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Application of dissolved air flotation on separation of waste plastics ABS and PS

Wang Hui *, Chen Xiao-lei, Bai Yang, Guo Chao, Zhang Li

School of Chemistry and Chemical Engineering, Key Laboratory of Resource Chemistry of Nonferrous Metals, Ministry of Education, Central South University, Changsha, 410083 Hunan, China

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ABSTRACT

The aim of this research was to separate waste plastics acrylonitrile butadiene styrene (ABS) and polystyrene (PS) by dissolved air flotation in a self-designed dissolved air flotation apparatus. The effects of wetting agents, frother, conditioning time and flotation time on flotation behavior of waste plastics ABS (w-ABS) and PS (w-PS) were investigated and the optimized separation conditions were obtained. The results showed that when using 25 mg L^{-1} tannic acid, 5 mg L^{-1} terpineol, 15 min conditioning time and 15 min flotation time, mixtures of w-ABS and w-PS were separated successfully by dissolved air flotation in two stages, the results revealed that the purity and recovery rate of w-PS in the floated products were 90.12% and 97.45%, respectively, and the purity and recovery rate of w-ABS in the depressed products were 97.24% and 89.38%, respectively. Based on the studies of wetting mechanism of plastic flotation, it is found that the electrostatic force and hydrophobic attraction cannot be the main factor of the interaction between wetting agent molecules and plastic particles, which can be completed through water molecules as a mesophase, and a hydrogen bonding adsorption model with hydration shell as a mesophase was proposed.

1. Introduction

Plastic is a large class of new material developed in the beginning of 20th century, and has developed at an incomparable speed for the past decades. According to a number of recent studies, the production of plastics materials has increased by an average of almost 10% every year on a global basic since 1939, while it reached to 254 million tonne in 2008 (Brydson, 1999; The China Plastics Industry Editorial Office, 2011). The rapid rate of plastic consumption has lead to a rapid increase of plastics waste in municipal solid waste (MSW). Take USA for example, the amount of plastics waste reached 29.7 million tons in 2006 and it comprised 11.7% of MSW by weight (Panda et al., 2010).

Plastics waste has a great impact on environment because of its nonbiodegradability. Recycling is the most effective way to disposal plastics waste, and separation of different plastics is an important process in waste plastics recycling. Several separation technologies including optical sorting, wind election, gravity separation, electrostatic separation as well as froth flotation (Izumi, 1975; Stuckrad et al., 1997; Shen et al., 1999; Pongstabodee et al., 2008) can be applied to separate mixed plastics. In general, the separation of ABS and PS is difficult since their similar physical properties, such as density and natural floatability (Shen et al., 2002). However, froth flotation using selective wetting agents is a possible separation technique (Wang et al., 2005). Many reports revealed that froth flotation of plastic has advantages in sorting mixture plastics of ABS and PS with similar density, charge and natural floatability. For example, Pascoe (2005) reported the use of selective depressants for the separation of ABS and HIPS by froth flotation. More recently, Pongstabodee et al. (2008) separated ABS from PS when using 500 mg L^{-1} calcium lignosulfonate, 0.01 ppm MIBC, 0.1 mg L^{-1} $CaCl_2$ at pH 7 by selective flotation.

Dissolved air flotation (DAF) which was used to separate mineral particles in the early 1900s is one of separation methods in froth flotation, and a US patent was reported in 1906 for minerals separation using pressurized aeration followed by pressure release (Sulman et al., 1906). At present, DAF is used mainly to remove suspended and colloidal solids as well as fine-particles by decreasing their apparent density. It is widely used in dealing with municipal sewage and purifying industrial wastewater such as algal-rich, refinery, cutting oil/water, poultry slaughterhouse wastewater (Teixeira and Rosa, 2006; Hami et al., 2007; Bensadok et al., 2007; De Nardi et al., 2008; Gao, 2010; Palaniandy et al., 2010) as well as the treatment of fine-grained minerals, coal ash, low-grade slag, etc. (Rodrigues and Rubio, 2007; Demir et al., 2008; Valderrama and Rubio, 2008). For DAF process, bubbles are generated from a supersaturated solution of a pressurized gas/liquid mixture by pressure release. With regard to plastics flotation, the lower density of materials determines that the flotation process must be performed in the situation of small disturbances and low-turbulent flow. To ensure small disturbance and low-turbulent, the tiny bubbles are recommended.

* Corresponding author. Tel.: +86 731 88879616.
E-mail address: huiwang1968@163.com (H. Wang).

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For mixture plastics, especially plastics with similar surface properties, it is required to change the surface properties of one or several plastics by selective wetting agents to achieve selective separation. Selective wetting of plastic surface can be completed by the adsorption of wetting agent. Some researchers discussed the wetting mechanism of plastic flotation in their research field. Stuckrad et al. (1997) claimed that selective physical adsorption was caused by van der Waals dispersion force and hydrogen bonding. Fraunholcz and Dalmijn (1997, 1998) held that the hydrophobic interaction and electrostatic interaction were the main factor. However, Guern et al. (1997, 2000, 2001) deemed that the physical adsorption was mainly based on electrostatic interaction.

