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HIGH PERFORMANCE RECYCLING SYSTEM FOR SHREDDED PLASTICS BY USING RAMAN IDENTIFICATION

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Abstract

Raman Spectroscopy is able to identify plastic components, similar to infrared absorption. This paper shows the potential application of Raman spectroscopy to waste plastic recycling when massive and accurate sorting processes are required. We developed a high-speed Raman apparatus for scanning with an appropriate wavelength region of less as 1.5 milliseconds, and a precise analyzing methodology. Spectroscopic identification could show additives and deterioration of the plastics. This technique is successfully implemented into the online sorting in a shredded plastic recycling plant with more than three hundred cycle decisions per second in one laser line. A practical-scale demonstration facility with fifty Raman apparatuses is constructed including the preprocessing system of specific gravity classification tank and metal remover for shredded plastics from used home appliances.

Keywords: *material recycling, plastic sorter, waste plastics, home appliances, Raman spectroscopy.*

1. Introduction

There is a growing need for plastic recycles globally. The classification of each kind of post-consumer plastic is the crucial technology for the material and chemical recycling that is very effective for saving natural resources and energy. However, few technique provides enough performance in respect of both speed and accuracy in the recycle industry. Spectroscopic identifica-tions such as infrared (IR) and near-IR (NIR) reflectance measurements are one of sophisticated candidates in the reliability comparing batch-screening techniques via specific gravity differences. In laboratoies, IR measure-ment is a common method used to identify kinds of plastics via molecular vibration information. Raman scattering measurement also provide similar information about the molecular structures. Such spectroscopic methods can definitively classify plastics [1]. In this paper, we present the applicability of Raman spectroscopy to industrial-scale waste plastic recycling that requires massive processing [2]. Figure 1 presents a scheme of the plastic sorting system in which Raman identifiers were implemented.

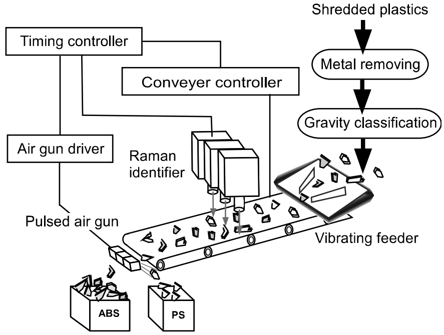

Fig. 1. Plastic sorting system with Raman spectroscopy

2. Materials and Methods

In Japan, a law encourages the recycle of the resources of home appliances and states that the used appliances (air-conditioner, refrigerator, TV and washing machine) should be collected by their distributors and sent to recycle plants operated by electronics companies. The collected appliances amounted up to 0.64 million tons in 2009. The shredded plastics as feedstock in our sorting system are excreted from these used home appliances and should be classified into main three kinds of plastics; polypropylene (PP), polystyrene (PS) and acrylonitrile-butadiene-styrene (ABS) polymers.

We have also developed the compact, high-speed and sensitive, home-made Raman spectrometer that is specialized for the plastic sorting. An optical part consists of a 785-nm high-power diode laser operated at 2 watts and a backside incident FFT-CCD detector of 1024 x 58 pixels. The optical system is designed to achieve high optical throughput with the appropriate resolution of 20 cm^{-1}. A data analysis part is embedded in a field programmable gate array circuit that is used instead of a CPU to reduce the signal processing time.

An overall sorting process is as follows; removing metal parts and electric wires by using magnetic force, classifying the shredded plastic mixture into PP and PS/ABS roughly in a water tank based on the specific gravity difference. Then the plastic pieces are fed under the Raman identifier by a high-speed (100 m/min.) belt conveyor. At the end of the conveyor a series of pulsed air guns sorts the identified plastic piece in synchronized timing. The fifty Raman identifiers in an array work parallelly in the one conveyor lane for the massive amount processing of 600 Kg / hour.

