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Separation of polycarbonate and acrylonitrile–butadiene–styrene waste plastics by froth flotation combined with ammonia pretreatment

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ABSTRACT

The objective of this research is flotation separation of polycarbonate (PC) and acrylonitrile–butadiene–styrene (ABS) waste plastics combined with ammonia pretreatment. The PC and ABS plastics show similar hydrophobicity, and ammonia treatment changes selectively floatability of PC plastic while ABS is insensitive to ammonia treatment. The contact angle measurement indicates the dropping of flotation recovery of PC is ascribed to a decline of contact angle. X-ray photoelectron spectroscopy demonstrates reactions occur on PC surface, which makes PC surface more hydrophilic. Separation of PC and ABS waste plastics was conducted based on the flotation behavior of single plastic. At different temperatures, PC and ABS mixtures were separated efficiently through froth flotation with ammonia pretreatment for different time (13 min at 23 °C, 18 min at 18 °C and 30 min at 23 °C). For both PC and ABS, the purity and recovery is more than 95.31% and 95.35%, respectively; the purity of PC and ABS is up to 99.72% and 99.23%, respectively. PC and ABS mixtures with different particle sizes were separated effectively, implying that ammonia treatment possesses superior applicability.

1. Introduction

Plastics have been one of the most widely used materials in our daily life and industrial production due to their properties of low cost, light weight, hygiene, strength and design adaptability of plastics (Gent et al., 2009). Plastic wastes generated from the automotive (Christen, 2006; Xanthos, 2012), electronic and IT fields (Imai et al., 2003), as well as from packaging materials, fluid containers, clothing, and household products (Al-Salem et al., 2009; Park et al., 2007b) are constantly increasing due to the industrial development and short life span of the materials (Park et al., 2007b). The growth of plastic wastes has a great impact on their management. The incineration and landfill deposition of plastic wastes cause environmental problems and become more expensive due to their increasing volume and the decreasing landfill capacity for disposal (Abbasi et al., 2010; Lea, 1996). As plastic wastes are potential resources that can be recovered and reprocessed, the emphasis of plastic management has shifted into recycling.

Recycling of polymers encompasses four activities: collection, separation, processing and marketing (Shent et al., 1999). Different types of plastics cannot be mixed together for recycling process due to their incompatibility during melt processing, and thus efficient techniques for separation of plastics mixtures are necessary. A number of promising technologies were investigated such as hydrocyclone (Malcolm Richard et al., 2011), sink-float (Dodbiba et al., 2002; Pongstabodee et al., 2008) and electrostatic separation (Park et al., 2007a,b). Plastics flotation is an alternative method, which shows advantages such as cost-effective and higher separation efficiency, especially for plastics with similar density (Jody et al., 2003; Takoungsakdakun and Pongstabodee, 2007; Wang et al., 2012, 2013, 2014).

Flotation separation is performed through wetting selectively plastic or plastics in the mixtures, which can be achieved by adjusting the gas–liquid interfacial tension (referred as gamma flotation), adsorption by surfactants and surface pretreatment with physical techniques (Fraunholcz, 2004; Shent et al., 1999). Numerous physical methods were reported such as plasma treatment (Fraunholcz, 2004), ozonation (Okuda et al., 2007; Reddy et al., 2007), flame treatment (Pascoe and O'Connell, 2003) and wet oxidation (Drelich et al., 1999). Stückrad proposed a method applying plasma treatment to achieve selective wetting of plastic particles; experiments demonstrated that both plasma-treated polycarbonate (PC) and acrylonitrile–butadiene–styrene (ABS) were wetted and the floatability of ABS restored while PC remained wettable within a few days (Fraunholcz, 2004).

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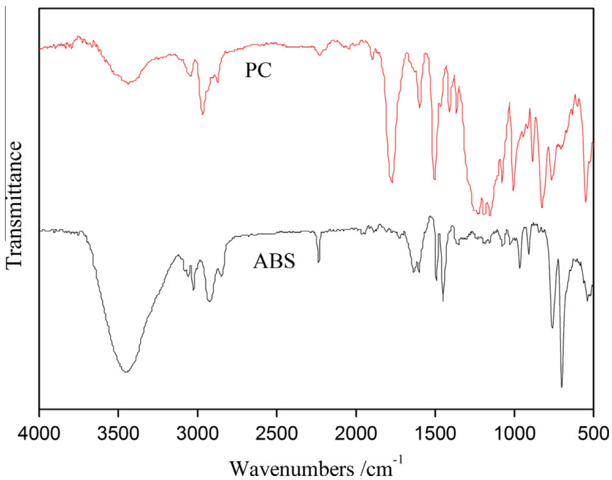

Fig. 1. The Fourier transform infrared of samples.

