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PVC removal from mixed plastics by triboelectrostatic separation

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Abstract

Ever increasing oil price and the constant growth in generation of waste plastics stimulate a research on material separation for recycling of waste plastics. At present, most waste plastics cause serious environmental problems due to the disposal by reclamation and incineration. Particularly, polyvinyl chloride (PVC) materials among waste plastics generates hazardous HCl gas, dioxins containing Cl, and so on, which lead to air pollution and shorten the life of incinerator, and it makes difficultly recycling of other plastics. Therefore, we designed a bench scale triboelectrostatic separator for PVC removal from mixed plastics (polyvinyl chloride/polyethylene terephthalate), and then carried out material separation tests. In triboelectrostatic separation, PVC and PET particles are charged negatively and positively, respectively, due to the difference of the work function of plastics in tribo charger of the fluidized-bed, and are separated by means of splitter through an opposite electric field. In this study, the charge efficiency of PVC and PET was strongly dependent on the tribo charger material (polypropylene), relative humidity (below 30%), air velocity (over 10 m/s), and mixture ratio (PET:PVC = 1:1). At the optimum conditions (electrode potential of 20 kV and splitter position of −2 cm), PVC rejection and PET recovery in PET products were 99.60 and 98.10%, respectively, and the reproducibility of optimal test was very good (±1%). In addition, as a change of splitter position, we developed the technique to recover high purity PET (over 99.99%) although PET recovery decreases by degrees.

Keywords: Waste plastics; Recycling; Triboelectrostatic; Tribo charger; PVC rejection

1. Introduction

Plastics are excellent and very useful material to replace ceramic, wood and metals because they are very functional, hygienic, light and economical. Therefore, uses of plastics are increasing more and more every year. Korea is one of the major producers of plastic in the world with total production capacity of around 11 million t/year owing to the development of oil industry [1]. USA, Europe and Japan together generate about 50 million t of post consumer waste plastics every year [2,3]. The generation of waste plastics in Korea is about 4 million tonnes every year with a small portion being recycled (<30%) [4,5]. Hence, development of material separation technique for recycling of waste plastics is a necessary situation. At present, most waste plastics are disposed by reclamation and incineration. Such a disposal of waste plastics has become a major environmental problem all over the world. Traditional waste plastic disposal, in fact, could lead to the release of hazardous substances either by weathering and natural drying or by incineration processes. Reclamation could cause the release of plastic additives such as phthalates and various dyes polluting ground water [6]. Incineration is an alternative to reclamation disposal of waste plastics, but this practice could result in the formation of unacceptable emissions of gases such as nitrous oxide, sulfur oxides, dusts, dioxins and other toxins [7].

Especially, waste plastics containing PVC pollute the environment and shorten the life of incinerator as generating hazardous HCl gas, dioxins containing Cl, etc. Also, PVC materials not only creates difficulty in recycling process, but also decreases recycling ratio of plastics, by forming compounds or deteriorating the nature of other materials even if a very small quantity of PVC is present in main a plastic [3,8–10]. Therefore, the development of material separation technique for PVC removal from waste plastics needs attention.

Waste plastics must be separated and concentrated for their reusing or recycling. Hence, many efforts to find the proper

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physical method have been attempting for a long time. In general, physical separation techniques that can recycle the mixed plastics are classified by electrostatic separation, dry and wet gravity separation, froth flotation, NIR and color sorting [2,10–13]. Gravity separation is difficult for materials of similar specific gravity, such as PVC and PET [11]. Froth flotation has the problem of waste water disposal by agents. Also, NIR and color sorting is not a perfect technique because it is difficult to separate the mixed plastics having similar properties such as same color and peak [2]. The electrostatic separation methods that can separate the mixed materials are corona discharge, induction electrostatic and triboelectrostatic. Corona discharge and induction electrostatic can separate a mixture of conductor/non conductor; whereas, triboelectrostatic method has the advantage of separating different types of materials [13–16]. Tribo charging phenomenon is utilized in numerous technical applications, such as electro-photography, electrostatic copy and printing techniques, electrostatic filtration, precipitation and coloring. Also, this separation has been used processing of valuable mineral, coal and fly ash [6,17].

