Development of NIR Composition Imaging System "Compovision"

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We have developed the composition imaging system with a near infrared (NIR) spectrographic camera. This camera incorporates a sensitive sensor that can detect the distinctive absorption spectra reflected or absorbed by organic substances in the wide wavelength band of 1,000-2,350 nm. The camera can process hyper-spectral data of 320 x 256 pixels at the frame rate of 100-320 fps, and thus enables precise real-time imaging. The composition imaging system is expected to be used for the non-destructive inspection of food and pharmaceutical products for their quality control and evaluation. This paper outlines the NIR spectroscopic camera and presents actual examples of image processing.

Keywords: near infrared camera, hyper-spectral camera

1. Introduction

In the pharmaceutical and food industries, product safety and quality control are becoming increasingly important. Therefore, inspection instruments that can measure the composition or concentration distribution of a specific substance without destroying the samples are strongly desired. Among these instruments, composition imaging systems that enable real-time inspection for the elimination of defective products are highly needed to realize high level quality assurance and reduce production costs.

As the measurement methods of product compositions and concentration distribution, near infrared (NIR) spectroscopic analyses, such as Fourier transform infrared spectroscopy (FT-IR), are commonly used. However, most of these measurement methods require thinly sliced samples because NIR rays are absorbed by water in the samples.

As the non-destructive and non-invasive measurement methods for the composition of a substance, multivariate analysis on the reflective spectra measured by NIR spectroscopic cameras is practically used. However, these cameras can only detect spectra in the wavelength range of 700-1,000 nm. The distinguishing features of spectra from a pharmaceutical or food product usually appear in the wavelength range up to 2,500 nm, which cannot be detected by practically used cameras.

To address these situations, we have developed a real-time composition imaging system "Compovision." This system has a newly developed NIR spectroscopic camera that can detect the NIR ray in the wavelength range of 1,000-2,350 nm[(1)-(3)].

In this paper, we introduce the features of the Compovision system and its application examples.

2. Composition Imaging with NIR Camera

The NIR spectroscopic camera processes hyper spectral data, in which each pixel has spectral data instead of a visible image. Therefore, by means of spectral analysis, the composition and concentration distribution of a target material can be determined for each pixel.

Figure 1 describes the mechanism of the hyper spectral imaging method. The NIR spectroscopic camera has a spectrograph in the camera body and a 2-dimenstional matrix NIR detector chip. The X-axis and Y-axis of the chip correspond to the spatial direction and wavelength, respectively. By moving the sample while taking hyper spectral images repeatedly at a high frame rate, 2-dimentional images with spectral data can be processed.

The NIR ray is invisible, but by assigning specific wavelengths to red, green and blue parameters, the Compovision system creates visible images of the sample. These images are called quasi-RGB images. In the quasi-RGB image, by choosing a distinguishing wavelength, the product composition can be displayed as a visible image.

In the wavelength range of 1,000-2,350 nm, there are distinguishing wavelength bands of water, fat and protein. Therefore, our NIR spectroscopic camera can inspect various food and pharmaceutical products.

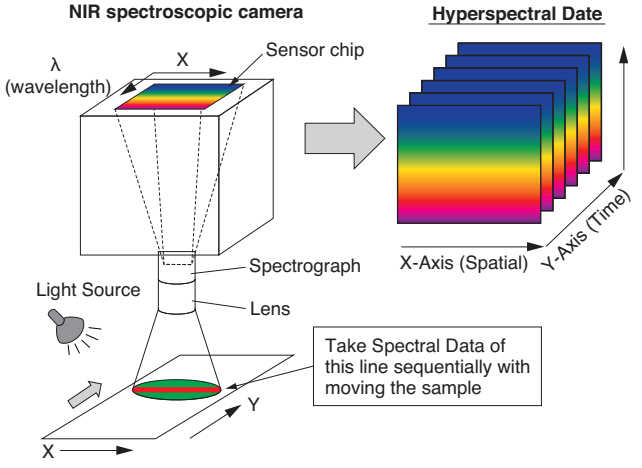


Fig. 1. Processing of Hyper spectral data with NIR spectroscopic camera

In our Compovision system, multivariate analysis is used for precise analysis of the hyper spectral data. Multivariate analysis can process the features of all spectra that contain composition information for 2-3 parameters. By using these parameters, composition imaging can be realized.

