# *Technology for Recycling Mixtures of Residual Plastics from Waste Household Appliances*

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## 1. Introduction

Material recycling of plastic mixtures recovered from waste household appliances requires separation of plastics by type. This study found that acrylonitrile-butadiene-styrene (ABS) and polystyrene (PS) can be separated with high purity by an electrostatic separation method, and verified that material recycling reduces $CO_2$ emissions compared with other disposal methods.

## 2. Background and Challenges

The Law for Recycling of Specified Kinds of Home Appliances came into effect in April 2001, since when four categories of home appliances (air-conditioners, TV sets, refrigerators/freezers, and washing machines) have been actively recycled. The total recycling ratio of these four types of products (ratio of total weight of products that can be handed over to external dealers at cost or no cost from the recycling plant to the total weight of waste home appliances) in fiscal 2007 was 77%, far exceeding the required legal standard ratios (60% or higher for air-conditioners, 55% or higher for television sets, and 50% or higher for refrigerators/freezers and washing machines)[1]. Metals in particular achieved a high recycling ratio of approximately 90%. To further improve the total recycling ratio, it is necessary to recycle plastics, which account for more than 25% of the material composition ratio among the four items. From the viewpoints of environmental load and depletion of resources, the closed-loop recycling of plastic from waste home appliances is necessary, by using the plastic as a new raw material for home appliances.

Mitsubishi Electric has established Hyper Cycle Systems (HCS), the first plant for recycling household electric appliances in the industry, in Ichikawa City, Chiba ahead of legislation and has actively been developing plastic recycling technologies. Figure 1 shows an outline of the HCS closed-loop system for recycling plastics. HCS aims to achieve high-quality recycling and a closed-loop recycling system for reusing the plastics as a raw material for household appliances, by scrapping waste plastic items manually [2]. HCS has also developed a separation technology based on the difference in specific gravity to recover polypropylene

