J. of Korean Inst. of Resources Recycling
Vol. 16, No. 5, 2007, 51-56
≫ 研究論文 ≪

HDPE 싸이클론 荷電裝置를 이용한 終末品 廢플라스틱으로부터 PET의 回收†

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韓國地質資源硏究院

Recovery of PET from Final Plastic Wastes using HDPE Cyclone Charger†

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요 약

플라스틱은 아주 유용한 물질로서 우리 일상생활에 폭넓게 이용되고 있다. 국내에서는 약 400 만톤의 폐플라스틱이 발생되고 있지만 재활용율은 30% 이하로 대부분 소각이나 매립에 의해 처리되고 있다. 따라서 폐플라스틱을 재활용할 수 있는 재질분리 기술개발 필요한 실정이다. 본 연구에서는 폐플라스틱 종말품으로부터 PET 회수를 위한 마찰하전 정전선별이 수행되었다. 하전특성 연구결과에 의하면, PET와 PVC의 하전극성과 하전량은 HDPE와 PP의 하전물질 그리고 상대습도가 낮을수록 효과적이었다. HDPE 싸이클론 하전장치를 이용한 재질분리 실험결과, PET의 품위와 회수율은 전극전압 30 kV 이상, 분리대위치 -2cm의 조건에서 각각 96.8%와 85.0%로 얻어졌으며, 분리대의 위치(-6cm)에 따라 PET 회수율이 24% 감소하지만 품위를 98.5%까지 분리할 수 있는 기술을 개발하였다.

주제어 : 하전장치, 싸이클론, 폐플라스틱, 정전선별

Abstract

Plastics are widely used in everyday life as very useful material. In Korea, about 4 million tons of plastic wastes are generated annually. However, recycling ratio is below 30%, and most of plastic wastes are disposed by landfill and incineration. Hence, the development of material separation technique that can recycle plastic wastes is a necessary situation. In this study, Triboelectrostatic separation for recovery of PET from final plastic wastes obtained from the sink product after wet-type gravity separation has been carried out. In the charging properties, the charge polarity and charge density of PET and PVC were very effective with the tirbo-charger made of PP and HDPE with the decrease in relative humidity. In material separation using HDPE cyclone charger, a PET grade of 96.80% and a recovery of 85.0% were achieved at 30 kV and the splitter position -2cm from the center. In order to obtain PET grade of 98.5%, PET recovery should be sacrificed by 24% with moving the splitter from the center to -6cm position.

Key words : charger, cyclone, plastic wastes, electrostatic separation

1. Introduction

The landfill and incineration of plastic wastes have been restricted by law and the recycling of plastic wastes has been promoted by the enforcement of the extended producer responsibility (EPR) system of Korea since the year 2003[1-2]. Ever increasing oil price and the constant growth in generation of waste plastics stimulate a research on material separation for recycling of plastic wastes with stable demand and supply of plastics[2]. The constant generation of plastic wastes and their disposal generate environmental problems along with economic loss. Especially, mixed plastic

† 2007년 9월 6일 접수, 2007년 10월 5일 수리
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wastes are difficult to recycle because of their inferior characteristics[3,4]. Therefore, development of electrostatic separation technique for material separation of final plastic wastes is of great importance from the environmental standpoint, particularly in Korea that occupies limited land with a large population.

The electrostatic methods to separate mixed materials include corona discharge, electrostatic induction and triboelectrostatic separation. Corona discharge and electrostatic induction can separate a mixture of conductor and non-conductor (metal/insulator), whereas the triboelectrostatic method has an advantage of separating different types of materials[5-6]. Tribo-charging phenomenon is utilized in numerous technical applications such as electro-photography, electrostatic copy and printing techniques, electrostatic filtration, precipitation and coloring. In addition, this separation technique been used for processing valuable minerals such as coal and fly ash[7-8]. 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 classical separation methods[9-13].

Tribo-charging occurs when particles are charged with opposite polarities by particle-particle and particle-surface charging mechanisms, due to their work function or the triboelectric series[5,14-15]. The selective charging of materials is an important parameter and the triboelectric series is widely used as an indicator of selectively charging plastics in triboelectrostatic separation. This study aims at separating sink product (final plastic wastes) obtained from gravity separation. Therefore, charging test on the final plastic wastes using a vertical-reciprocation tribo-charger and various charging materials was carried out. It was found that PP, HDPE were a proper charging materials to make high charge density (nC/g) with an opposite polarity for PET and PVC. Where, HDPE material was applied to cyclone charger. From a bench scale triboelectrostatic separator unit, the optimal electrode potential and splitter position affecting the separation efficiency in a triboelectrostatic separator has been standardized

2. Experimental

2.1. Materials

Materials used in this study were the sink product ontained from the gravity separation process in the recycling facility in Dae-Jeon city. The plastic wastes contained 78.5% polyethylene terephthalate and 21.5% polyvinyl chloride. The samples were shredded using a cutting mill and then a representative fraction of the plastics was sieved as –2+6 mm.

