minerals

Editorial

Editorial for Special Issue "Advances on Fine Particles and Bubbles Flotation"

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The froth-flotation process allows for the separation of solid particles according to differences in their physical and surface-chemistry properties. It is the most efficient and cost-effective separation process for particles within a narrow size range, especially that of minerals ranging from 10 to 100 μm. Since recent advances made in grinding, allowing for low-grade mineral deposits to be economically exploited, the flotation of fine particles (−10 μm) has become increasingly relevant. The recovery of fine particles by flotation is dependent on bubble–particle collisions, the probability of which decreases with both decreasing particle size and increasing the probability of detachment [1–5] and increases with increased particle size and decreasing bubble size. Currently, the most popular practice in froth floatation is particle collection via air bubbles [6,7], though it has been proven that nanobubbles can be used to improve the fine-particle flotation effect [8,9]. Many studies have also aimed to solve the fine-particle flotation problem by exploiting microbubble flotation equipment; for instance, the Reflux™ Flotation Cell was used to recover and clean fine hydrophobic particles, resulting in the stripping of fewer hydrophobic particles [10–13]. Further, it is well known that nanobubbles, referring to bubbles measuring only a few hundred nanometers wide, can extend the lower particle-size limits for the effective flotation of coal, phosphate, iron ore, and a number of other typical oxidized minerals [14–18]. With a wealth of research experience in microbubble-enhanced fine-particle flotation, the author is dedicated to demonstrating how nanobubbles offer an effective means of enhancing fine-particle flotation recovery, making it a subject of significant interest.

Thus, this Special Issue focuses on recent advances in fine particles and bubble flotation that are worth further study and application. Meanwhile, this collection provides guidance for those engaged in research on fine flotation, featuring studies including, but not limited to, the following topics: fine-particle flotation, microbubble flotation, nanobubble flotation, particle–bubble interaction, particle–bubble collision and adhesion, particle–bubble interface science, the aggregation of fine particle and bubbles, and the dynamic study of fine particles and bubble flotation systems. This Special Issue aims to contribute to the development of efficient and cost-effective fine-particle-enhanced flotation technologies for fine and ultrafine particles in the field of froth flotation.

One of the problems involved in fine-particle flotation is fine-gangue entrainment [9]. Mei et al. [19] studied the efficient separation of ultrafine coal using polyvinylpyrrolidone (PVP) as a regulator. They found that the addition of PVP improved the combustible recovery of clean coal and decreased the ash content, and that this effect was also presented by the selectivity index. Their study also revealed that the electrokinetic potential of minerals was sensitive to varying PVP concentrations, while the particle-size distribution and surface elemental compositions were also influenced by PVP. The findings of this research expand our understanding of the role of PVP as a regulator and provide a basis for the efficient separation of ultrafine coal.

The method of increasing mineral particle size is mostly used to solve problems associated with fine particles. Ming et al. [20] studied the sedimentation of fine arsenopyrite

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with polyethyleneimine (PEI), a flocculant, and attempted to enhance fine-particle flotation by increasing its apparent size. They found that at approximately pH 7.5, after the addition of PEI-2, its recovery could be increased to 90%, while the maximum (D 100) and median (D 50) particle size of the arsenopyrite increased from 20 and 11 μm to 48 and 28 μm, respectively. The adsorption of PEI-2 on the arsenopyrite surface was caused by the chemisorption between the imino group and the active Fe/As sites. Applying PEI-2 to a fine disseminated arsenopyrite-type gold ore, a concentrate containing 36 g/t Au with a Au recovery of 88% could be obtained. Additionally, Guo et al. [21] studied the flocculation behavior of ultrafine silica particles in acid-leaching pulp using nonionic polymeric flocculants, finding that the tannic acid promotes the bridging flocculation of polyethylene oxide-quartz by forming associative complexes with larger clusters in solution, while montmorillonite electrostatically adsorbs on the quartz surface, enhancing its bridging with polyacrylamide. The low turbidity benefited from the higher shear resistance of the compact flocs structure, provided by polyethylene oxide/polyethylene oxide + tannic acid/polyacrylamide + montmorillonite. An efficient solid–liquid separation was achieved by using the synergistic flocculation of small molecule cofactors and polymer flocculants.

