Powder Technology 309 (2017) 61–67

Contents lists available at ScienceDirect

Powder Technology

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

Electrophoretic mobility study for heterocoagulation of montmorillonite with fluorite in aqueous solutions

Tianxing Chen, Yunliang Zhao, Shaoxian Song *

School of Resources and Environmental Engineering, Wuhan University of Technology, Luoshi Road 122, Wuhan, Hubei 430070, China
Hubei Provincial Collaborative Innovation Center for High Efficient Utilization of Vanadium Resources, Wuhan University of Technology, Luoshi Road 122, Wuhan, Hubei 430070, China
Hubei Key Laboratory of Mineral Resources Processing and Environment, Wuhan University of Technology, Luoshi Road 122, Wuhan, Hubei 430070, China

ARTICLE INFO

Article history:
Received 24 September 2016
Received in revised form 24 December 2016
Accepted 29 December 2016
Available online 31 December 2016

Keywords:
Electrophoretic mobility distribution
Heterocoagulation
Montmorillonite
Fluorite

ABSTRACT

In this work, the heterocoagulation of fine montmorillonite (MMT) and fluorite particles in aqueous suspensions was investigated through the measurement of electrophoretic mobility distributions. The experimental results have shown that the heterocoagulation closely correlated to the electrophoretic mobility distribution of the mixed mineral dispersion. If a strong heterocoagulation happened, a single-modal electrophoretic mobility distribution with only one peak could be determined, and the peak located between the peaks of the two individual minerals. Without heterocoagulation, a bimodal electrophoretic mobility distribution with two peaks could be observed, which was consistent with the peaks of the two individual minerals. It is demonstrated that the heterocoagulation of two mineral fines in aqueous suspensions could be predicted by the electrophoretic mobility distribution of the mixed mineral dispersion.

1. Introduction

The coagulation of poly-dispersed particles, which is also termed as heterocoagulation, actually occurs in a broad range of applications. This situation is associated with the fact that heterocoagulation exhibits more complicated behavior and thus is more difficult to study through modeling. In this regard, as a relatively simple example, the heterocoagulation of two differently sized colloidal particles has received significant attention [1]. Heterocoagulation is an important step in many solid-liquid separation processes and is widely used in water and wastewater treatment [2,3]. Common processes such as filtration and sedimentation become more effective as the size of the particles is increased substantially by causing them to form aggregates. In mineral flotation process, the heterocoagulation of valuable and invaluable minerals is extremely detrimental to the separation between them, because the formation of the heterocoagulates would lead to the reduction of concentrate grade and recovery no matter if the heterocoagulates enter into the concentrates or tailings [4–6].

The significant impact of fine clays presented in the slurry on minerals processing has been recognized both in the industrial operations and in laboratory tests [7–10]. The diverse characteristics of clay can induce the production of a large amount of colloidal particles and cause a wide range of different problems in mineral beneficiation circuits. For example, fine clay particles, which usually have a negative surface charge, are attracted to positively charged larger fluorite particles in the fluorite flotation. And the sedimentation rate of fine clay particles was found to be significantly slow due to the effective dispersion of the fine clay particles when lignosulfonate was used resulting in a high-turbidity of recycled water in the flotation circuit [11]. Therefore, the desliming process is usually applied to remove the ultrafine particle fraction before flotation. It is necessary to use an ideal and well-controlled experimental system to study the heterocoagulation of clay mineral with other minerals in aqueous solutions.

Many researchers have studied the heterocoagulation through different means. Using an atomic force microscope (AFM), Liu et al. [2] found that calcium ions could depress the long-range repulsion and increase the adhesion between silica and bitumen in prepared solutions. Maroto and Nieves [12] studied the colloidal stability of aqueous dispersions of uniform spherical cationic and anionic particles by turbidity measurements in homocoagulation and heterocoagulation processes. Unlike the heterocoagulation interpret the stability of colloidal dispersions consisting of more than one kind of particle, the homocoagulation only include one kind of particle. Stephen et al. [13] described a new thin-film, freeze-drying/scanning electron microscopy technique for directly observing the adsorption of small colloidal particles onto larger colloidal particles of opposite charge.

