Extraction of Silicon from Tailings Slurry of Gold Mine Treatment Plant by Alkali Fusion Technique

Müge Sarı Yılmaz, and Sabriye Pişkin

***Abstract*—** The total gold production in Turkey increases every year associated with the number of new gold ores. This increase in gold production results in the increase of tailings slurry which is obtained during the recovery of gold from ore.

The aims of the present study were to establish a process of extraction of silicon (Si) from tailings slurry by alkali fusion and determine the amount of the extracted Si for a potential applicability as a recycling process of tailings slurry on the obtained results. For this purpose, the Si in the slurry was activated by fusion technique with sodium hydroxide. The silicon dioxide content of extract was analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES). In addition, the chemical compositions and phase analysis of the slurry were analyzed by X-ray fluorescence (XRF) spectroscopy and X-ray diffraction (XRD).

***Keywords*—** Gold mine, Fusion, Silicon, Tailings slurry.

I. Introduction

Turkey has gold reserves/resources of approximately 979 tons in 51 deposits [1]. The total gold production of Turkey reached to 106.5 tonnes since 2001 and the production increases every year associated with the number of new gold mines [2].

Various methods such as gravity concentration, flotation, panning, pyrometallurgy, cyanidation etc. were used for the recovery of the gold metal from its ores [3]. After recovery of the gold, the tailings are treated in a three-stage chemical destruction circuit to reduce the concentration of residual cyanide and heavy metals in the effluent tailings stream to the limits set by the Ministry of Environment [4]. About 277.882 tonnes of the tailings slurry of gold mine treatment is produced every year during the recovery of gold [5].

Large amount of tailing slurry brings big amount of disposal requirement of those slurries that is quite expensive and dangerous for environment. Therefore, the recycling of this kind of slurries into useful materials is quite important in terms of economical and environmental aspects.

The objective of this study is to evaluate the chemical compositions of the tailings slurry for a potential application in some industrial applications. For this purpose, different treatment conditions where NaOH/slurry ratio of 0.8, 1, and 1.5, and leach time at 16 and 24 hours were performed to extract of Si from tailings slurry of gold mine treatment plant.

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II. Experimental Procedure

A. Materials

The tailings slurry used in the present study was obtained from the Bergama Ovacık Gold Mine Treatment Plant, Turkey. The slurry was dried at 105°C for 2 hours and ground to pass through a 90 μm sieve and stored before analysis. Sodium hydroxide was commercially available and used as supplied without further purification. The presence of cyanide in the slurry was determined by TS 12271 "Wastes-Standard test methods for the detection of cyanides". According to analysis results, the slurry does not contain any cyanide.

B. Characterization of tailings slurry

The structure of the slurry was investigated using X-ray powder diffraction (XRD). The XRD patterns were obtained at room temperature on a Philips PanAnalytical X'Pert-Pro diffractometer with a CuKα (0.15406 nm) radiation source in the 2θ range from 5° to 90°. The chemical composition of the slurry was performed using PANalytical MiniPal4 X-ray fluorescence spectrometer (XRF) analysis. Infrared spectroscopy analysis was carried out using Perkin Elmer Spectrum One Fourier Transformed infrared (FT-IR) spectrometer with recorded in the region 4000–450 cm^{-1} using spectroscopic quality KBr powder. In addition, the elemental concentration of extracted solutions was measured using a Perkin Elmer Optima 2100 DV model Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES).

C. Fusion Technique

To extract the Si from tailings slurry of gold mine treatment plant, alkali fusion technique was adopted. Firstly, a given amount of slurry was mixed and ground with NaOH to obtain a homogeneous mixture. Then, the mixture was placed in a nickel crucible and subjected to a temperature of 550°C in an oven in the presence of air atmosphere for 1 h. Different NaOH/slurry weight ratios (0.8, 1, and 1.5) were used to explore the effect of this parameter in the fusion technique.

Secondly, the fusion product was ground and dissolved in distilled water and the mixture agitated for 16 and 24 h at 25°C. After 24 h, the solution was separated from the mixture by a filtration process. The elemental concentrations (Si, Al, and Na) of the extracted solution were determined with ICP-OES analysis. The experimental procedure was given in Fig. 1.

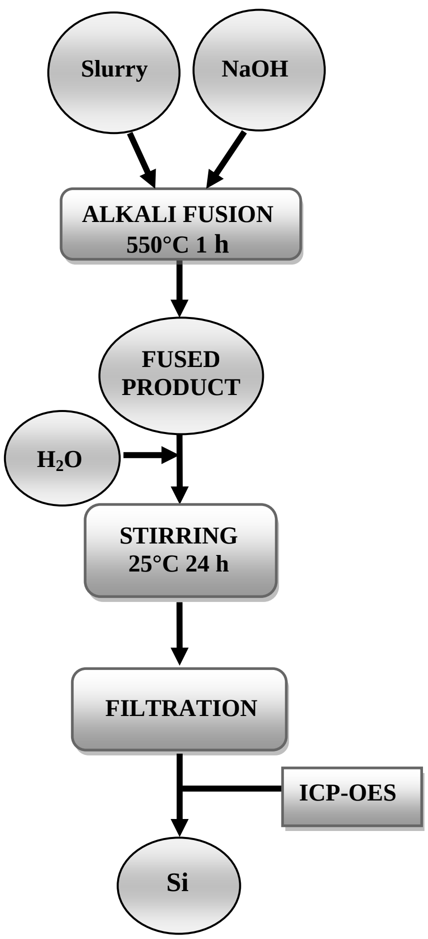

Fig. 1 Flow chart of the extraction of Si from tailings slurry of gold mine treatment plant by alkali fusion technique

III. Results and Discussion

A. Characterization of the slurry

The XRD pattern of the slurry is shown in Fig. 2.Slurry mainly consists of quartz (SiO_2, PDF no: 01-087-2096) and aluminum oxide (Al_2O_3, PDF no: 00-012-0539). The major crystalline phase was SiO_2 with peaks at 26.61°, 0.81°, and 50.08°. The other phase was Al_2O_3 with peaks at 25.67°, 34.73°, and 73.46°.

