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Contact Angle Measurement of Magnesite Mineral in Alkaline pH by Using the Simple Bubble Attachment Method

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Abstract: Contact angle is one of the most important parameters for the flotation process. Researchers have performed many experiments and used many different methods to determine the contact angle. In this present study, simple bubble attachment method (SBA), which was firstly utilized by Hunning and Rutter (1989), was used to determine the contact angle of magnesite mineral in the presence of various amount of collector such as oleic acid, R801, R845, sodium dodecyl sulphate and sodium oleat. According to the results of SBA, the highest degree of contact angle was obtained as 82° at the presence of oleic acid. The results of the study show that SBA method seems like a cheap and beneficial method for contact angle measurement.

Keywords: Contact angle measurement, simple bubble attachment method, flotation.

Introduction

Flotation is a physicochemical process that is used for separation of finely grained and low grade valuable minerals from its gangue. Flotation is used for beneficiation of metallic and non-metallic minerals and coal, removal of ink from the recycled paper, and environmental application. The success of flotation process depends on chemical and operational parameters such as particle size, bubble size, turbulence, hold up and hydrophobicity. Therefore, one of the most important parameters which have to be measured correctly is contact angle which is one of the indicators for hydrophobicity of mineral surface.

In the literature, there are many contact angle measurement techniques which can be classified in two categories. These categories are measurement on flat surface and measurement on non-ideal surface (Chau, 1999). The measurement on flat surface is carried out by the use of so called sessile drop (Hunter, 2001), captive bubble (Taggart et al., 1930), adsa-p (Axisymmetric drop shape analysis-profile) (Rotenberg et al., 1983), Wilhelmy plate (Wilhelmy, 1863), capillary rise (Chau, 1999) and confocal microscopy (Ralston et al., 1999) techniques. On the other hand, the contact angle measurement techniques on non-ideal surfaces are adsa-d (axisymmetric drop shape analysis-diameter) (Chau, 1999), capillary penetration (Diggins and Ralston, 1993), thin layer wicking (Chibowski, 1992), single bubble hollimond tube (Drzymala, 1994, Kowalczuk and Drzymala, 2011) methods. In addition to this, Drzymala (2007) briefly explained contact angle measurement types in his book. Drzymala improved flotometry for determining contact angle (Drzymala and Lekki, 1989).

The most widely used contact angle measurement method is sessile drop, which is applied for all kinds of pure minerals having polished surface as Bigelow et al. (1946), and was initially used in the. This optical method has some advantages in terms of simplicity and the necessity of only small surface of material (a few millimeters length and width). On the other hand, there are two main problems with the sessile drop method. One of them is about easy contamination due to small size of particles, while the second risk is about consistency of the researcher in the calculation of tangent line. Another disadvantage of the method is the necessity of equipment which are relatively expensive. Therefore, a simple and cheap method is necessary to determine the contact angle of the samples, and the simple bubble attachment method, which was used initially by Hunning and Rutter (1989), can be a useful tool.

Magnesite is one of the important sources for refractory industry. Because of the small liberation size of the present magnesite minerals from its gangue in Kutahya-Turkey, flotation remains a good alternative to beneficiation of magnesite. Generally, metallic gangue minerals are removed from the magnesite by the use of magnetic separation. But specifically, other fine grained gangue mineral such as quartz and dolomite are removed by flotation. There are many studies about magnesite flotation carried out by Gence and Özdağ (1995), Drzymala (1995), Santana and Peres (2001), Chen and Tao (2004), Gence (2006), etc. Gence (2006) determined the contact angle of magnesite in sodium oleat as 79° by using the sessile drop method but there are not many studies about determination of contact angle of magnesite.

In this study, contact angle of magnesite mineral in various collector solution has been determined by the use of simple bubble attachment method. Thus, different types of collector solutions were subjected to the simple bubble attachment method to determine the contact angle of magnesite ore for the first time.

Material and Methods

The sample used in the study was obtained from Kutahya Region. The high purity of natural crystals of magnesite was used for contact angle measurements. The chemical composition of these crystals includes 48.74% MgO, 0.28% SiO_2, 0.16% Fe_2O_3, and 0.03% Al_2O_3 etc.

In this study, three different types of collectors were used in the experiments. These collectors are oleic acid, R801 (petroleum sulphonate) and R845 (petroleum sulphonate) which were coded by Cytec Co. All measurements were carried out in pH 10 to provide a buffer solution.

The zeta potential of the sample was determined by using the Zeta 3.0+ meter.

The selected pure magnesite crystals were crushed and classified by using laboratory type screens having the size -4+2 mm,-2+1 mm and -1+0.5 mm. Ten pieces of particles from each size group separately put onto the surface of the silica porous plate of the test were set up which contains shott funnel and silica porous plate (Fig. 1). Solution (water with/without collector) is pumped gently to silica plate. If the particle is hydrophobic enough, levitation occurs but if it is not then the particles fall down and sink. Experiments are carried out to find maximum floatable particle size by using groups of each size.

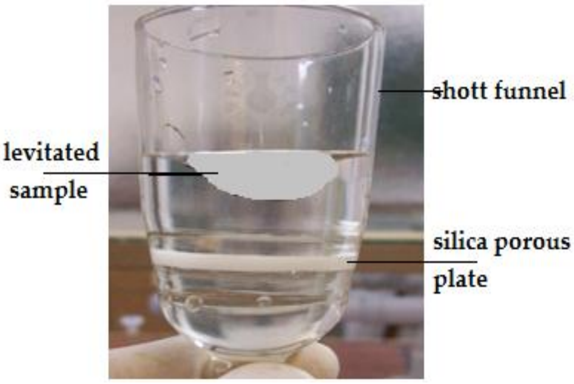

Fig. 1 Levitation experiment set up.