3. Specification of Compovision System

The Compovision system consists of an NIR spectroscopic camera, which has a spectroscope and 2-dimenstional NIR detecting chip for the wavelength range of 1,000-2,350 nm, and software for analysing and imaging hyper spectral data.

Our NIR spectroscopic camera can process hyper spectral data with 320 pixels in the spatial direction at the maximum frame rate of 320 fps (frames per second). This high frame rate enables high speed real-time imaging.

Photo 1 and **Table 1** show the image and specification of our NIR spectroscopic camera, respectively.

Photo 1. Compovision NIR spectroscopic camera

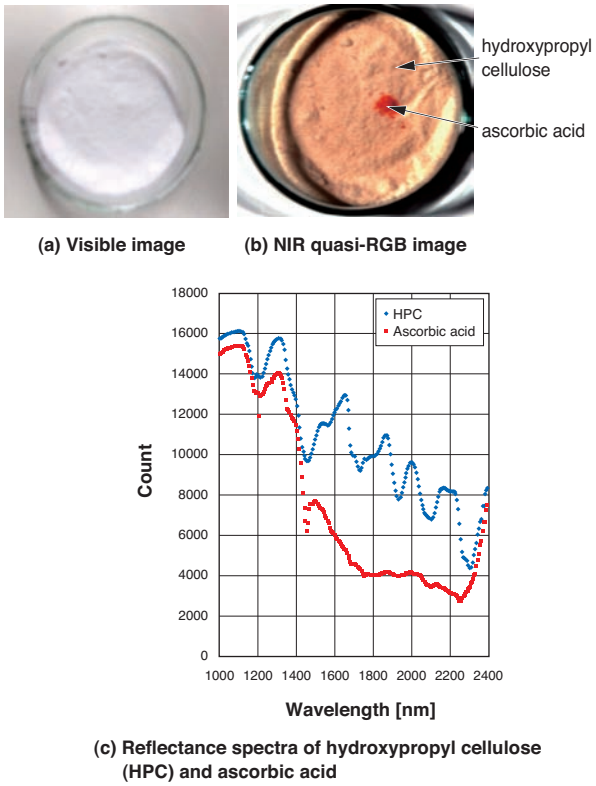
Table 1. Specification of NIR spectroscopic camera

Item	Specification
Detective wavelength range [nm]	1,000 - 2,350
Pixel (spatial)	320
Pixel (wavelength)	256
Pixel pitch [microns]	30
Frame rate [fps]	100 - 320
Operating temperature [deg. C]	5 - 40
Size [mm]	W120 × D410 × H130
Weight [kg]	7
Exposure time [ms]	1 - 9
Output data [bit]	16

4. Examples of Composition Imaging

4-1 Mixed white powders

Figure 2 shows the application of the Compovision system for the detection of differences between white powder and another kind of white powder.



(a) Visible image **(b) NIR quasi-RGB image**

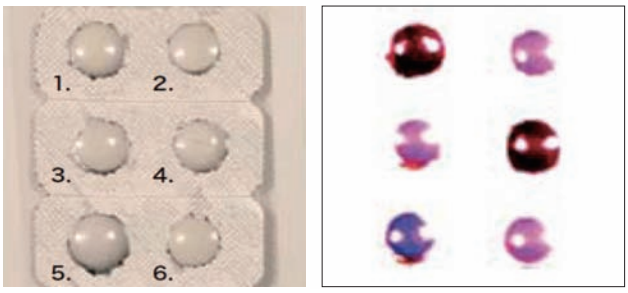
(c) Reflectance spectra of hydroxypropyl cellulose (HPC) and ascorbic acid

Fig. 2. Detection of mixed white powders

Figure 2 (a) shows a visible image of a mixture of kalium ascorbate and hydroxypropylcellulose (HPC), both of which are white powder. In the **Fig. 2 (a)**, the two kinds of powder cannot be distinguished from each other, but as shown in **Fig. 2 (b)**, the NIR image clearly shows the difference. This difference can be visualized by utilizing the difference of reflectance spectra as shown in **Fig. 2 (c)**.