3. Results and Discussion

Raman spectra of PP, PS and ABS are shown in Fig.2. The samples are real waste plastics with white color and move in the speed of 100m/min. The measurement time is 3 ms without graphical displaying and the amount of Raman shift in horizontal axis corresponds in the direct pixel position of the CCD detector for the fast identification. A bottom axis shows the common representation in the unit of cm^{-1}. Even in the 3-ms measurement, they show the spectroscopic features with sufficient signal-to-noise ratio for the identification. A peak around 2300 cm^{-1} could distinguish ABS from PS; both plastics did not classify by the specific gravity separation.

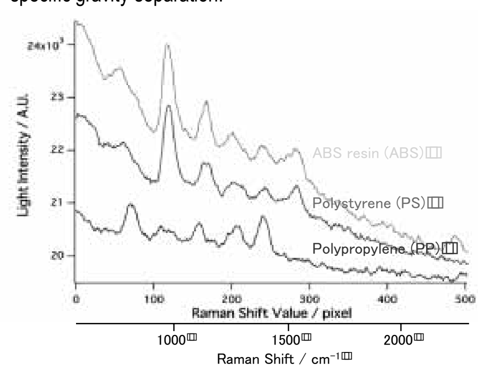

Fig. 2. Raman spectra of plastics in 3-ms measurement

The waste plastics contain many kinds of additives to improve the property for wide range applications of the polymers. High quality recycles such as a closed loop one require the sort and removal of the plastics containing the certain amount of the additives. Especially brominated flame retardants that is one of RoHS-regulated chemicals must be reduce less than 0.1 %. Fig. 2 shows the Raman spectra of prepared standard samples of PP containing Decabromodiphenyl Ether

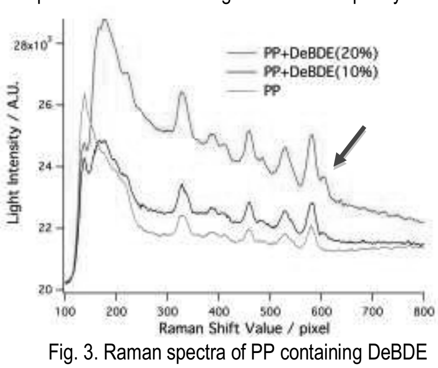

Fig. 3. Raman spectra of PP containing DeBDE

(DeBDE) in the measurement time of 100 ms. A Raman spectrum shows sharp peaks generally comparing IR and NIR one. The measurement in a fraction of a second provides a clear peak originating from a carbon-bromine bond at the arrow indication in Fig. 2.

The implemented identification algorism seeks the presence of normalized peaks simply. We are also developing the multivariate analysis technique based on Mahalanobis' generalized distance for data mining. This off-line analysis could provide the information about deterioration of the waste plastics.

Figure 4 presents an example of the performance of our waste plastic sorting system developed. The upper charts show the content percentages before and after sorting for the suspending samples in the specific-gravity-separation water tank and the lower for the settling. The purity of 98 % is obtained and its degradation is mainly affected by operation of the pulsed air guns.

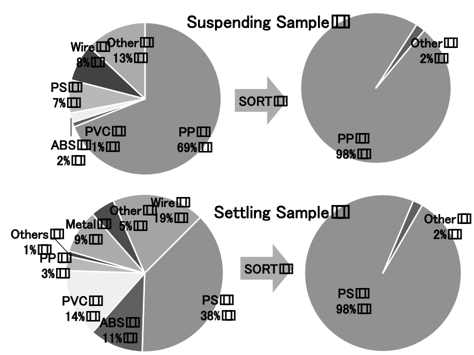

Fig. 4. Performance of the waste plastic sorting system based on Raman spectroscopy

4. Conclusions

In this paper we could successfully demonstrated that the applicability of Raman spectroscopy to the industrial-scale post-consumer plastic recycling with the acceptable performance in comercial stages. This identifying technique based on the Raman scattering could be applied not only the waste samples but also the fresh products for the quality control.

References

[1] V.Allen, J.H. Kalivas, and R. G. Rodriguez, "Post-Consumer Plastic Identification Using Raman Spectroscopy" *Applide Spectroscopy*, 53 (1999), 672.

[2]H. Kawazumi, Y. Tsuchida, Japan Patent No. 2008-209128, 2008.

Acknowledgment

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