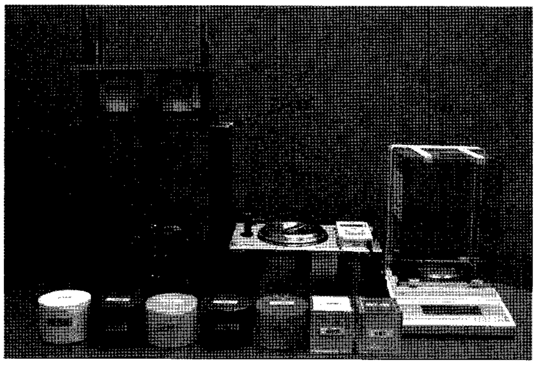

Fig. 1. A vertical-reciprocation charger set and peripheral measurement equipment
(1: vertical-reciprocation charger, 2: charging bottles, 3: Faraday cage, 4: electric balance).

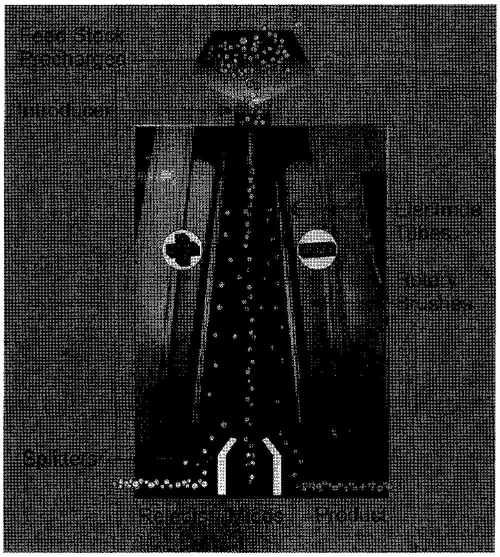

Fig. 2. Schematic representation of triboelectrostatic separation.

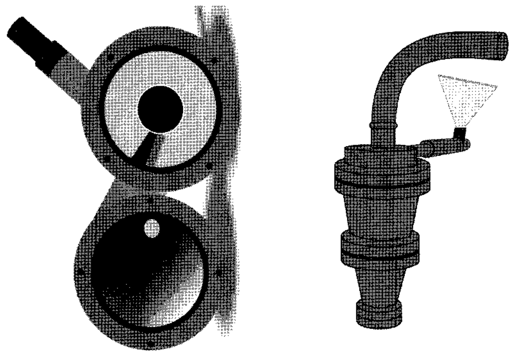

Fig. 3. Cyclone-type tribo-charger used in the present study.

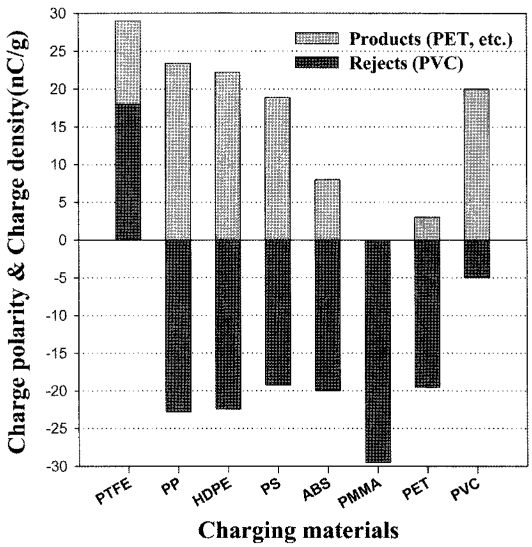

Fig. 4. Charge density of plastic wastes as charging materials.

2.2. Methods

Fig. 1 shows the experimental system consisting of the vertical-reciprocation charger (1), the charging bottles (2), a Faraday cage (3) and an electric balance (4). This apparatus was designed to charge the plastics into the charging bottle at the top by a transfer from rotating motion to reciprocation by the cam axis located at the lower section. It can be used in charger material selection or a preparatory experiment. Sample was crushed into size of -4mm using a cutting mill. Eight different types of materials, i.e. bottles made of PTFE, PS, HDPE, PP, PVC, ABS, PET and PMMA were used as a material for tribo-charger in charging material selection tests. In addition charging material showing high charging efficiency was applied to cyclone charger. Fig. 2 shows a schematic representation of triboelectrostatic separation. Fig. 3 shows a tribo-charger of HDPE cyclone type used in this study. After mixed plastics are fed into a cyclone with air, they are charged with opposite polarity owing to the work function in cyclone charger and then the charged particles are deflected under the influence of the electric field between the electrodes which are connected to a high-voltage power supply (±30 kV). The charge density of products was measured by Faraday cage and PVC content of products was analyzed by tetrahydrofuran solution.

