Asian Journal of Chemistry; *Vol. 24, No. 11 (2012), 5283-5285*

ASIAN JOURNAL OF CHEMISTRY

www.asianjournalofchemistry.co.in

A Novel Approach for the Removal of Impurities from Feldspar Ores

EROL KAYA[1], UFUK MALAYOGLU[1], ECE KILINC AKSAY[2] and IREM KURCAN[3]

[1]Department of Mining Engineering, Dokuz Eylul University, Buca, Izmir, Turkey
[2]Torbali Vocational School of Higher Education, Dokuz Eylul University, Torbali 35860, Izmir, Turkey
[3]Kalemaden Inc., Canakkale, Turkey

*Corresponding author: Fax: +90 232 4530868; Tel: +90 232 3017514; E-mail: erol.kaya@deu.edu.tr

(*Received*: 24 October 2011; *Accepted*: 16 June 2012) AJC-11616

The objective of this study was to bulk float the discoloured impurities from feldspar ores at alkali conditions compared to conventional treatment method where the impurities are removed from the ore in acidic conditions in two stages. Conventionally, the feldspar concentrate is produced by reverse multi-stage flotation of impurities such as micaceous and heavy minerals separately in an acidic medium in two-stages using two different collectors of amine and oleate types. This study showed that the impurities in three different feldspar ores, received from Aydin, Milas and Manisa, located in the western part of Turkey, were bulk floated successfully in an alkali medium, using a fatty acid based collector. With this novel approach, increased capacity, decreased collector and acid consumption, easy circuit control, lower unit cost were achieved. The results of bench scale flotation tests with this novel method were compared to conventional method and its applicability was discussed.

Key Words: Feldspar, Flotation, Fatty acids.

INTRODUCTION

Feldspar minerals are essentially aluminum silicates combined with varying percentage of potassium, sodium and calcium. The main feldspar minerals of albite and orthoclase are primarily used in various industrial applications such as glass and ceramics. Feldspar ores are usually associated with the impurities of micaceous minerals (muscovite and biotite), heavy minerals (iron oxide and titanium minerals of ilmenite, rutile and sphene) and silicate minerals (quartz, tourmaline, hornblende). These discolouring impurities reduce the revenue and quality of the concentrate and are generally removed from the feldspar by the use of reverse multi-stage flotation[1-6].

Fatty acids are the most common collectors used for the removal of coloured impurities from feldspar ores. The fatty acid collector is normally used in neutral and basic circuits with best effectiveness in most nonmetallic mineral circuits[7,8]. While albite has an isoelectric point (iep) of around 1.5, rutile is the major titanium mineral in albite and the reported isoelectric point of natural rutile varies from 3.5 to 5.5. Rutile can easily be floated with unsaturated fatty acids at pH 4-6 but the extend of floatability decreases depending on the fatty acids which contains oleic acid, linoleic acid and linolenic acid, respectively. The greater the number of double bonds in the hydrocarbon chain of a fatty acid, the lower the maximum value of pH at which rutile flotation is possible[9-17]. The adsorption mechanism of oleate on titanium minerals such as rutile is regarded as chemisorption with titanium[7]. The point of zero charge (pzc) of rutile is obtained at pH 6.7 but rutile flotation is determined to be more dependent on sodium-oleate concentration than that of pzc. At 10^{-6} M and 10^{-7} M sodium-oleate concentrations, rutile flotation is obtained below rutile pzc values, whereas higher concentration of sodium-oleate in rutile flotation is obtained at higher pH values above the pzc[11,18].

Conventionally, all finely disseminated minerals are removed from the ore by desliming first, then, micaceous minerals are floated by amine (cationic) collectors at pH of 3-5, followed by the flotation of iron and titanium bearing heavy minerals using sulfonates at pH of 2.5-3.0 and fatty acids at pH 4-6 and finally, feldspar-quartz separation is accomplished at pH of 2.0-2.5 with cationic amine collectors and hydrofloric acid[13,14]. The use of alkyl succunamate together with petroleum sulfonate, increases the success of flotation in the removal of heavy minerals[19-22]. Titanium minerals can also be floated with hydroxamates at pH 6.5, oleoyl sarcosine at pH 7.7 and potassium oleate at pH 7.7[1,6,18].