4-2 Detection of tablets

The NIR ray can transmit through PTP film, and therefore, the Compovision system can inspect tablets packed in PTP encasement. Thus, the system is expected to be used for the detection of mistakenly mixed tablets in the packing process.



(a) Visible image **(b) NIR quasi-RGB image**

1, 4 : Cold medicine
2, 3, 6 : Headache medicine
5 : Vitamin supplement

Fig. 3. NIR imaging through PTP encasement

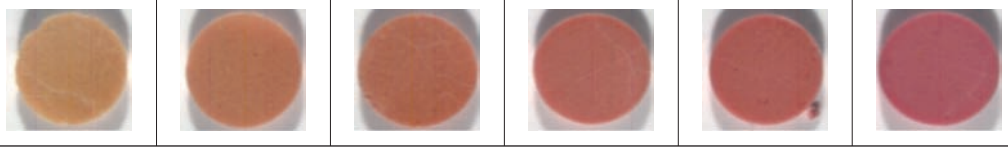
dextrin	10%	30%	40%	55%	60%	80%
Vitamin C	80%	60%	50%	35%	30%	10%
Visible image						
Quasi-RGB image						

Fig. 4. Consistency imaging

Figure 3 (a) shows the visible image of three kinds of white tablets in PTP encasement. As shown in this figure, the tablets cannot be distinguished from each other. Whereas, the Compovision system can create the visualized composition image based on the difference in the NIR spectra, as shown in **Fig. 3 (b)**.

4-3 Quantitative analysis of consistency

Figure 4 shows images of the mixtures of HPC with ascorbic acid or dextrin in different proportions.

Dextrin has reflectance spectra with distinguishing features in 1,900 nm band. There is a clear relationship between the spectrum shape and the mixture proportion. Based on this relationship, the mixture proportion can be estimated quantitatively and the resulting image can be visualized as shown in **Fig. 4**.

4-4 Analysis of tablet coating thickness

Figure 5 shows the measurement result of a coated tablet using the Compovision system. The tablet in **Fig. 5 (a)** is coated with a uniform thickness of magnesium stearate. On contrary, the tablet in **Fig. 5 (b)** has a non-uniform thickness coating.

NIR rays penetrate the tablet while partly being reflected by the coating material. Therefore, the thickness of the coating material can be analyzed from the reflected spectra.

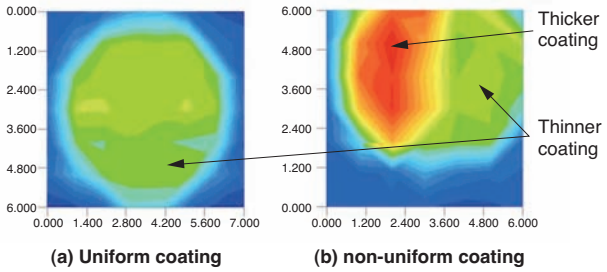


Fig. 5. Image of thickness of magnesium stearate coating
(This figure is result of collaborative work with prof. Ozaki group in Kwansei Gakuin Univ.)

In **Fig. 5 (b)**, the portion coated with a thicker coating is shown in red. This result shows the ability of the Compovision system to detect variations in coating thickness.

4-5 Analysis of oleic acid in beef

Multivariate analysis with the Compovison system enables the identification of amino acids contained in meat and the visualization of their distribution.

