Study of the Flotation behaviour mechanisms of quartz and K-feldspar using Biodegradable chemicals

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Abstract

This study explores the absorption mechanisms of quartz and K-feldspar using DR2200, a biodegradable polymer collector designed for the reverse flotation separation of quartz from K-feldspar. The flotation behaviour and surface interactions were analysed through single mineral flotation tests, Fourier-transform infrared spectroscopy (FTIR), Atomic force microscopy (AFM), and contact angle measurements. Quartz exhibited poor floatability with DR4000, while DR2200 demonstrated pH and concentration-dependent flotation efficiency. FTIR analysis shows that DR2200 has a higher adsorption affinity for quartz. These findings were further validated through batch flotation experiments. Thus, DR2200 proves to be a viable option for the quartz flotation while depressing K-feldspar; DR2200 could be used as a quartz flotation while depressing K-feldspar. Overall, the results suggest that DR2200 is a promising eco-friendly alternative to traditional collectors, providing a sustainable solution for the selective mineral separation in flotation processes.

Introduction

Quartz, a vital raw material in high-tech industries like photovoltaic and semiconductor microelectronics, is one of the most common bulk silicate rock-forming minerals found in nature, often alongside many other minerals. Flotation is a standard method for quartz recovery. Currently, two main flotation processes are employed to extract quartz: the direct flotation process using a cationic collector (such as quaternary ammonium salts, fatty amines, ether amines, etc.) and the metal ion-activated flotation process (using ions like Ca2+, Cu2+, Pb2+, Mg2+, Fe3+, etc.) with an anionic collector (such as sodium alkyl sulfonate, NaOL, and sodium alkyl sulfate).

The success of the process relies on surface interactions between mineral particles and flotation reagents. Developing environmentally friendly alternatives is vital to improve flotation efficiency and selectivity. These reagents adsorb onto quartz surfaces at specific pH levels, making the mineral hydrophobic so it can attach to air bubbles. However, traditional chemical reagents often come with high costs and environmental concerns. Using biodegradable chemicals provides alternative solutions that selectively modify mineral surface properties to promote or inhibit flotation. These technical findings indicate that this new biochemical could be the most effective option for increasing the purity of silicon production by removing pure quartz in neutral pH conditions, aiding in the separation of quartz and K-feldspar from artificial mixed material samples. Anionic/cationic mixed surfactants have recently gained significant interest from researchers because of their crucial role in the flotation separation of quartz and other minerals. Although several studies have been published on the wettability and flotation of quartz using cationic and anionic surfactants, most of these research efforts have focused on separating other valuable minerals from quartz but have not investigated the

Learned from the flotation separation of K feldspar from quartz that the presence of DR2200 enhances the surfactant ability of anionic surfactants on K feldspar. In flotation systems, the influence of biochemical factors has been the focus and challenge of research. Researchers have directed attention to studying the flotation mechanism of biochemical interactions with activated quartz and K feldspar.

Materials and methods

Materials

This study used Jordi Pond's quartz and Vicar SA Feldspar pure samples (Spain). Before flotation experiments, the materials were crushed, screened, and ground. They used a size range of 53–200 μm.

Table 1. Main chemical components of the quartz and feldspar samples (mass %).

Oxide	**Quartz**	**Kfs**
SiO2	95.33	64.62
Al2O3	2.82	17.35
TiO2	0.04	-
Fe2O3	0.14	0.10
MgO	0.10	0.02
CaO	0.25	0.21
Na2O	0.51	2.60
K2O	0.70	15.00

Reagents

DR2200 and DR4000 1% were used in concentrated form, and pure pine oil was used in a concentrated state. An Outotec and Larmann automated cell was used to examine flotation behavior.

Characterization

The particle size analyzer utilized was a Horiba. XRF was employed to analyze the chemical composition of the sample (Portable Malvern Analytical, Spain). An X-ray powder diffractometer (Bruker, Spain) was used to scan the XRD pattern of the sample. The contact angle of the sample was measured with a contact angle goniometer (Terrasa, Spain). The zeta potential was determined using the Litesizer DLS500 from Anton Paar, Spain. The surface functional groups of the samples were characterized by a Nicolet iS 10 Fourier Transform Infrared Spectrometer (FTIR) from PerkinElmer, Germany. AFM analysis (a Bruker MultiMode 8 AFM) described the surface morphology by measuring the interaction force between the probe and the sample, commonly used to detect mineral absorption with flotation reagents.

Result and discussion

zeta potential

zeta potential	after flotation value
DR 2200 qtz f 1	0.00014
DR 2200 qtz f 1	0.0035

Zeta potential behavior reflects a +ve value with flotation chemical treatment, although the samples initially have a negative value.