In this investigation, feldspar concentrates were produced from three different feldspar ores by a single-stage (bulk) reverse flotation of diccolouring impurities. A fatty acid based anionic collector was tested at alkaline medium to remove micaceous and heavy minerals from three different feldspar ores. The collector was received from Cytec Inc. under a name of Aero 704. It is a straight tall oil fatty acid promoter with varying acid values, rosin acid content and per cent fatty acid[23]. The results of single-stage flotation studies employed at alkali pH conditions using the fatty acid based collector were compared with the conventional two-stage flotation using amine and sodium oleate at acidic pH conditions.

EXPERIMENTAL

Feldspar ore samples used in the experiments were supplied from Aydin-Çine, Manisa-Demirci and Mugla-Milas regions, located in the western part of Turkey. The chemical composition of the samples is presented in Table-1. The chemical and microscopic analysis revealed that Cine and Milas ores contain mainly albite and Demirci ore contains primarily orthoclase with minor amounts of quartz, titanium minerals (rutile and minor amounts of sphene), iron oxide minerals and small quantities of mica minerals (muscovite and biotite) and weathered clay minerals.

Conventional flotation tests were conducted with Armac T (amine) and oleic acid supplied by Merck, Germany. Alternative flotation tests were performed with fatty acid promoter, a mixture of various types of straight tall oil fatty acids and surfactants, supplied under the name of Aero 704 promoter by Cytec Industries Inc. (USA)[23]. The pH of the system was adjusted with H_2SO_4 and NaOH.

The feldspar ores were crushed to below 2 mm by a laboratory jaw and hammer crushers respectively and ground to below 300 μm by a porcelain ball mill. A closed system was operated with 5 min intervals to separate the ground 300 μm sieve size. Prior to flotation tests, the samples were deslimed at 45 μm with wet sieving. The amount of the material removed is about 10 % by weight. All the flotation tests were conducted on 300 ± 45 mm fractions with 500 g samples.

The impurities from the samples were removed by reverse flotation method, *i.e.*, mica and heavy minerals were floated. A 2 L, self-aerated Denver D12 flotation machine was used. Flotation tests were performed at 30 % solids, 40 min conditioning and 20 min flotation time. Collectors were added into the cell stage-wise. In flotation tests 20 g/t commercial pine oil was used as frother. All the flotation products (feed, slime, concentrate and tailings) were analyzed by XRF to determine the best performing collector.

With the conventional flotation method, mica is removed first at pH 2,5 adjusted by H_2SO_4 and using 300 g/tons of Armac T. Later, heavy minerals (titanium bearing minerals and iron oxides) were removed at pH 6, adjusted by NaOH using 2000 g/tons oleic acid for Cine ore and at pH 4 adjusted by H_2SO_4 using 550 g/tons Aero 801+Aero 825 (received from Cytec) for Demirci ore. Conventional tests were not performed for Milas ore.

With the alternative (novel) method, mica and heavy minerals were bulk floated at pHs of 7, 8 and 9 with varying amounts of Aero 704 collector for Cine and Milas ores. Demirci ore was tested at pH 9 only.

RESULTS AND DISCUSSION

The results of the conventional and alternative (novel) flotation tests are presented in Table-2 for Aydin Cine ore, in Table-3 for Manisa-Demirci ore and in Table-4 for Mugla-Milas ore. Conventional method applied to Cine ore gave a marketable feldspar product. Feldspar product marketing specifications are given in the last row of Table-2. Alternative method was tested for Cine feldspar ore at pH values of 7, 8 and 9 at a collector dosage of 1125 g/t. Varying collector dosages were used at pH 9 (Table-2). The best results were achieved at pH 9 and a collector dosage of 1125 g/t. Kalemaden Inc. (Turkey) started using the alternative method at their plant. They realized several advantages *i.e.*, reduced acid consumption, reduced unit cost because of the use of one collector, reduced frother use and increased capacity.

For Demirci ore, a marketable feldspar product was produced with both the conventional and alternative methods (Table-3). A marketable product was also produced with the alternative method using Aero 704 tested at pH 9 only, but at a slightly higher collector dosage of 1300 g/t compared to Cine ore. With this ore, a final feldspar concentrate was produced after feldspar-quartz separation at a reduced pH of 2.0-2.5 using amine collectors and hydrofluoric acid because the ore contained a substantial amount of quartz.