Contact angle (Θ) is calculated using the Equation 1.

$$\cos\Theta = 1 - \frac{4R_p{}^2 \rho g}{3\sigma}$$

WhereRp is particle radious, ρ is density of liquid, g is the gravity, σ is the surface tension of the liquid.

Results and Discussion

In the first step of the study, zeta potential of the magnesite sample was revealed (Figure 2). Thus, the zero points of charge (zpc) and net surface charge of the samples were determined. The zpc for the sample is around pH 7 which was also confirmed in the literature (Gence, 2006). Above the zpc, the surface charge of the sample is negative. It means that the collectors used in the study were adsorbed to the magnesite surface by chemical adsorption.

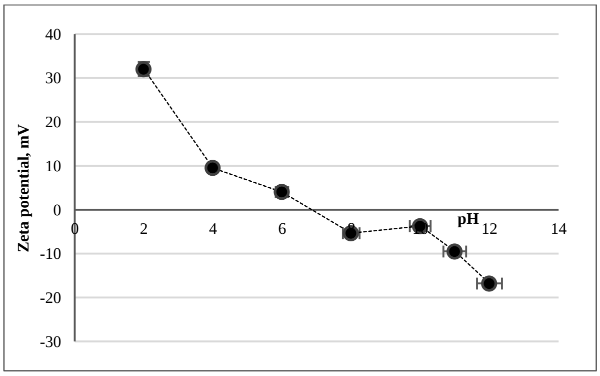

Fig. 2 Zeta Potential of the magnesite.

Contact angle can be directly used to determine the wetting characteristics of minerals. Thus, the measurement results of contact angle can be used for performance evaluation of any mineral in flotation. There are many contact angle measurement techniques such as sessile drop, captive bubble etc. as given in introduction part. In this study, simple bubble attachment method was firstly used to determine the contact angle of magnesite ore in Kutahya region. According to results obtained from Figure 3, oleic acid gives the highest degree of contact angle in every collector concentration. In $1.16x10^{-3}$ M collector dosages, the degree of contact angle for magnesite is 58º, 31º and 42º by the use of oleic acid, R801 and R845, respectively. The more there is the collector dosage, the higher the contact angle for all collector types. The contact angle of magnesite increased to 65º, 53º and 45º for oleic acid, R801 and R845, when the dosage of each collector increased to $4x10^{-3}$ M. Finally, the highest degree of contact angle for magnesite was obtained as 86º by using the 10^{-2} M of oleic acid. In addition, the degree is not as high as it is when using the R801 and R845 type collector even though the dosages were increased to 10^{-2} M for them as well.

The results have the same trend with the findings of Gence (2006) for the magnesite crystals obtained from Konya Region. Gence (2006) obtained the highest contact angle degree for magnesite by the use of sodium oleat. On the other hand the contact angle degree did not reach even 30º by the use of R801 and R845 in the mentioned study. On the contrary, the contact angle degree reached nearly 65º by using the R845 in this study. Simple bubble attachment method is a kind of dynamic contact angle measurement method because of which it gives much more useful data for real flotation test than static measurements.

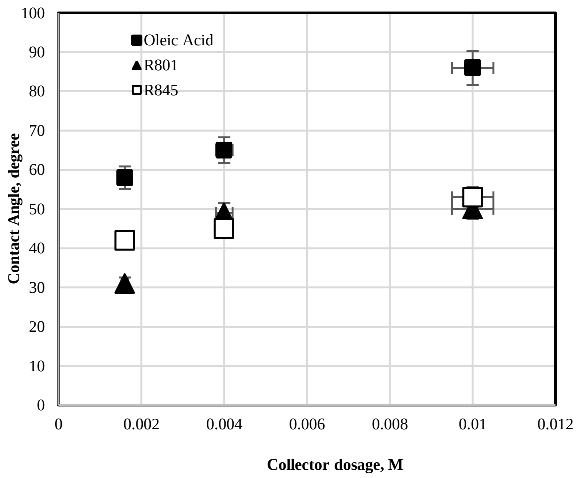

Fig. 3 Contact angle degree of magnesite in various collectors (oleic acid, R801 and R845).

According to results obtained from Figure 3, the oleic acid can be used as a collector for magnesite samples. There are significant differences between oleic acid and R-type collectors in terms of contact angles. The results confirm the previous studies carried out for magnesite minerals and show the usability of simple bubble attachment method for the contact angle measurement.

Conclusion

Contact angle is one of the most important parameters showing the surface characteristics of minerals. Therefore, it is very important to determine the contact angle to evaluate the real flotation tests. There are many different measurement techniques for determination of contact angles and researchers search for the easiest and effective techniques. Cost of measurements is another issue in this case. Simple bubble attachment method can be a useful tool to reveal any kind of mineral's surface properties. In this study, the simple bubble attachment method was applied to magnesite sample in presence of various types of collectors such as oleic acid, R801 and R845. According to the results, the highest contact angle degree was 86 º which was obtained by the use of oleic acid solution having 10^{-2} M of concentration. The results for other concentrations with all reagents seem logical surface characteristics. Further study can be performed to determine the contact angle of samples in different pH conditions.

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