In this study, an attempt has been made to investigate heterocoagulation of montmorillonite with fluorite in aqueous solutions through electrophoretic mobility distribution measurement. The objective is to establish the relationship between heterocoagulation and electrokinetic characteristics of montmorillonite with fluorite particles in

* Corresponding author.
E-mail address: shaoxian@uaslp.mx (S. Song).

http://dx.doi.org/10.1016/j.powtec.2016.12.086
0032-5910/

aqueous solutions, in order to obtain more understandings of the stability of the binary colloidal dispersions.

2. Experimental

2.1. Materials

The original MMT used in the present study was obtained from Sanding Technology Co., Ltd., Zhejiang province, China. A common method for obtaining purified colloidal MMT is fractionation by sedimentation after removal of carbonates, oxides, and organic materials and smashed by the ultrasonic grinder. Fig. 1 gave the X-ray diffraction (XRD) image of the sample, showing that the colloidal MMT particles were very high grade and contained negligible impurities.

The samples of fluorite (CaF_2) were high-grade mineral obtained from Yunfeng (Jiangxi, China). The stochiometric composition of fluorite is 97.05% CaF_2, 1.27% $CaCO_3$, 1.51% $BaSO_4$ and the chemical analysis indicated that the sample contained a small amount of impurities. Fig. 2 gave the X-ray diffraction (XRD) image of the fluorite. Sodium hydroxide (NaOH) and hydrochloric acid (HCl) for adjusting pH were from the Sinopharm Chemical Reagent Co., Ltd., (China). All of them were of analytical purity. The water used in this work was produced using a Millipore Milli-Q Direct 8/16 water purification system with 18.2 MΩ.

2.2. Measurements

The particle size distribution of the fluorite and MMT were estimated by light scattering, using a Malvern Mastersizer 2000. Sample aliquots were placed in an ultrasonic bath for 1 min before measurement. As shown in Fig. 3, the fluorite particle size at 50% cumulative undersize (D_{50}) and the particle size at 80% cumulative undersize (D_{80}) were of 6.5 μm and 11 μm, respectively. And the MMT sample at 50% cumulative undersize (D_{50}) and the particle size at 80% cumulative undersize (D_{80}) were of 0.8 μm and 1.4 μm, respectively.

The sedimentation rate was evaluated from the changes in turbidity with time in a Turb 555 IR nephelometer. The nephelometer is connected to a computer which collects the data.

A Malvern Zetasizer Zeta-Nano was used to determine the electrophoretic mobility of the MMT and fluorite in aqueous solutions. This instrument works with the technique of laser doppler electrophoresis. In the case of a binary fluorite–MMT mixture suspension, the prepared fluorite and MMT suspension were mixed at a specified ratio and conditioned in an ultrasonic bath for about 15 min before electrophoretic mobility measurements. This procedure ensures identical solution chemistry conditions as those used in the measurement with individual components while maintaining a suitable particle concentration for the measurement, which facilitates the interpretation of the results. Then, the suspension was poured into the measuring cell of zeta meter. The temperature was kept at 25 ± 1 °C throughout the measurement. Every individual measurements can get the distribution of electrophoretic mobility. And the average value that calculated from 10 individual measurements was reported in this paper. All the measurements were performed with 1 mM KCl background electrolyte concentration.

The fluorite samples for particle size distribution, turbidity and electrophoretic mobility measurements are just the same. The fluorite suspension (50 mL, 1 g/L) diluted in the corresponding KCl electrolyte concentration (1 mM) was placed in a beaker. After sediment for 15 min, the sample suspension was then introduced in the cell for the measurements. In the case of a binary MMT–fluorite mixture suspension, the MMT and fluorite samples were mixed at a specified ratio and conditioned in an ultrasonic bath for about 15 min before zeta potential measurements. This procedure ensures the number concentration of the two kinds of particles is almost same, which facilitates the interpretation of the results.