For Milas ore, the performance of Aero 704 collector was tested with various collector dosages at pH 9 and with 1000 g/t collector dosage at pHs of 7 and 9 (Table-4). The conventional method was not tested for this ore. The results were evaluated on the basis of TiO_2 and Fe_2O_3 grades in the albite concentrate and recoveries of the coloured impurities from the albite ore. Based on the bulk flotation results shown in Table-4, Aero 704 promoter exhibited the best performance at pH 9 with a collector dosage of 1000 g/t. The performance of Aero 704 has decreased slightly above the optimum dosage.

The results with three feldspar ores received from different regions showed that the reagent-ore interactions are not depend on the formation of the ore body, because all the samples gave the best performance at pH 9.

Conclusion

The objective of this study was to bulk float the discoloured impurities of micaceous and heavy minerals from the feldspar ores at alkali conditions compared to conventional treatment method where the impurities are removed in acidic conditions in two stages using two different collectors of amine and oleate types.

The results of bench flotation tests studies with the alternative (novel) method for the removal of micaceous and heavy

TABLE-1
CHEMICAL COMPOSITIONS (%) OF THE FELDSPAR ORES USED IN THIS STUDY

Region	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	Na_2O	K_2O
Aydin, Cine (Albite ore)	66.10	19.66	0.38	0.45	1.36	0.66	9.56	0.75
Manisa, Demirci (Orthoclase ore)	74.39	15.50	0.05	0.42	0.81	0.04	4.22	3.92
Mugla, Milas (Albite ore)	68.10	18.20	0.34	0.42	1.06	0.65	9.95	0.76

TABLE-2
FLOTATION TEST RESULTS FOR CINE ORE

Products (pH, collector dosage)	SiO_2 (%)	Al_2O_3 (%)	TiO_2 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	Na_2O (%)	K_2O (%)
Conventional flotation results								
Slime removal	61.4	22.35	0.29	0.65	1.55	0.99	9.72	0.71
Mica mid-product	60.3	22.33	0.36	0.07	1.65	1.01	9.75	0.61
Heavy mineral product (Concentrate)	61.1	23.01	0.06	0.07	1.61	0.98	10.04	0.55
Alternative (novel) flotation results								
Slime removal	60.1	23.33	0.32	0.68	1.47	1.01	9.61	0.74
Tailings pH 9, 1125g/t	50.9	21.15	3.34	1.66	4.07	4.64	6.88	2.42
Concentrate pH 9, 2700g/t	69.1	19.55	0.01	0.02	1.69	0.15	9.21	0.29
Concentrate pH 9, 2100g/t	68.8	19.45	0.02	0.04	1.79	0.21	9.30	0.37
Concentrate pH 9, 1500g/t	68.1	20.21	0.05	0.07	1.62	0.10	9.56	0.25
Concentrate pH 9, 1125g/t	**67.0**	**20.42**	**0.05**	**0.06**	**1.85**	**0.11**	**10.09**	**0.37**
Concentrate pH 9, 750g/t	68.0	19.65	0.08	0.10	1.70	0.09	10.05	0.35
Concentrate pH 8, 1125 g/t	67.4	20.57	0.06	0.08	1.73	0.15	9.87	0.26
Concentrate pH 7, 1125 g/t	67.9	19.95	0.06	0.09	1.83	0.18	9.70	0.25
Specifications	–	–	Max. 0.07	Max. 0.08	–	–	Min. 9.50	–

TABLE-3
FLOTATION TEST RESULTS FOR DEMIRCI ORE

Products	Assay (%)				Distribution (%)			
	TiO_2	Fe_2O_3	Na_2O	K_2O	TiO_2	Fe_2O_3	Na_2O	K_2O
Conventional flotation results								
Mica Concentrate	0.25	2.60	4.33	3.46	41.7	59.15	9.75	8.44
Heavy Mineral Concentrate	0.15	2.13	3.78	4.10	13.78	26.68	4.69	5.51
Feldspar - Quartz Concentrate	0.03	0.07	4.27	3.96	44.52	14.17	85.56	86.05
Alternative (novel) flotation results (tested at pH 9 only)								
Mica + Heavy Mineral Concentrate	0.23	2.40	1.55	0.90	69.15	87.86	5.92	3.69
Feldspar - Quartz Concentrate	0.02	0.07	4.80	4.58	30.85	12.14	94.08	96.31

TABLE-4
FLOTATION TEST RESULTS FOR MILAS ORE WITH ALTERNATIVE METHOD

pH	Collector dosage (g/t)	Concentrate grade (%)		Recovery (%)	
		TiO_2	Fe_2O_3	TiO_2	Fe_2O_3
7	1000	0.128	0.116	70	77
8	1000	0.096	0.080	78	84
9	800	0.134	0.080	67	84
	1000	0.070	0.042	85	91
	1200	0.084	0.065	81	86
	1400	0.088	0.070	80	85
10	1000	0.085	0.072	80	86

minerals from three different feldspar ores showed that the use of a fatty acid based promotor of Aero 704 was effective in the bulk removal of coloured impurities in an alkali pH conditions.