AFM

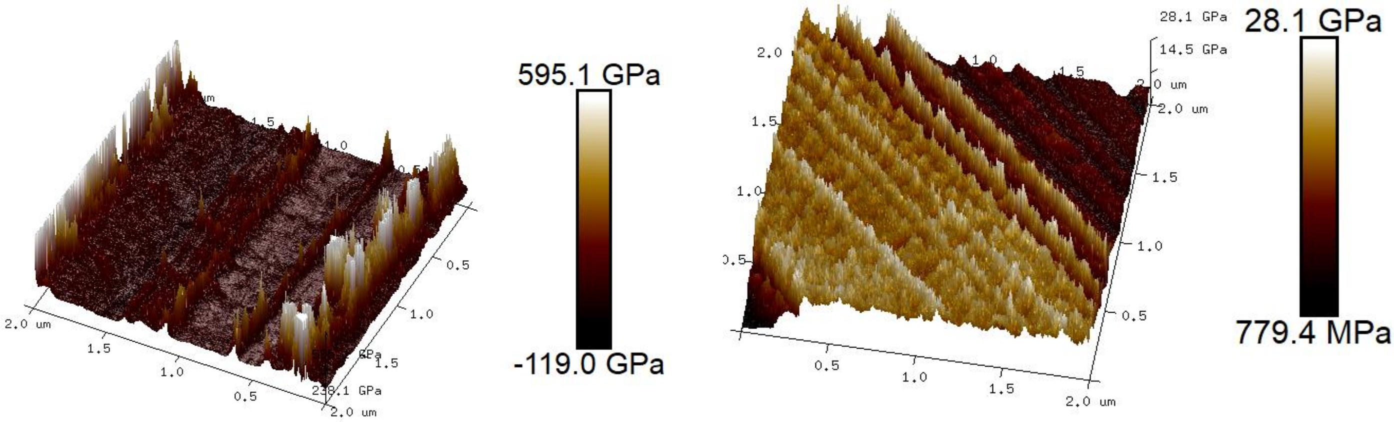

Figure 1. AFM images of the surface of (a) quartz, (b) Kfeldspar,

Atomic Force Microscopy (AFM) images of pure quartz and K-feldspar are essential for understanding their surface properties related to selective flotation. AFM provides high-resolution visualization of surface topography, roughness, and chemical heterogeneity at the nanoscale, which directly affect the adsorption of flotation reagents such as collectors and activators. In flotation, separating quartz from feldspar is difficult because of their similar surface characteristics; however, AFM can detect subtle differences in surface structure and reactivity. For instance, feldspar surfaces may show more heterogeneous or reactive sites that encourage the selective adsorption of reagents like fluoride ions, aiding flotation separation. These insights assist in optimizing reagent choice and conditioning strategies to enhance mineral recovery and purity in industrial applications.

Quartz and Feldspar concentrates were analysed Larmann flotation cell. The grade-recovery curves of quartz and feldspar data are demonstrated. The biodegradable surfactant, DR2200, was first used as a collector for the separation of the K-feldspar and quartz. Flotation experiments indicated that the flotation performance of the DR2200 on the K feldspar and quartz was extremely different. At the 703g/t DR2200 in the natural pulp pH, the recovery of the feldspar was 80%. The optimal separation indexes of the concentrate were obtained with the natural pulp pH (about 7.2) and the 700g/t DR2200 as the collector, and the K feldspar recovery and grade were 75% respectively. The flotation tests indicated that the DR2200 had good selectivity and great potential as an effective collector in the flotation desilication process of K feldspar. The contact angle measurements showed that the DR2200 could selectively adsorb on the k feldspar surface to enhance its surface hydrophobicity. The AFM analysis also confirmed that DR2200 could selectively adsorb on the quartz surface rather than the K feldspar surface to improve the interface difference between them. The results of the FTIR analyses indicated that the element on the quartz surface participated in the adsorption process between the DR2200 and the quartz surface, and the DR2200 selectively adsorbed on the surface of the quartz mainly through electrostatic interaction and hydrogen bonding.

As shown in this study, the new concept could be used to produce a pure feldspar concentrate and could be especially valuable at a particular dosage to remove the last traces of quartz from the product.

FTIR

The chemical reagent DR2200, (composed of cationic polyacrylamide with a cationic charge density of 4 mol%), exhibits several characteristic FTIR bands. A broad signal between 3500 and 3200 cm^{-1} is observed, corresponding to the stretching vibrations of N–H (amines) and/or O–H groups, possibly due to residual water or hydrogen bonding. A distinct peak at approximately 2900 cm^{-1} is attributed to aliphatic C–H stretching. The band near 1640 cm^{-1} can be assigned to the C=O group (amide I), while the peak at 1460 cm^{-1} is associated with C–N or CH_2 deformations. Additionally, a strong absorption band is present in the 1100–1200 cm^{-1} region, likely corresponding to C–N or C–O stretching vibrations, or to skeletal vibrations of the polymer backbone.

This set of functional groups enables various types of interactions with quartz. Firstly, quartz surfaces under neutral to slightly basic pH conditions are typically negatively charged due to deprotonated $Si–O^-$ groups, which favor electrostatic attraction with the cationic sites of DR2200. Furthermore, the N–H and C=O groups in the polymer may form hydrogen bonds with Si–OH groups on the quartz surface. These interactions can contribute to the stabilization of adsorption of the polymer onto the mineral.

observations

This study demonstrates a high flotation separation selectivity between quartz and different types of K feldspar with neutral pH.

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