The triboelectrostatic separation is a method that separates the particles charged by means of particle/particle and particle/charger charging mechanisms, due to its work function or tribo series of materials through electric field [14,18]. Table 1 shows the relative tribo charging series of common plastics [19,20]. Tribo series show the degree of work function of materials. When two materials are brought into contact or collision, charge transfer can occur between them until their fermi levels equalize by the work function difference between the two materials. Then, material with high work function and low work function are charged positively and negatively, respectively and negatively charged material is moved toward positive electrode, and positively charged material is moved toward negative electrode [10,21]. In triboelectrostatic separation, the selective charging and optimum charge density of materials are most important parameters. Therefore, this separation method can improve separation efficiency according to development of charging material and tribo charger. Triboelectrostatic separation is much cheaper and the separation efficiency is much better than that using the above mentioned classical separation methods [15–19].

The aim of this study is to remove PVC from mixed plastics (PVC/PET) using fluidized bed tribo charger (pipe line). Hence, we designed a bench scale triboelectrostatic separator unit and thus investigated the charge polarity and charge density of PET, PVC on charging materials and various factors such as charging materials, air velocity (the impact of collision or contact), mixture ratio, relative humidity effecting on charge efficiency. Also, we standardized the optimal electrode potential and splitter position effecting on the separation efficiency in triboelectrostatic separator. In addition, we confirmed a recovery possibility of high purity PET and the reproducibility of optimum test.

2. Experimental

2.1. Materials

The samples used in this study were well-defined virgin polyethylene terephthalate (PET) and polyvinyl chloride (PVC) which containing a minimum amount of additives and impurities. The samples were shredded by a cutting mill ('pulverisette 19') provided by FRITSCH GmbH, Germany and then a representative fraction of the plastics was sieved as a size fraction of −2.0 + 1.6 mm. The charged plastic particles by cutter of cutting mill neutralized the initial charges on each particle by means of air ions produced by discharger (Kasuga Denki Inc., Japan). Nine kinds of materials, namely polytetrafluoroethylene (PTFE), polyvinyl chloride (PVC), polypropylene (PP), high density polyethylene (HDPE), polystyrene (PS), polyethylene terephthalate (PET), acrylonitrile butadiene styrene (ABS) and polymethyl methacrylate (PMMA) were used as material for tribo charger in the charging material selection test.

2.2. Method

The aim of our work was focused to investigate the charging property of plastics and PVC removal from mixed plastics. Hence, it was important to use a charging unit and a separator that were able to charge and separate quantities of those substances. Fig. 1 shows a schematic diagram of triboelectrostatic separator and peripheral equipments used in this work. It is consisted of feeding zone ((6)–(9)), charging zone (1), and separation zone ((2)–(5)). A various dimensions of electrode, pipe line and splitter were the following: electrode of the screen mesh type (diameter: 1 mm, covering: 15 mm), distance between the electrodes (the upper: 50 mm, the lower: 280 mm), electrode length 450 mm, electrode width 260 mm, electrode angle to vertical axis 10°, total length of the pipe line 1660 mm, pipe line diameter 16 mm, splitter length 260 mm, splitter width 260 mm and splitter diameter 10 mm. The air-conditioning system supplies necessary an air for moving and fluidization of the plastic samples at a certain relative humidity and temperature. The plastic of 20 g is provided into pipe line with an air, and then the charged particles are deflected under the influence of the electric field between the electrodes that are connected to the high-voltage power supply (±30 kV). The charge of particles that were collected in the faraday cups are induced into faraday cup and then an electrometer measures the induced charges. The weight of particles was measured by electronic balance. Hence, the charge density was determined by charge to mass ratio (nC/g) [26]. Faraday cage (10) used in this study was MODEL of KQ-

Table 1
Tribo series of plastics

Material	PUR	PMMA	ABS	PC	PS	RUBBER	PET	HDPE	LDPE	PP	PVC	PTFE
Series	+ (more positive) ←									→ (more negative) −		