Alkaline solution of sodium hydroxide is able to destroy the hydrophobicity of poly(ethylene terephthalate) (PET), and flotation separation of polyvinyl chloride (PVC) and PET plastics combined with alkaline treatment was achieved at bench scale (Drelich et al., 1999; Marques and Tenório, 2000; Pongstabodee et al., 2008). The action mechanism is supposed to be destruction of ester bonds in PET, which increases the number of hydrophilic groups (hydroxyl and carboxyl) and thus makes PET hydrophilic. Similar to alkaline treatment, ammonia solution promotes the hydrolysis of the PC surface (Fraunholcz, 2004). Ammonia pretreatment for flotation separation of waste plastics were developed initially in this study, and the effects of ammonia on the PC surface were investigated through contact angle measurements and X-ray photoelectron spectroscopy (XPS) analysis.

2. Materials and methods

2.1. Materials

Samples of two different kinds of waste plastics, namely PC and ABS, were obtained from a waste plastics market (Miluo, Hunan Province, China), and the samples were identified by Fourier transform infrared analysis. As shown in Fig. 1, ABS sample shows a typical molecular vibrations at 1600 cm^{-1}, 1490 cm^{-1}, 1454 cm^{-1} (the stretching in aromatic rings), —C≡N stretch at 2240 cm^{-1} (acrylonitrile), —C—H stretch at 3030 cm^{-1} (aromatic rings), 2850 cm^{-1} and 2920 cm^{-1} (ethylene); —C—H bending vibrations at 700 cm^{-1}, 760 cm^{-1} (aromatic rings); PC sample shows a typical molecular vibrations at 1190 cm^{-1}, 1770 cm^{-1} (phenylester), —C—O at 1150 cm^{-1} and 1230 cm^{-1}, alkyl at 2970 cm^{-1} and 829 cm^{-1}, and the stretching in aromatic rings at 1500 cm^{-1}.

Each of the samples was crushed, rinsed and screened, and the sieve size fractions used in the flotation experiments were 3.2–4.0 mm, 2.5–3.2 mm and 2.0–2.5 mm. The original picture of the samples is shown in Fig. 2. It can be observed that PC and ABS are of different colors, which makes analysis of purity of the plastics through manual sorting at the end of each experiment easier. Virgin PC plastic obtained from Anheda Plastics Products Co., Ltd (China) was used in contact angle and XPS measurements.

Terpineol with molecular formula $C_{10}H_{18}O$ was used as frother. Terpineol and ammonia was obtained from Xilong Chemical Co., Ltd and Tianjin Kemiou Chemical Reagent Co., Ltd., respectively. They were analytically grade and used as received. Tap water was used throughout the flotation tests.

2.2. Ammonia treatment of plastics

The samples of plastics were treated with ammonia in a 100 mL wild-mouth bottle. In the case of flotation behavior of simple

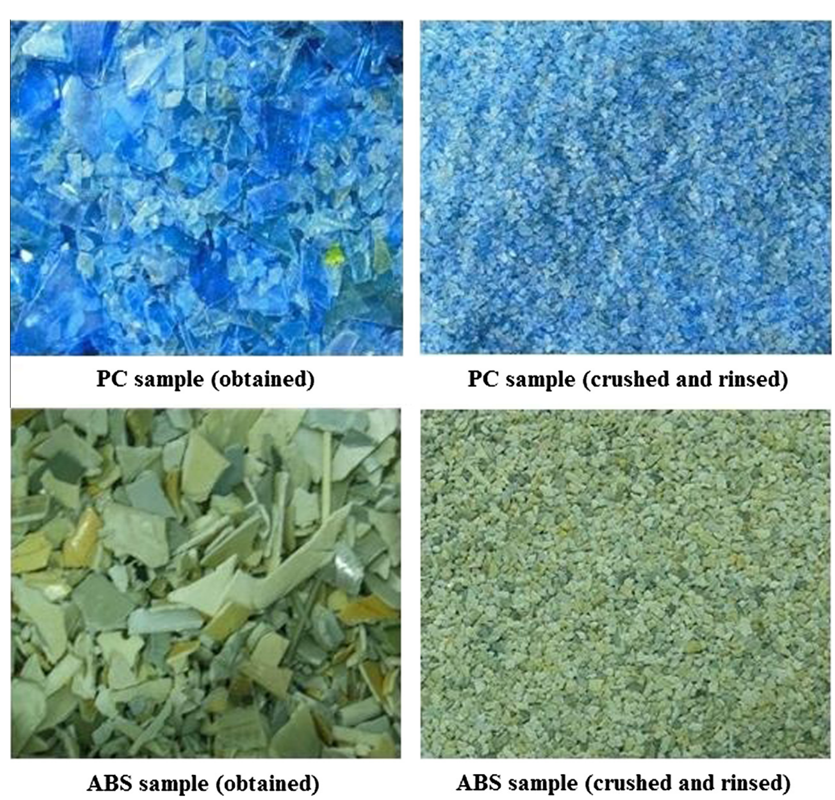

Fig. 2. The original picture of PC and ABS samples.