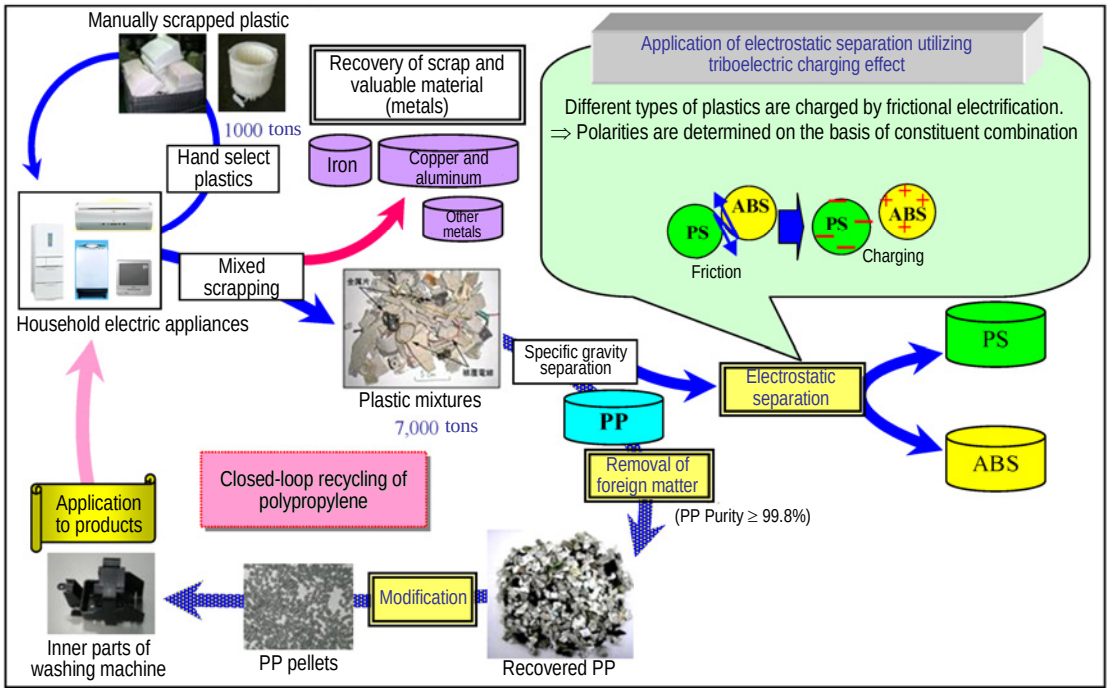


Fig. 1 Closed-loop recycling system for plastics

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(PP) plastics with a purity of 99% or more. Polypropylene plastics account for approximately 30% of plastic mixtures from waste household appliances, which mostly consist of plastic parts that cannot be scrapped manually and that have been landfilled or incinerated as shredder waste[2]. However, ABS and PS, which account for about 40% of the plastic mixtures, have almost no difference in specific gravity and so need to be separated by a new separation technology.

This paper discusses the current situation of the development of an electrostatic separation method[3] that utilizes the difference in charging characteristic of ABS and PS to separate plastic mixtures containing ABS and PS. The results of an evaluation on how much the closed-loop recycling method can reduce environmental load compared with landfill, incineration, and chemical recycling[4] are also described.

## 3. Electrostatic Separation Technology

### 3.1 Principle of electrostatic separation

Figure 2 shows the principle of electrostatic separation. ABS/PS plastic mixture is stirred in a rotating cylindrical triboelectric charger (made of ABS) for triboelectric charging. The polarities in triboelectric charging of different types of plastics are determined in accordance with the combinations of constituents as shown in Fig. 3. ABS plastic is charged positively (+), while PS plastic is charged negatively (–). After being charged, ABS and PS are separated by electrostatic force while they descend between electrodes.

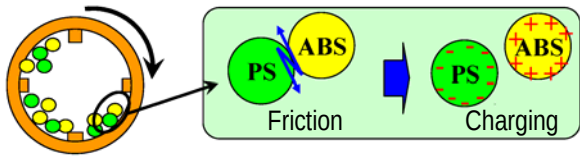


Fig. 2 Principle of electrostatic separation


Fig. 3 Relative position in triboelectric series of plastics

### 3.2 Verification of electrostatic separation accuracy

Table 1 shows the weight ratios of constituents of ABS/PS plastic mixture after specific gravity separation. PP, the specific gravity of which became 1.0 or higher because of the amount of fillers, accounts for 5% or more of the approximately 6% for "others" shown in the table. Figure 3 shows an electrostatic separator. The first-step electrostatic separation of ABS/PS plastic mixture is performed, and then the second-step electrostatic separation is applied to the material recovered in the recovery containers after the first-step electrostatic separation, and finally the composition of the material recovered after the second-step electrostatic separation is analyzed.

Table 1 Weight ratio of plastic mixture after specific gravity separation

| | |
|---|---|
| ABS | 32.4% |
| PS | 61.3% |
| Others | 6.3% |

Figure 5 shows the purities and recovery ratios of ABS and PS in the material collected from high-purity portions after the first-step electrostatic separation and the second-step electrostatic separation. The recovery ratios indicate the ratios of the ABS and PS contained in the collected material to their total amounts, respectively. Both the purities and recovery ratios of ABS and PS after the second separation were higher than those after the first separation. The highest purities of ABS and PS recorded after the second separation were 99.2% and 94.7%, respectively. However, their purities decreased to about 90% when the recovery ratios were above 90%. To increase both purities and recovery ratios, it is necessary to increase the degree of electrostatic charge of both ABS and PS. The reason why the purity of PS was lower than that of ABS is that the separation of PP which was charged with the same polarities as PS was not sufficient due to the relative

