening, scrubbing, flotation, sizing, iron removal, grinding and acid leaching. However, removal of surface staining is more difficult and at present the main process used is hot acid leaching. This process involves pre-heating the sand to 140ºC before it is mixed with sulphuric acid, contacted for 1 h, then washed. The process is very effective in reducing the iron staining in sand but the procedure is energy intensive uses hazardous chemicals and requires large areas for settlement lagoons. Colouring minerals are effectively separated by cationic flotation in acidic pH. For instance, the separation of quartz and Na-feldspar from K-feldspar requires HF as an activator in amine flotation[3-5] but it causes considerable environmental and health problems although there are some HF free methods available to separate quartz from feldspar[6-8]. Camis Mining Company has been operated since 1970 as a main supplier of the Sisecam A.S. (Turkey) for optical glass, tableware and borosilicate glass production. The ore deposit has quartz (88 %), orthoclase (10 %), iron oxides (0.25 %) and trace elements such as Zn, Cr and Ti. The plant produces three types of concentrates with different qualities and the total capacity of the concentrator is 600,000 metric tonnes of silica sand per year[9]. The aim of the study was to remove noxious components up to minimum admissible contents from flotation silica/glass sand concentrates (clear flat/float glass quality, $Fe_2O_3 < 0.1$ %) and so, the upgraded concentrate can be utilized for manufacturing the household white glass ($Fe_2O_3 \leq$ 0.05%).

EXPERIMENTAL

Test material weighed 50 kg as preliminary silica sand concentrate was taken from Camis Mining Company, Turkey. The Camis Mining plant, established in 1995 as a department of Sisecam A.S. (Turkey), treats about 200,000 metric tonnes of silica sand per year. After a series of crushing and grinding operations, the blended material is subjected to flotation stage. Reagents, Aero 801 and Aero 825[10], are added to the flotation feed in pump boxes for separating silica sand concentrate. Chemical composition of the sample is showed in Table-1. The mineralogical analysis was conducted on the silica concentrate by optic mineralogical observations correlated to X-ray diffraction and chemical analyses. It was pointed out that the sample of sand as contained high percentage of granular quartz, a small quantity of weathered feldspars (less than 2 %) and about 1 % heavy minerals (*e.g.*, iron, titanium oxides, hydroxides, tourmaline, *etc.*) were identified. In view of the small quantity of the contaminating minerals in the silica/glass sand concentrate total mass, the reverse flotation was used, with the colouring minerals entering into the froth. The individual mineral flotation tests were performed in a Denver mechanical flotation cell with a 2 L stainless steel tank at a solids concentration of 50 %. Initially, 1 kg of the silica/glass sand concentrate was conditioned at the desired pH for 5 min then a further 10 min conditioning followed the addition of a predetermined quantity of the modifier and collector solutions. Any pH change during the conditioning period was adjusted. According to the preliminary test results, froth scrape time was determined as 5 min. The floated (iron-bearing minerals) and tailings fractions (un-floated residue/cleaned concentrates) were vacuum filtered and dried in an oven at 90 ± 5ºC to constant weight and assayed for iron (Fe_2O_3) content using X-ray fluorescence spectrometry at Sisecam, Istanbul. Tap water was used throughout the experiments. Flotation test parameters are presented in Table-2. Akzo Chemical International, Holland, supplied the flotation reagents (Armac-C, Armac-T, Armoflote-64, Armoflote-586, Armoflote-565 and Armoflote-P). Each flotation test was performed in duplicate and the average of the two residual Fe_2O_3 concentrations presented. All data in this study were analyzed using statistical methods. The criteria assigned for the relative error was 5 %. When the relative error exceeded this criterion, the data were discarded and a third experiment conducted until the relative error fell within an acceptable range.

RESULTS AND DISCUSSION

The cationic effect of metal ions on the separation for upgrading of silica sand concentrate was evaluated using $Pb(NO_3)_2$ and Armac-C as a collector at a series of flotation tests as presented in Table-3. Since, the

TABLE-1
CHEMICAL COMPOSITION OF THE SAMPLE

Contents	(%)	Contents	(%)
SiO_2	97.410	CaO	0.080
Al_2O_3	1.110	MgO	0.030
Fe_2O_3	0.098	TiO_2	0.700
Na_2O	0.050	L.O.I.	0.390
K_2O	0.130		

TABLE-2
FLOTATION TEST PARAMETERS

Parameters	Conditions
Particle size	0.600 ± 0.106 mm
pH	3.0
Mixing speed	1400 rpm
Temperature	22 ± 2°C
Solids/liquid	50 % solids
Amount of $Pb(NO_3)_2$	200 g/t
Collector	Armac-C, Armac-T, Armoflote-64, Armoflote-586, Armoflote-565 and Armoflote-P
Collector dosage	200-1000 g/t
Conditioning time	5-10 min
Flotation time	5 min

