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Material Discrimination Technique Using Hyperspectral Camera

1. Introduction

Spectroscopic analysis is used in various fields as a technique for measuring the chemical and physical properties of materials based on the spectrum of the reflected or transmitted light from the object. However, since many of the instruments are point-type spectroscopes targeting a single-point, application to measurement of large areas and measurements in in-line total inspections is difficult.

In response to this challenge, JFE Techno-Research Corporation developed an instrument which is capable of measuring the spectral data of all points in a 2-dimensional region using a hyperspectral camera that combines an "*ImSpector*" imaging spectrograph and a monochrome area camera. The available wavelength measurement range extends from visible light (380–800 nm) to the near-infrared region (1 000–2 500 nm). In this range, reflection and absorption spectra depending on the physical properties of the object can be obtained in the near-infrared region, allowing component analysis (qualitative and quantitative evaluation) of the object. Moreover, since these electromagnetic waves have low-energy, measurements can be performed as non-destructive inspections without damaging the material.

Utilizing these features, the hyperspectral camera can be applied to measurement and inspection in a variety of applications.

2. Imaging Spectrograph

The *ImSpector* imaging spectrograph is a transmission-type optical system which is materialized by a PGP (prism/grating/prism) element with a structure consisting of a holographic diffraction grating arranged between two prisms, and is used in combination with a monochrome area camera (**Fig. 1**).

This device converts light to 2-dimensional information by linearizing received light by a slit at the focal point of the lens and dispersing that light into separate wavelengths in the direction perpendicular to the slit as it passes through the PGP element. This 2-dimensional information is then captured as image data by the monochrome area camera located after the *ImSpector* and is transmitted to the computer. In the camera image data, the axis parallel to the slit is spatial information, and the perpendicular axis is wavelength information, allowing simultaneous multipoint spectroscopy corresponding to the pixel number of the camera.

Continuous spectral information for 2-dimensional space is obtained by relative movement of either the measurement target or the hyperspectral camera in the direction perpendicular to the linear field of view region of the hyperspectral camera, and continuously acquiring hyperspectral data.

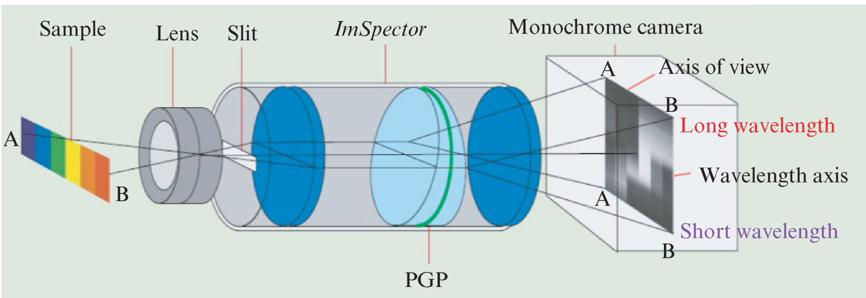


Fig. 1 Principle of *ImSpector*

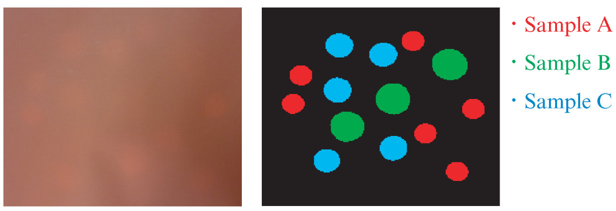
† Originally published in *JFE GIHO* No. 56 (Aug. 2025), p. 93−94

3. Applications of Near-Infrared Hyperspectral Camera

3.1 Measurement of Food in Packaging

"Food safety" is critical in the food industry, requiring component analysis and foreign object inspection. Near-infrared analysis is an effective technique for this purpose because foods contain many components such as water, fats, etc. for which information can be obtained in the near-infrared region. Since near-infrared light is transmitted through plastics, etc., it is also possible to measure the package interior, which cannot be checked by visual inspection. **Figure 2** shows the results of discrimination of the contents by multivariate analysis when multiple types of food products were measured in a plastic bag. Concretely, these are the results of discrimination of the types of contents from differences in the dispersion of the principal component score in a principal component analysis of the reflection spectra of the contents acquired by transmission through the packaging. Although inspection of the package contents is not possible by visual inspection, a total inspection can be performed at high speed by measuring the 2-dimensional region, making it possible to inspect products for foreign matter prior to shipment, even after the product is packaged.

On the other hand, contamination by foreign matter when raw materials for food products are received is also a challenge. Since materials for foods are harvested and transported in large quantities in the natural environment, it is difficult to completely eliminate foreign matter, such as leaves and branches in the case of fruits, when food materials are harvested. However, in this case as well, foreign matter can be excluded by performing raw material inspections using the near-infrared hyperspectral camera at the production line after the materials are delivered.