Based on the bulk flotation test results, Aero 704 promoter exhibited the best performance at pH 9 for all the three feldspar ores but at a varying collector dosages changing from 1000 g/t to 1300 g/t. The results showed that the reagent-ore interactions are not depend on the formation of the ore body. There are several advantages realized with the alternative novel method *i.e.*, reduced acid consumption, reduced unite cost because of the use of one collector, reduced frother use, easy control of operations due to a one-stage flotation system and increased capacity.

ACKNOWLEDGEMENTS

The authors thank Dokuz Eylul University, Scientific Research Projects (BAP) Coordination Council, for partially funding this research.

REFERENCES

1. M.S. Celik, B. Pehlivanoglu, A. Aslanbas and R. Asmatulu, *Miner. Metallurg. Proces.*, **18**, 101 (2001).
2. E.C. Orhan and I. Bayraktar, *Miner. Eng.*, **19**, 48 (2006).
3. I. Dogu and A.I. Arol, *Powder Technol.*, **139**, 258 (2004).
4. E.K. Aksay, A. Akar, E. Kaya and I. Cocen, *Asian J. Chem.*, **21**, 2263 (2009).
5. C. Karaguzel, I. Gulgonul, C. Demir, C. Cinar and M.S. Celik, *Int. J. Miner. Process.*, **81**, 122 (2006).
6. I. Kurcan, E. Kaya, I. Kececi, U. Malayoglu and A. Seyrankaya, 6th International Industrial Minerals Symposium, Izmir, Turkey, pp. 156-163 (2007).
7. M.S. Celik, I. Can and R.H. Eren, *Miner. Eng.*, **11**, 1201 (1998).
8. R.E. Baarson, C.L. Ray and H.B. Treweek, in ed.: D.W. Fuerstenau, Plant Practice in Nonmetallic Mineral Flotation, Froth Flotation, 50th Anniversary Volume, SME AIME, New York (1962).
9. Z. Sekulic, N. Canic, Z. Bartulovic and A. Dakovic, *Miner. Eng.*, **17**, 77 (2004).
10. E.K. Aksay, *Asian J. Chem.*, **20**, 3623 (2008).
11. I. Bayraktar, S. Ersayin and O.Y. Gulsoy, *Miner. Eng.*, **1**, 1363 (1997).
12. A. Vidyadhar, K.H. Rao and K.S.E. Forssberg, *J. Colloid. Interf. Sci.*, **248**, 19 (2002).
13. O. Bayat, V. Arslan and Y. Cebeci, *Miner. Eng.*, **19**, 98 (2006).
14. A.G. Parks, *Chem. Rev.*, **65**, 177 (1965).
15. Q. Liu and Y. Peng, *Miner. Eng.*, **12**, 1419 (1999).
16. M.C. Fuerstenau and B.R. Palmer, in ed: M.C. Fuerstenau, Anionic Flotation of Oxides and Silicates, Flotation, A.M. Gaudin Memorial Vol. 1, SME AIME, New York (1976).
17. G. Purcell and S.C. Sun, *Trans. AIME*, **254**, 13 (1963).
18. A. Akar, 5th International Mineral Processing Symposium, Cappadocia, Turkey, pp. 243-249 (1994).
19. A. Seyrankaya and A. Akar, 7th Balkan Conference on Mineral Processing, Romania, pp. 173-178 (1997).
20. G. Akar, A. Seyrankaya, E. Guler and A. Akar, 8th International Mineral Processing Symposium, Antalya, pp. 317-321 (2000).
21. O. Pavez and A.E.C. Peres, *Miner. Eng.*, **6**, 69 (1993).
22. A.C. Araujo, P.R.M. Viana and A.E.C. Peres, *Miner. Eng.*, **18**, 219 (2005).
23. Cytec Industries Inc., in ed.: A. Day, Flotation of Nonsulfide Ore, Mining Chemicals Handbook, USA (2002).