TABLE-3
EFFECT OF METAL IONS ON GRADE
(COLLECTOR: ARMAC-C, 500 g/t; 2-STAGES CLEANING)

Activator	Concentrate; Fe_2O_3 (%)
None	0.071
$Pb(NO_3)_2$	0.056

study lead provided a good separation, flotation tests were repeated to choose the best type of collector. The comparison of different collectors using a dosage of 500 g/t on the separation of colouring/iron bearing minerals from the silica/glass sand concentrates are presented in Table-4. Satisfactory results were obtained when Armoflote-565 was utilized for upgrading tests. The effect of collector dosage on the separation of iron-bearing minerals from the silica/glass sand concentrate is shown in Fig. 1. As it was seen from the graph, an upgraded concentrate with 0.03 % Fe_2O_3 and 77.5 % iron removal recovery from the silica/glass sand concentrate would be possible to obtain at pH 3 by using Armoflote-565 at 800 g/t. The chemical composition of the upgraded concentrate and the floated (iron bearing minerals) product after 2-stage amine flotation is presented in Table-5. The results showed that upgraded silica sand concentrate consisted of 0.03 %

Fe_2O_3 as a high quality product and the quantity of impurities (*e.g.*, Al_2O_3, TiO_2 and other minerals) was determined very low value in the upgrading process.

TABLE-4
EXPERIMENTAL RESULTS USING CATIONIC COLLECTORS
(DOSAGE 500 g/t; 2-STAGES CLEANING)

Collector	Upgraded Concentrate; Fe_2O_3 (%)
Armac-C	0.056
Armac-T	0.061
Armoflote-64	0.041
Armoflote-586	0.044
Armoflote-565	0.035
Armoflote-P	0.048

TABLE-5
CHEMICAL COMPOSITION OF THE UPGRADED SILICA/GLASS SAND CONCENTRATE AND THE TAILING PRODUCT
(COLLECTOR:ARMOFLOTE-565; DOSAGE, 800 g/t)

Contents (%)	The upgraded silica sand concentrate	The tailing product (iron-bearing minerals)
Al_2O_3	0.02	4.82
Fe_2O_3	0.03	2.29
Na_2O	0.38	2.51
K_2O	0.33	2.27
CaO	-	0.02
MgO	0.04	0.69
TiO_2	-	1.88
L.O.I.	0.32	2.91

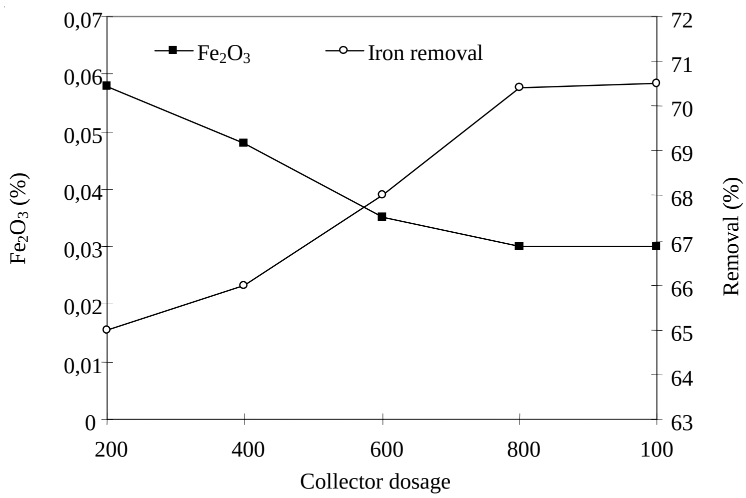

Fig. 1 Variation of Armoflote-565 dosage and Fe_2O_3 for 2 stages cleaning

Conclusions

These results showed that lead is effective as activator for titanium oxides and feldspars in the flotation system. Collector dosage is an important parameter and an excess use of it in the flotation system reduces the recovery.

An upgraded concentrate from the clear flat glass quality silica/glass sand concentrate (about 20 US$/tonnes) with a small scale modifying the whole flotation system can provide many advantages such as better price (*ca.* 40 US$/tonnes) for the upgraded concentrate for manufacturing the household white glass ($Fe_2O_3 \leq 0.05\%$) and increasing the capacity of the plant evaluating/processing the low grade silica sand ores. The floated product can be a raw material for production of some titanium concentrates due to its TiO_2 content.

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