(a) Digital camera (b) Discrimination result

Fig. 2 Discrimination of food sample in a bag

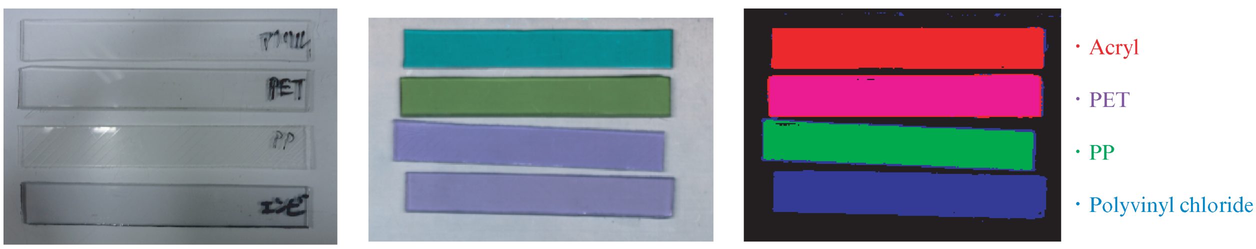
3.2 Measurement of Recycled Plastics

Since plastic products are treated by recycling in many cases, and the processing of each type of plastic is different, it is necessary to discriminate the types of plastics in the processing line. At present, manual sorting is frequently performed in recycling processing, but labor-saving devices that can sort the object materials at high speed are required. **Figure 3** shows the results of measurements of 4 types of plastic samples (acryl, polyethylene terephthalate (PET), polypropylene (PP), and polyvinyl chloride). Although all the samples appear transparent in visible light, it is possible to discriminate the various types of plastics by capturing the differences in the constituent components in the near-infrared region and applying an algorithm using multivariate analysis, etc. In spite of the large volume of samples flowing on the belt conveyor in the recycling process, inspection is possible without reducing the treatment rate by using a hyperspectral camera system. Moreover, because many organic materials have near-infrared characteristics, the hyperspectral camera can also be applied as an in-line inspection device for other materials, not limited to plastics.

4. Conclusion

In recent years, high quality has been demanded in all industries. To address this need, in-line inspection of the condition and foreign matter content of inspection objects (**Fig. 4**) is possible by introducing an inspection system using a hyperspectral camera that enables high-speed, 2-dimensional spectral analysis in the near-infrared region, as described in this article, making is possible to maintain a higher quality condition.

Utilizing the technologies and knowledge related to hyperspectral cameras cultivated by JFE Techno-Research over many years, we have proposed numerous



(a) Digital camera (b) Analysis results (c) Discrimination results

Fig. 3 Discrimination of plastics

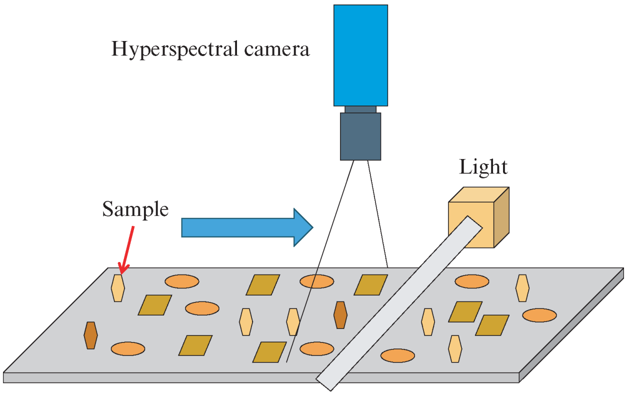


Fig. 4 Image of in-line inspection system

systems necessary to solve customer problems. Since JFE Techno-Research performs all the work from construction of the hardware for systems using hyperspectral cameras to development of the required software as an integrated process, we can also customize systems to meet the specific needs of each customer and supply a wide range of systems, from in-line equipment for commercial operations to experimental devices for use in research and development.

Because near-infrared hyperspectral cameras have the power to solve a wide variety of inspection-related problems, demand for these systems is expected to increase in the future. We hope that this article will encourage a wider interest in hyperspectral cameras among potential users.

Although the focus of this article is near-infrared hyperspectral cameras, JFE Techno-Research has also developed systems using hyperspectral cameras in a wide range of wavelength regions, including the visible light region. We also hope to contribute to the development of production and inspection technologies in various industries through the use of these hyperspectral camera systems.

For Further Information, Please Contact:

Sales Managing Dept., JFE Techno-Research
Phone: (81) 3–5877–5612
Homepage: https://www.jfe-tec.co.jp/en/