3. Results and Discussion

3.1. Charger material selection and charging property

The triboelectrostatic separation is important to optimize the charge density and selective charging on each material. In the present study, the charge polarity and the charge density of PET, PVC as a function of charger materials were investigated. Fig. 4 shows the charge density and charge polarity of PET, PVC after vertical-reciprocation within various charging bottles made of PTFE, PS, HDPE, PP, PVC, ABS, PET and PMMA. This test was carried out at a retention time of 5 min, an frequency of 250, a relative humidity of 30% and a temperature of 20°C. As shown in Fig. 4, the charge density of PET, PVC samples was over about ±20nC/g when using the PP, HDPE and HIPS bottles. This may be attributed to the work function of PP, HDPE and HIPS laid between PVC and PET in the triboelectric series[4]. Both PET and PVC are charged positively with the charging material of PTFE because their work function is lower than that of PTFE, whereas they are charged negatively with PMMA. On the other hand, the difference in charge density between PET and PVC is the maximum with PP and HDPE: the charge density difference totaled 45.1 and 44.6 nC/g, respectively. the charger made of HDPE was selected for further tests separating PET and PVC.

Fig. 5 shows the effect of relative humidity on the charge density of PET and PVC in tribo charging test using HDPE cyclone charger. This test was carried out at the relative humidity of 20-70% and an air velocity of 10m/s. The charge density of PVC and PET decreases as the relative humidity increases in the opposite direction, it increases as the relative humidity decreases. The charge density of PET and PVC was over +32.5 nC/g and -22.0 nC/g, respectively when the relative humidity was below 30%. The relative humidity influence on the charging and discharging behavior of

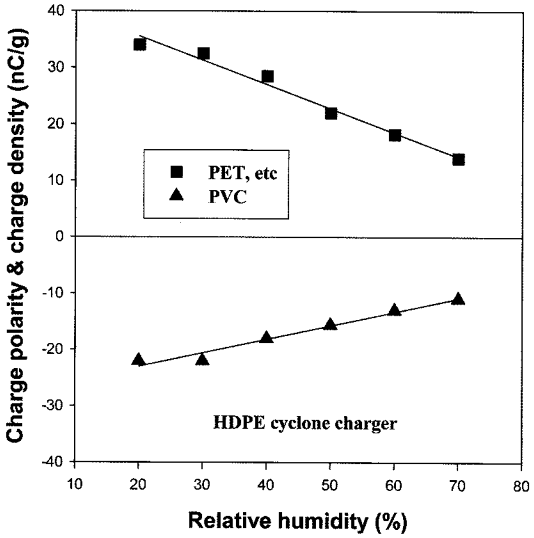

Fig. 5. Effect of relative humidity on charge density of plastic wastes in HDPE charger.

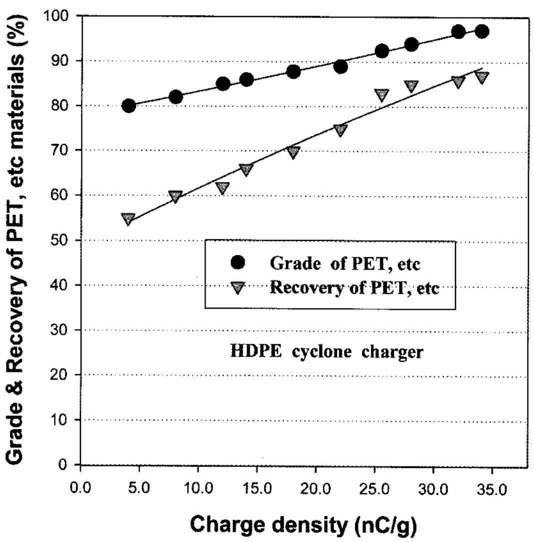

Fig. 6. The relation between the separation efficiency and charge density of PVC in triboelectrostatic separation unit.

plastics could be explained by the formation of water films onto plastic surfaces. Tribo charging test in higher relative humidity shows that water can either form adsorption layers onto plastic surfaces or swell the plastic surface. In this study, it was found that the relative humidity affects absolute for the charge density and the charge polarity of PET and PVC. As expected, the separation efficiency decreases as the relative humidity increases, probably due to the discharge of the electron through the moisture attached on the surface.

Fig. 6 shows the effect of charge density on the separation efficiency of PET from a mixture of PET and PVC in the triboelectrostatic separation unit. A net-charge density of separation products is measured with the Faraday cage. The results indicate that the PET grade and recovery are increased as the net-charge density rises gradually. The particle which has high charge density can be easily deflected toward the electrode although its potential is low. Therefore, it was confirmed that the optimum charge density of materials is most important parameter in triboelectrostatic separation.

