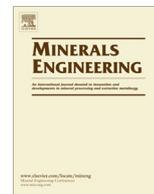




Contents lists available at ScienceDirect

Minerals Engineering

journal homepage: www.elsevier.com/locate/mineng

Flotation studies of monazite and dolomite

E.R.L. Espiritu, K.E. Waters*

Department of Mining and Materials Engineering, McGill University, 3610 University Street, Montreal, Quebec H3A 0C5, Canada

ARTICLE INFO

Article history:

Received 12 February 2016
Revised 7 February 2017
Accepted 21 February 2017
Available online xxx

Keywords:

Rare earth elements
Rare earth minerals
Flotation
Zeta potential
Monazite
Dolomite
Benzohydroxamic acid
Sodium oleate
Organic phosphoric acid
Phosphoric acid ester

ABSTRACT

Rare earth elements (REE) are key components of many emerging green technologies. This leads to an increase in demand for REE, hence to the development of new deposits, such as the Niobec carbonatite rare earth deposit in Quebec, Canada. One of the valuable minerals in this deposit is monazite, one of the primary sources of REE. Although there has already been previous research investigating monazite flotation, most of these are focused on monazite from heavy mineral deposits. Since minerals from different deposits may behave differently, it is important to investigate the flotation behavior of monazite from carbonatites as well. This work investigates the surface properties of monazite from carbonatite deposit through zeta potential analyses. Electrophoretic zeta potential measurements were conducted to identify the interaction of monazite and dolomite, a gangue mineral commonly associated with carbonatites, with different collectors (namely sodium oleate, organic phosphoric acid and benzohydroxamic acid). Floatability of the minerals were analyzed through microflotation tests, to obtain the potential conditions for effective separation. Zeta potential measurements of monazite and dolomite showed that the isoelectric point (IEP) for both minerals occur at a pH of approximately 5. Sodium oleate, benzohydroxamic acid and Flotisor 1682 (organic phosphoric acid) have been shown to adsorb on to monazite at pH 7. The results suggest that benzohydroxamic acid can be selective at neutral pH condition, sodium oleate can be potentially used in reverse flotation of monazite in acidic condition and Flotisor 1682 (organic phosphoric acid) can be a potential collector for monazite. However, the use of reagents such as activators and depressants is suggested to achieve a more selective separation.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

The rare earth elements (REE) consist of yttrium (Y) and the lanthanides, which can be further divided into light REE (La to Eu) and heavy REE (Gd to Lu, and Y) (Gupta and Krishnamurthy, 1992). Due to their unique chemical properties, they are regarded as essential components of emerging green technologies such as wind turbines, hybrid vehicles and storage batteries (Kara et al., 2010). This leads to an increase in demand for REE, hence the development of new deposits, such as the Niobec rare earth deposit in Quebec, Canada. This rare earth deposit, which is adjacent to their existing Niobium mine, is a carbonatite complex containing monazite as one of the valuable minerals.

Monazite (REPO_4), a RE phosphate, is one of the primary sources of light REE (Kamitani, 1991). The most significant sources of this mineral are heavy mineral sands (Gupta and Krishnamurthy, 1992). Monazite is usually beneficiated from heavy mineral sands using gravity, magnetic and electrostatic separation (Bulatovic,

2010). When the mineral grains are too fine for these methods, a more suitable beneficiation method such as flotation is employed (Bulatovic, 2010). Research studies have shown that flotation of monazite from heavy mineral sand deposit is possible using collectors such as: fatty acids; amines; sulfonates; and hydroxamates (Abeidu, 1972; Cheng et al., 1993; Cuthbertson, 1952; Houot et al., 1991; Pavez and Peres, 1993a, 1993b, 1994). Monazite can also occur as finely disseminated in carbonatites (Zaitsev et al., 1998); however, research work involving monazite from carbonatites are very limited (Chelgani et al., 2015; Jordens et al., 2013). The aim of this work is thus to examine the flotation behavior of monazite from this type of deposit.

In general, oxhydryl collectors (e.g., carboxylates, phosphoric acid esters and hydroxamates) have been the focus of rare earth mineral flotation studies due to their efficiency (Bulatovic, 2010; Zhang et al., 2013). These oxhydryl collectors have two oxygen atoms, which are responsible for bonding with metal cations. Carboxylates (e.g., fatty acids, oleates and tall oils) are the most widely used industrial collectors (Bulatovic, 2007b), however, they have poor selectivity towards rare earth minerals (REM) (Wills and Finch, 2016). Hydroxamates have caught the interest of many researchers due to their selectivity and efficiency. Various flotation

* Corresponding author.

E-mail addresses: eileen.espiritu@mail.mcgill.ca (E.R.L. Espiritu), kristian.waters@mcgill.ca (K.E. Waters).

studies demonstrated that this collector is more selective than carboxylates (Bulatovic, 2010; Houot et al., 1991; Pradip and Fuerstenau, 2013; Zhang et al., 2013), which is attributed to its formation of more stable chelates with rare earth cations than with alkaline earth cations (such as those found in the gangue minerals) (Fuerstenau, 2005). Another type of collector that has been investigated includes phosphoric acid esters (organic phosphoric acid). These have shown potential to be a REM collector (Ren et al., 2003). However, available literature with regards to the response of organic phosphoric acid with monazite is scarce (Chelgani et al., 2015). This study provides information on the flotation of monazite using this type of collector, in comparison to the conventional REM collectors – carboxylate and hydroxamate. Moreover, it will investigate the flotation response of dolomite (which is one of the major gangue minerals in the Niobec rare earth deposit), providing information on flotation conditions where separation from monazite are possible.