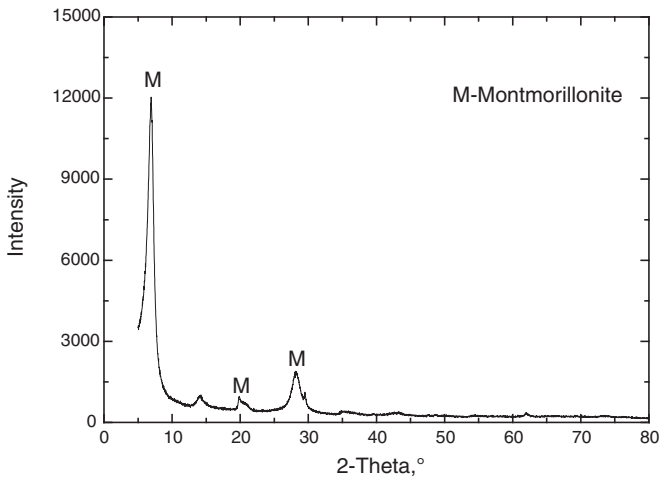

Fig. 1. XRD trace of the MMT.

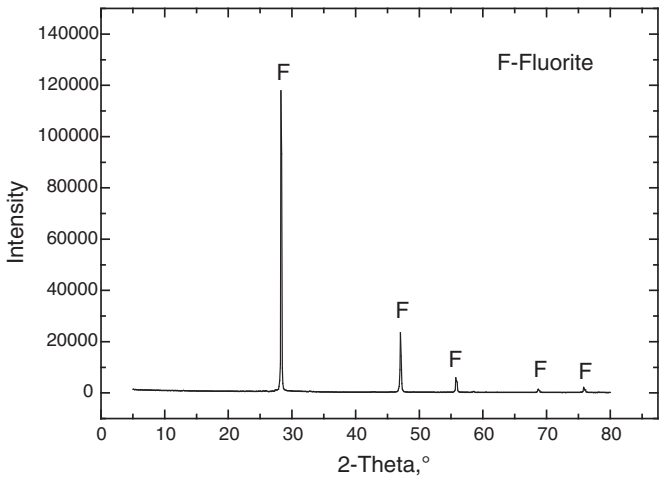

Fig. 2. XRD trace of the fluorite.

3. Results and discussions

To optimize the conditions for further study, the average zeta potentials for the two components of interest (fluorite and MMT) were first measured. The effect of solution pH on the zeta potentials of fluorite and MMT suspensions prepared in a 1 mM KCl solution is shown in

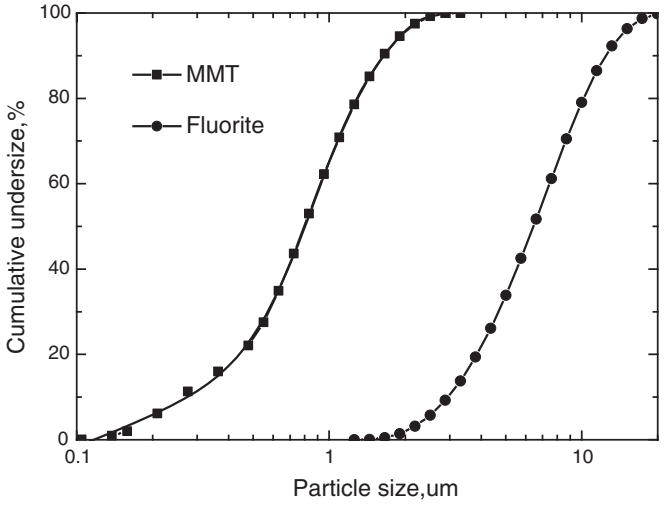

Fig. 3. Particle size distribution of the samples of fluorite and MMT.