In the fine-particle separation process, the particle sizes of target and gangue minerals may be different, despite the lack of research on the flotation separation of two minerals with different particle sizes. Therefore, it is essential to further research fine-particle separations of gangue with different particle sizes. In Zhang et al.'s article [22], −10 μm rutile and −30 μm garnet particles were selected as samples. The authors proved that BHA and SPA changed the chemical environment of rutile but not garnet, and that SSF slightly affects the environment in which BHA and SPA interact with rutile. However, various reagents and reagent combinations have little effect on the surface-chemical environment of garnet, providing a certain basis for the flotation separation of fine rutile and garnet. In the future, in addition to flotation reagents, the separation of the two can also be studied in detail in terms of particle size. Otherwise, because of crystals' anisotropy, the exposed crystal-surface types of fine minerals are also important factors affecting fine-particle flotation. Moreover, as muscovite has a typical dioctahedral crystal structure, the atoms arranged in different directions of its crystal lattice cause the anisotropy of the physical and chemical properties of its crystal planes, leading to the anisotropy of these crystal planes in flotation. Ren et al. [23] studied the adsorption difference of octadecylamine on (002) and (131) crystal planes of fine muscovite, finding that (002) crystal planes have a higher surface energy and are more easily exposed than that of (131). Further, compared to Si–O bonds, Al–O bonds in muscovite had lower covalent-bond compositions and were easier to break, while O atoms acted as active sites in the flotation of muscovite, and the (131) crystal plane was more likely to adsorb with ODA than the (002) crystal plane. These results suggest that flotation efficiency can be improved by exposing more (131) crystal planes in the grinding stage.

In recent years, most studies in this area have been designed to determine the optimum conditions for the flotation of very fine minerals. For instance, Batjargal et al. [24] studied the "Frothing Performance of Frother-Collector Mixtures as Determined by Dynamic Foam Analyzer and Its Implications in Flotation", finding that the effects of frother type and concentration play a particularly significant role in optimizing the flotation conditions, alongside parameters such as particle size, morphology, and pH. Therefore, one of the most important issues to address for flotation is the effect of froth stability. Additionally, it has been found that bubble sizes become finer even at low concentrations of PPG600 and PPG400 frothers, while a significant decreases in bubble size have been found for collector–frother mixture systems, regardless of the concentration of the frother.

At present, scholars mainly study the relationship between nanobubbles and useful minerals, often ignoring the influence of bubbles on fine gangue minerals. In real-life applications, particles of the fine gangue mineral often enter foam products via bubbles, significantly affecting the quality of the concentrate. Lu et al. [25] studied the role of nanobubbles in the flotation behavior of hydrophilic serpentine. They found that the nanobubbles were stable, with no change in size and only a slight decrease in number as the resting time increased. When nanobubbles were introduced into a serpentine flotation, the presence of nanobubbles significantly reduced the flotation recovery of serpentine and reduced the froth entrainment rate of microfine-grained serpentine, which in turn reduced its flotation rate. In the depressant group trials, the nanobubbles also reduced the amount of depressant. In short, the presence of nanobubbles can prevent the floating of fine hydrophilic gangues during flotation.

Furthermore, process optimization, reagent development, and particle-size control are all important aspect for minimizing problems relating to fine-particles. Wang et al. [26] proposed using a scrubbing–desliming and flotation process to enrich vanadium, nickel, and molybdenum, and in a study obtained Vanadium–molybdenum-rich sludge and nickel-containing tailings products. The V_2O_5 and molybdenum grades in the sludge were 4.10% and 0.44%, respectively, and the recovery levels were 41.31% and 51.40%, respectively, while the nickel grade in the tailings was 1.49%. These products were roasted and leached. The vanadium, nickel, and molybdenum in the stone coal were effectively recovered through the beneficiation–metallurgy combination process, and the comprehensive utilization rate of the stone coal was improved. Wang et al.'s [27] study proved that sodium silicate (SS) can effectively improve the flotation-separation effect of bastnaesite and fluorite in salicylhydroxamic acid (SHA) systems. SS had a strong binding effect with the Ca site on the fluorite surface but a weak binding effect with the Ce site on the bastnaesite surface. In turn, SS can be used as an effective depressant in the flotation separation of fluorite and bastnaesite.

Mineral particle size is an important parameter in the mineral-beneficiation process. In industrial processes, the grinding process produces pulp with a qualified particle size for subsequent flotation processes. In this Special Issue, a hierarchical intelligent control method for mineral particle size based on machine learning is proposed by Zou et al. [28]. They present the method's practical application in the SAB-production process of an international mine to demonstrate its automation and intelligence, where the process throughput is increased by 6.05%, the power consumption is reduced by 7.25%, and the annual economic benefit is significantly improved.

Conflicts of Interest: The author declares no conflicts of interest.

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