Figure 6 shows the measurement result of the distribution of oleic acid in three kinds of beef: A, B and C.

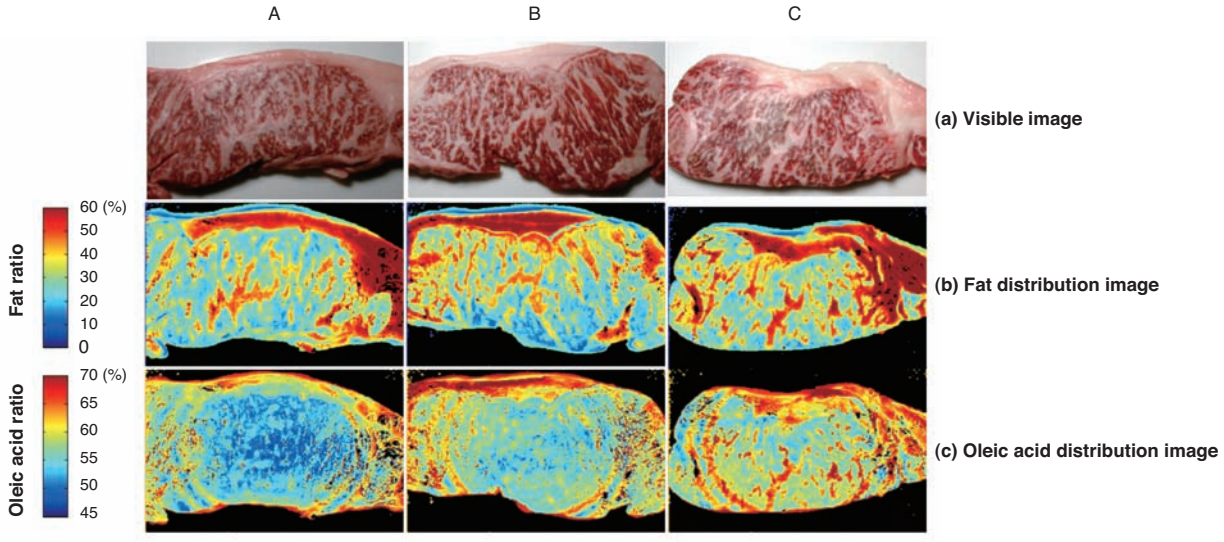


Fig. 6. Fat and Oleic acid distribution image of beef (This figure is from prof. Nakauchi in Toyohashi Univ. of technology)

Figure 6 (a) is the visible image. **Figures 6 (b) and (c)** are the imaging results showing the distribution of fat and oleic acid, respectively.

While samples A, B and C have similar fat distribution patterns as shown in **Fig. 6 (b)**, sample C has the largest amount of oleic acid as seen in **Fig. 6 (c)**. This means that the Compovision system can detect savory tastes of food.

5. Future Application of Compovision

As described above, NIR composition imaging technology is useful for quality control and inspection of pharmaceutical and food products. In addition to these applications, this technology is expected to be used in the inspection of homogeneity of creamy products and monitoring the status change of fermented food or beverage.

Sumitomo Electric Industries, Ltd. continues the research and development to find new applications of the Compovision system.

6. Conclusion

We have developed a composition imaging system "Compovision" that has a near infrared (NIR) spectroscopic camera. The Compovision system enables non-invasive and non-destructive composition measurements and real-time composition imaging. In this paper, we have introduced the features and application examples of this system.

The Compovision system has a high applicability for real-time inspection in the manufacturing process of food or pharmaceutical products, and is expected to improve quality control levels while also saving inspection costs.

References

(1) Inada, OPTRONICS (2012) No.5, p98
(2) Inada et al., SEI Technical Review, vol.177, p129, (2010 July)
(3) K. Awa et al., "Quality Evaluation of Pharmaceutical Tablets by using the New NIR Camera (Compovision) Developed for High Speed Wide Area Measurement," FACSS 2012

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