In this paper, a dissolved air flotation apparatus which was specially designed for plastics flotation separation was showed and the flotation behavior of waste plastics ABS (w-ABS) and PS (w-PS) using selective wetting agents were investigated. In addition, the wetting mechanism of plastics flotation was discussed.

2. Materials and methods

2.1. Materials

The samples of two different kinds of waste plastics, namely w-ABS and w-PS, were obtained from a waste plastics market (Miluo, Hunan Province, China). The w-ABS is a kind of air conditioning shell and w-PS is a kind of cassette shell, and their density is 1.109 and 1.137 g cm^{-3}, respectively. The samples were crushed to particles size lower than 5 mm using a plastics cutting mill. Original pictures of w-ABS and w-PS were showed in Fig. 1.

Two kinds of waste plastics w-ABS and w-PS for the experiments were identified by infrared spectrum and the results were shown in Fig. 2. Compared to pure ABS and PS polymer resins, the spectra of waste plastics were obviously impacted by filler, plasticizers and other ingredients.

Wetting agents used in DAF process were tannic acid (TA) (MaoYuan Chemical Co., Ltd., China) and lignosulfonate (LS) (Guangzhou paper Co., Ltd., China). The frother used was terpineol (Qixia Ore-dressing Reagents Plant, China). The additives used were industrial products. The chemical structural formula of TA and LS are showed in Figs. 3 and 4, respectively.

The testing liquids used in the measurement of contact angle included secondary distilled water (made in laboratory), glycerol (Sinopharm Chemical Reagent Co., Ltd., China), formamide (Tianjin Bodi Chemical Co., Ltd., China), diiodomethane (Shanghai Reagent Co., Ltd., China) and ethylene glycol (Hengyang Organic Reagent Co., Ltd., China). All the liquids have analytical purity.

2.2. Dissolved air flotation

The flotation experiments were carried out in a self-designed plastics dissolved air flotation apparatus, as shown in Fig. 5, which is composed of air compressor, dissolved air container (Φ219 × 600 mm), flotation column (Φ100 × 1000 mm), circulating pump, mixing tank, store tank (300 × 300 × 300 mm), bubble generator, flow meters, valves.

In this work, the dissolved air flotation is a batch separation process, and in this process, the experimental procedures are as follows:

(a) Fill the store tank full with tap water, open the circulating pump, add wetting agent and frother, and then turn on the blender to prepare a required flotation solution for flotation experiments.
(b) Feed a certain amount of waste plastics (flotation volume concentration of 5%) which were soaked by flotation solution and stirred for a while in mixing tank into the flotation column.
(c) Push air into the dissolved air container by air compressor until its pressure reaches a fixed value to form dissolved air water.
(d) Release the dissolved air water through the bubble generator to yield tiny air bubbles, when the flotation column is full of tiny bubbles, then the flotation experiment starts.
(e) At the end of the experiments, the floated and depressed products are dried at 110 °C and weighed. Two kinds of waste plastics are of different colors, and of sufficiently large size, which make it easier for the analysis of purity rate of plastics through manual sorting at the end of mixed plastics flotation separation experiments, and the w-PS (w-ABS) recovery rate can be calculated through its purity rate and the weight of floated (depressed) products. Purity and recovery rate of each experiment are calculated, and the purity and recovery rate correspond to the mean value of five tests.

2.3. The measurement of the contact angle and zeta potential

A JJC-I contact angle measuring instrument (Changchun Optical Instrument Factory, China) is applied to measure the contact angle of liquid on the solid surface. When measuring, at the distance of 3 mm above solid, the liquid is vertical, carefully dropped onto a solid surface to form a sessile drop by micro-injector (2.0 mL). Make sure the droplet size is 3–5 μL, diameter is 1–2 mm, and measuring time is less than 1 min. Ten measurements were taken, and an average value was reported. All measurements were conducted at room temperature, generally 25 °C (Wang et al., 2011).

Before conducting surface inspection, typical w-ABS and w-PS plates were selected and cut into 20 × 20 mm, then they was put into tap water containing washing powder, tap water and distilled water in sequence to clean for 10 min in ultrasonic generator (Shanghai Ultrasonic Co. Ltd., China). Take them out and rinse in distilled water for 5 min, then put them on filter paper to dry at

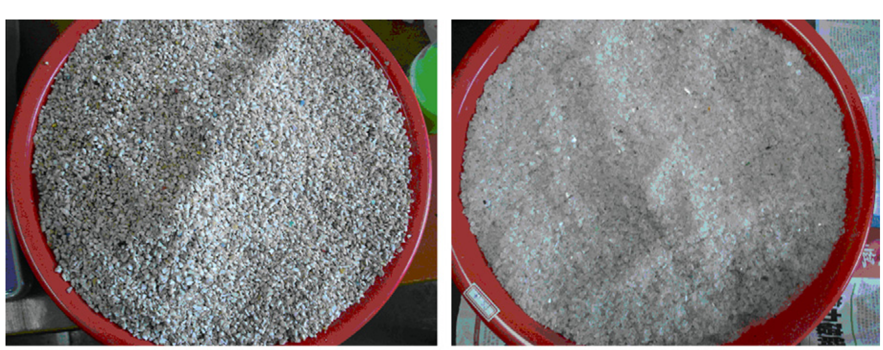

Fig. 1. Original pictures of w-ABS and w-PS.