Chemical composition has an important influence both on the potential application of slurry and on the environmental impact of its subsequent use. The composition of the slurry was shown in Table I. As listed in Table I, slurry are comprised of lots of SiO2 and Al2O3 and small amount of K2O, CaO, TiO2, MnO, Fe2O3, MoO3, and BaO.

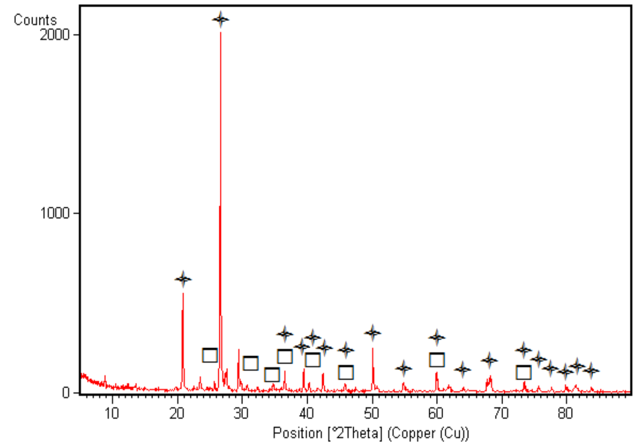

Fig. 2 XRD pattern of the slurry (□: SiO_2, □:Al_2O_3)

TABLE I
CHEMICAL COMPOSITION OF THE SLURRY

Compound	Content (wt%)
SiO_2	77.70
Al_2O_3	12.10
K_2O	3.05
CaO	3.32
TiO_2	0.21
MnO	0.05
Fe_2O_3	2.94
MoO_3	0.55
BaO	0.10

Fig. 3 depicts the FTIR spectrum of slurry. The absorption band at 3435.66 cm^{-1} corresponding to the O–H vibrations corresponding to the silanol groups. The absorption bands at 1032.83 and 779.64 cm^{-1} attributed to the asymmetric and symmetric Si-O-Si stretching vibration, while the band at 467.19 cm^{-1} is assigned to the Si-O-Si bending mode [6]. The absorption band at 1641.38 cm^{-1} was caused by deformational vibrations of adsorbed water molecule. The band at 692.92 cm^{-1} due to vibration of Si–O band, implying the presence of quartz [7]. The band at 641.33 cm^{-1} assigned to Si–O–Al bending mode [8]. The band at 576.83 cm^{-1} assigned to O-Si-O deformation modes [9].

B. Compositions of the alkali extracted solutions

The measured Si, Al, and Na ion concentrations in the extracted solutions which are prepared from different weight ratios NaOH/slurry fusion products for leach time at 16 and 24 hours were listed in Table II. As can be seen from the obtained results, the highest Si and Al contents found in the extracted solution from NaOH/slurry ratio of 1. Moreover, the Si and Al contents in this solution increased by increasing leaching time. In addition, the lowest Si and Al contents found in the extracted solution from NaOH/slurry ratio of 1.5

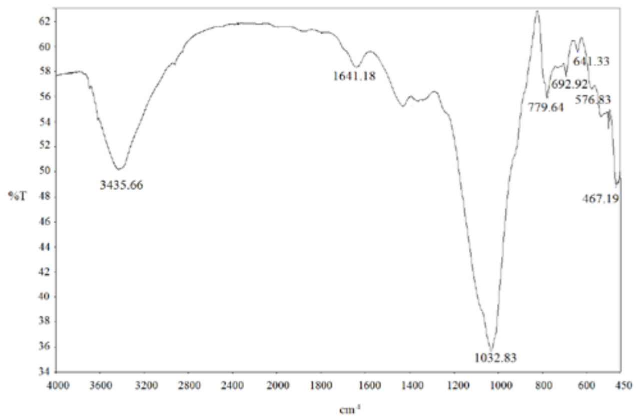

Fig. 3 FT-IR spectrum of the slurry

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TABLE II
THE ELEMENTAL CONCENTRATIONS OF DIFFERENT NAOH/SLURRY WEIGHT RATIOS OF EXTRACTED SOLUTIONS FOR DIFFERENT TIME

NaOH/slurry (g/g)	Leaching Time (hours)	Si (ppm)	Al (ppm)	Na (ppm)
0.8	16	24080	896	68741
	24	25445	972	69670
1	16	27790	1117	72758
	24	28330	1150	73102
1.5	16	20955	735	73835
	24	21350	787	74618

IV. CONCLUSION

Chemical composition has an important influence both on the potential application of slurry and on the environmental impact of its subsequent use. For this purpose, the sludge was characterized by different analysis techniques. According to XRD and XRF analyses, it is mainly composed of SiO_2. The Si in the slurry was activated by alkali fusion technique and the Si and Al content of fused solutions were determined by ICP-OES. The results show that the extracted solution from NaOH/slurry ratio of 1 has the highest Si and Al contents.

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