General classification of collector adsorption mechanisms is physisorption and chemisorption (Bulatovic, 2007a). If the adsorption involves forces such as electrostatic (Coulombic forces) or hydrophobic bonding, it is considered physical adsorption; however, if it involves covalent bonding, then it is chemisorption (Somasundaran and Moudgil, 1987). Fuerstenau and Urbina (1988) summarized the reactions involved in the flotation of sparingly soluble minerals (e.g., rare earth minerals, barite, calcite, apatite, and dolomite). These include: physical adsorption of the collector ions in the double layer; chemisorption in the Stern plane; surface formation of a more insoluble compound; chemisorption on hydrolyzed metal sites; surface reaction, dissolution of mineral and precipitation of metal-collector salt; and, auto-activation through surface dissolution, cation hydrolysis and re-adsorption of hydrolyzed ion. In addition, possible reactions between the metal ion and collector ions can also occur as surface precipitation and bulk precipitation. Surface precipitation happens when the reagent interacts with the surface “through movement of metal atoms from their lattice sites” while bulk precipitation of the metal reagent salts occurs when the dissolved lattice ions forms an insoluble compound with the collector away from the surface of the mineral (Chander and Fuerstenau, 1975). The reactions between the metal cations and the collector can be used to understand what is happening in the flotation system and as a guide in the improvement of flotation performance.

In this study, the surface properties of monazite (from carbonatite) and dolomite in the presence of Flotisor 1682 (organic phosphoric acid) were investigated through zeta potential measurements and microflotation tests. These were compared to the minerals' behavior in the presence of conventional REM collectors such as sodium oleate (carboxylate) and benzohydroxamic acid (hydroxamate). For a good introduction to zeta potentials and for the relevance to mineral flotation, the reader is referred to Hunter (1981) and Fuerstenau and Pradip (2005), respectively.

2. Experimental

2.1. Materials

Monazite from Eureka Farm 99 (carbonatite deposit) in Namibia was purchased from the Mineralogical Research Company (U.S.A.). Dolomite from Sterling Hill Mine in New Jersey, the gangue mineral investigated, was obtained from Ward's Science (U.S.A.).

Benzohydroxamic acid was purchased from Sigma-Aldrich (Canada), sodium oleate was obtained from Fischer Scientific Company (Canada) and Flotisor 1682 (organic phosphoric acid) was provided by Clariant (Canada). The frother (F150) was provided by Flottec (Canada).

The potassium chloride that was used as supporting electrolyte for zeta potential measurements was purchased from Sigma-Aldrich (Canada); while the hydrochloric acid and the potassium hydroxide that were used as pH modifiers, were purchased from Fisher Scientific (Canada).

2.2. Mineral purification

The purchased minerals were not pure, thus concentration steps (such as gravity and/or magnetic separation) were conducted prior to surface chemistry and flotation experiments. Since these methods are particle size dependent, mineral samples were first pulverized to 100% passing 212 μm and were divided into different size fractions ($-212 + 150 \mu\text{m}$, $-150 + 106 \mu\text{m}$, $-106 + 75 \mu\text{m}$, $-75 + 53 \mu\text{m}$, $-53 + 38 \mu\text{m}$ and $-38 \mu\text{m}$). All these size classes were processed using a Mozley MKII Laboratory Separator (Mozley, U. K.) separately. The heavy fraction was then further purified using a Frantz Isodynamic Separator (Frantz, U.S.A.) with a gradual increase in applied current (corresponding to increasing magnetic field). Since different minerals have different susceptibility to magnetic field, concentration can then be achieved.

2.3. Zeta potential measurements

Purified mineral samples were first pulverized using a Planetary Monomill Pulverisette (Fritsch, Germany) to obtain a particle size smaller than 10 μm . Solution of 1×10^{-3} M KCl was used as supporting electrolyte. The solution was pH adjusted using hydrochloric acid and potassium hydroxide prior to addition of the mineral particles. The suspension was then ultrasonicated for 180 s to ensure particle dispersion. Zeta potential measurements were then undertaken using a NanoBrook 90Plus Zeta Particle Size Analyzer (Brookhaven Instruments, U.S.A.).

2.4. Microflotation experiments

Microflotation tests were carried out using a modified Partridge-Smith cell (Partridge and Smith, 1971). The flotation volume of the cell is approximately 60 mL. The cell, made out of glass, has a porous silicate frit at the bottom; and a launder that receives the froth at the top. A magnetic stirring bar was employed to ensure that the minerals remained in suspension.

Mineral samples within the particle size range of $-106 + 38 \mu\text{m}$ were suspended in 40 mL reverse osmosis water (adjusted to desired pH). The pH of the suspension was maintained prior to addition of the collector, and throughout the 5 min of conditioning. The suspension was transferred to the microflotation cell and a further 20 mL of pH adjusted water was added. Then, 3 drops of 10 mg/mL F150 frother was added before air at a flowrate of 40 mL/min was bubbled through the cell. Flotation was conducted for 1 min.

3. Results

3.1. Mineral characterization

X-ray diffraction analyses of the mineral samples were conducted using Bruker D8 Discovery X-Ray Diffractometer (Cobalt source). The diffractograms of the samples before and after purification are presented in Fig. 1. The quantity of the minerals in the sample were analyzed using the Rietveld method. The results indicated that each mineral contains around 94% monazite and 99% dolomite, respectively.

Download English Version:

<https://daneshyari.com/en/article/6672635>

Download Persian Version:

<https://daneshyari.com/article/6672635>

[Daneshyari.com](https://daneshyari.com)