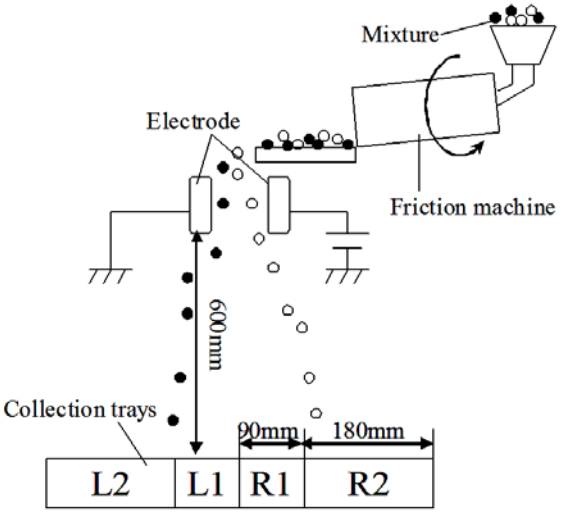


Fig. 4 Schematic diagram of electrostatic separation system

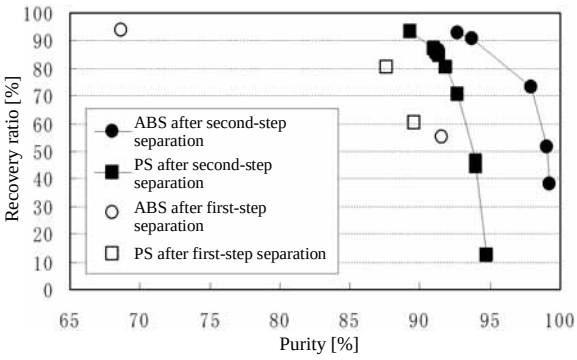


Fig. 5 Relation between purity and recovery after separation

position in the triboelectric series. It is clear that to improve the purity of PS, a method of improving the accuracy of PP separation is needed.

## 4. Life Cycle Assessment of Plastic Mixture Disposal Methods

Mitsubishi Electric's original material recycling technology, which can recycle PP, ABS, and PS contained in plastic mixtures from waste household appliances, was quantitatively assessed for its effectiveness in reducing the environmental load, in comparison with the conventional landfill method, incineration method, and chemical recycling method (for blast furnace material). For this assessment, we collected HCS data on the material balance, amount of energy required by processes, and so forth, and calculated $CO_2$ emissions during the plastic mixture disposal operation. The assumptions for the assessment included that PP, PS and ABS were obtained from material recycling, plastics of heavy specific gravity were obtained by incinerating PVC, while others were used for material and fuel for cement, and copper among metals was recycled. Figure 6 shows the results of LCA. The $CO_2$ emissions from the material recycling method were more than a third less than those from other disposal methods, proving that the material recycling method was the most efficient.

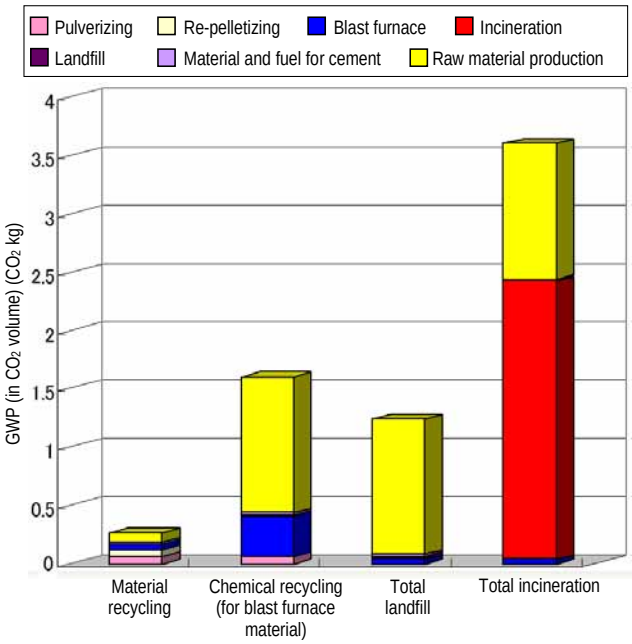


Fig. 6 Results of LCA of process to dispose of plastic mixture

## 5. Conclusion

PP separated from plastic mixtures of waste household appliances is already used for parts of washing machines and refrigerators. We will actively expand the scope of application to more parts, develop ABS/PS separation technologies as discussed in this paper, and promote the production of products designed for the environment by employing the closed-loop recycling method which was shown to be more advantageous than other disposal methods in terms of environmental load.

## References:

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