3.2. Material separation using HDPE Cyclone Charger

The plastic wastes charged in the tribo-charger are separated by splitter in the electric field between electrodes. In the present study, the effect of electrode

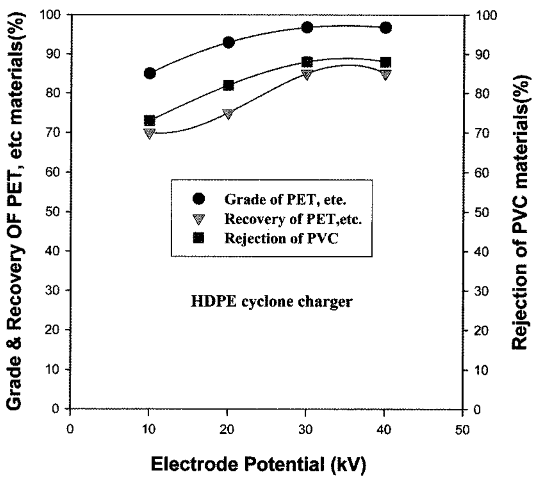

Fig. 7. Effect of potential difference on the separation efficiency of plastic wastes in tri-boelectrostatic separation.

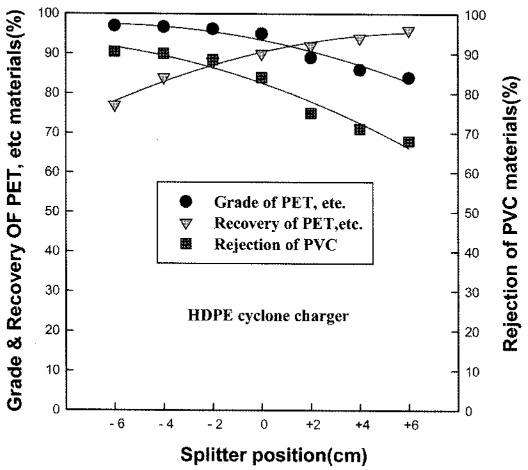

Fig. 8. Effect of splitter position on the separation efficiency of plastic wastes in tri-boelectrostatic separation.

potential and splitter position on PET recovery from mixed plastics were examined. As previously shown in charging property tests, PET and PVC are positively and negatively charged, respectively.

Fig. 7 shows PET grade and recovery as a function of electrode potential. The tests were carried out with the HDPE charger at 10 m/s air velocity and 30% relative humidity. The PET grade and recovery were increased as the electrode potential increased. For example, At 10 kV electrode potential, the PET grade and recovery were 85.1% and 70.5%, respectively. It appears that an electrode potential of 10kV is not strong enough to pull the charged particles toward the electrodes. PET grade 96.8% and recovery 85.0% were obtained at 30 kV. If the charge density of a particle is high, it can be deflected although electrode potential is relatively low. For the purpose of improving the separation efficiency, electrode potential has to increase in order that a particle with low charge density can be deflected. Fig. 8 shows PET grade and recovery as a function of splitter position. These tests were carried out at air velocity 10m/s, relative humidity 30% and electrode potential 30kV using the HDPE charger. Also, "-" and "+" cm sign in the splitter position in Fig. 8 signify moving direction from the center to the negative electrode and the positive electrode, respectively. As shown in Fig. 8, the PET grade was increased as the splitter position was moved to the negative electrode from the center, and PET recovery increased as the splitter position was moved to the positive electrode. PVC particles which have high negative charge density are strongly deflected to the positive electrode but some PVC particles which have low or neutral charge density fall freely or to the opposite side. In case of PET, some PET particles are not deflected to negative electrode and behave similarly to PVC. Such behavior of particles deteriorates the separation efficiency for PVC and PET. A PET grade of 96.8% and recovery of 85.0% were obtained at the splitter position -2 cm from the center to the negative electrode, which seems to be the optimum position. However, a PET purity of 98.5% could be obtained at the splitter position between -6 cm and the negative electrode although the PVC recovery was decreased considerably.

4. Conclusion

Triboelectrostatic separation for the recovery of PET from the final plastic wastes have been carried out. In the charging properties, the charge polarity and charge density of PET and PVC were very effective with the tirbo-charger made of PP and HDPE with the decrease in relative humidity. The PET grade and its recovery considerably depend on electrode potential and splitter position. A PET grade of 96.80% and a recovery of 85.0% were achieved at 30 kV and the splitter position -2 cm from the center. A PVC purity of over 98.5% could be obtained at the splitter position between -6 cm and the negative electrode at the expense of reduced recovery.

Acknowledgments

The authors would like to express special thanks to the Resource Recycling R&D Center, Ministry of Science & Technology of Korea for financial support.

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