2026.09

HAMAMATSU
PHOTON IS OUR BUSINESS

Products for Material Recycling

Contributing to a Sustainable Society with Light

Supporting Material Recycling with Optical Technology

Key devices provided by Hamamatsu Photonics

In global economic activities, large amounts of resources are consumed, many of which are non-renewable. The expansion of resource extraction, processing, and production not only increases the risk of resource depletion and supply instability but is also a major cause of greenhouse gas emissions and ecosystem destruction.
Against the backdrop of issues such as resource constraints, climate change, and waste problems, “material recycling” is gaining global importance in realizing a sustainable circular society.

Hamamatsu Photonics develops and manufactures optical devices that serve as key devices for material recycling, based on its optical technology cultivated over many years. These optical devices enable highly accurate sorting of materials that were previously difficult to identify, such as mixed materials and additives, thereby making high-quality recycling possible.

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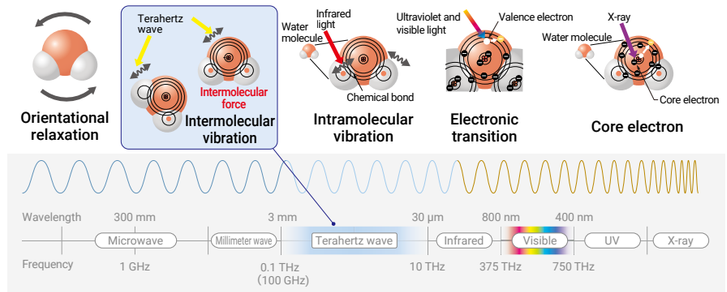
Optical Technology Used in Material Recycling

As various initiatives are being promoted around the world to realize a sustainable circular economy, “Material Recycling,” which involves converting used products and waste into raw materials and reusing them as materials for new products, is attracting attention as a core initiative in resource circulation.
In the EU, the WEEE*1 Directive and the ELV*2 Regulations legally define measures covering processes from collection to reuse, making high-quality material recycling essential. In particular, in the “small home appliances” and “automobiles” sectors, which use large amounts of materials and generate significant waste collection volumes, further advancement of material recycling is strongly required.
Hamamatsu Photonics provides optical technologies and key devices that contribute to higher precision in material identification and sorting across each process from collection to manufacturing in material recycling.

*1: Waste Electrical and Electronic Equipment (a system/regulation for the collection and recycling of waste electrical and electronic equipment in the EU)
*2: End-of-Life Vehicle (used vehicles)

Topics

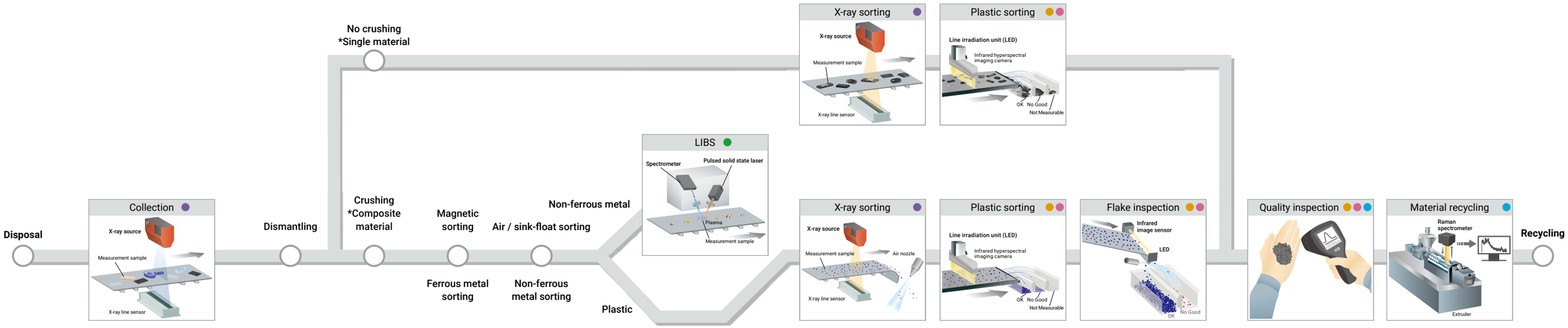
Material recycling using terahertz (THz) waves



Hamamatsu Photonics is advancing research on technology to non-destructively evaluate and estimate the strength and composition of recycled plastics derived from waste plastics, by utilizing machine learning and the characteristics of terahertz (THz) waves, which can penetrate into the interior of substances. Through this research, we aim to contribute to the realization of a resource-circulating society in the future.

This research was conducted under the Environment Research and Technology Development Fund (JPMEERF20253RB1) of the Ministry of the Environment, Japan and the Environmental Restoration and Conservation Agency.

Waste collection and sorting processes | Plastic sorting and manufacturing processes | Flaking | Repelletizing | Compounding



X-ray imaging

- Removal of LiB (lithium-ion batteries)
- Removal of plastics containing brominated flame retardants
- Removal of fiber-reinforced plastics

- **Dual energy X-ray line scan camera** P.8

LIBS (laser induced breakdown spectroscopy)

- Non-ferrous metal sorting

- **Mini spectrometer** P.10

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Near-infrared spectroscopy

- Plastic sorting
  e.g., PP, PE, PVC

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Mid-infrared spectroscopy

- Black plastic sorting
  e.g., PP, PE, PVC

- **InAsSb photovoltaic detector arrays** P.12

- **Mid-infrared LED** P.14

Raman spectroscopy

- Engineering plastic sorting
  e.g., PC, PA, POM, PBT
- Composition monitoring
  e.g., Additives (talc, reinforcing agents, etc.)

- **Raman spectroscopic module** P.21

Material recycling markets where Hamamatsu Photonics can contribute

Automobiles

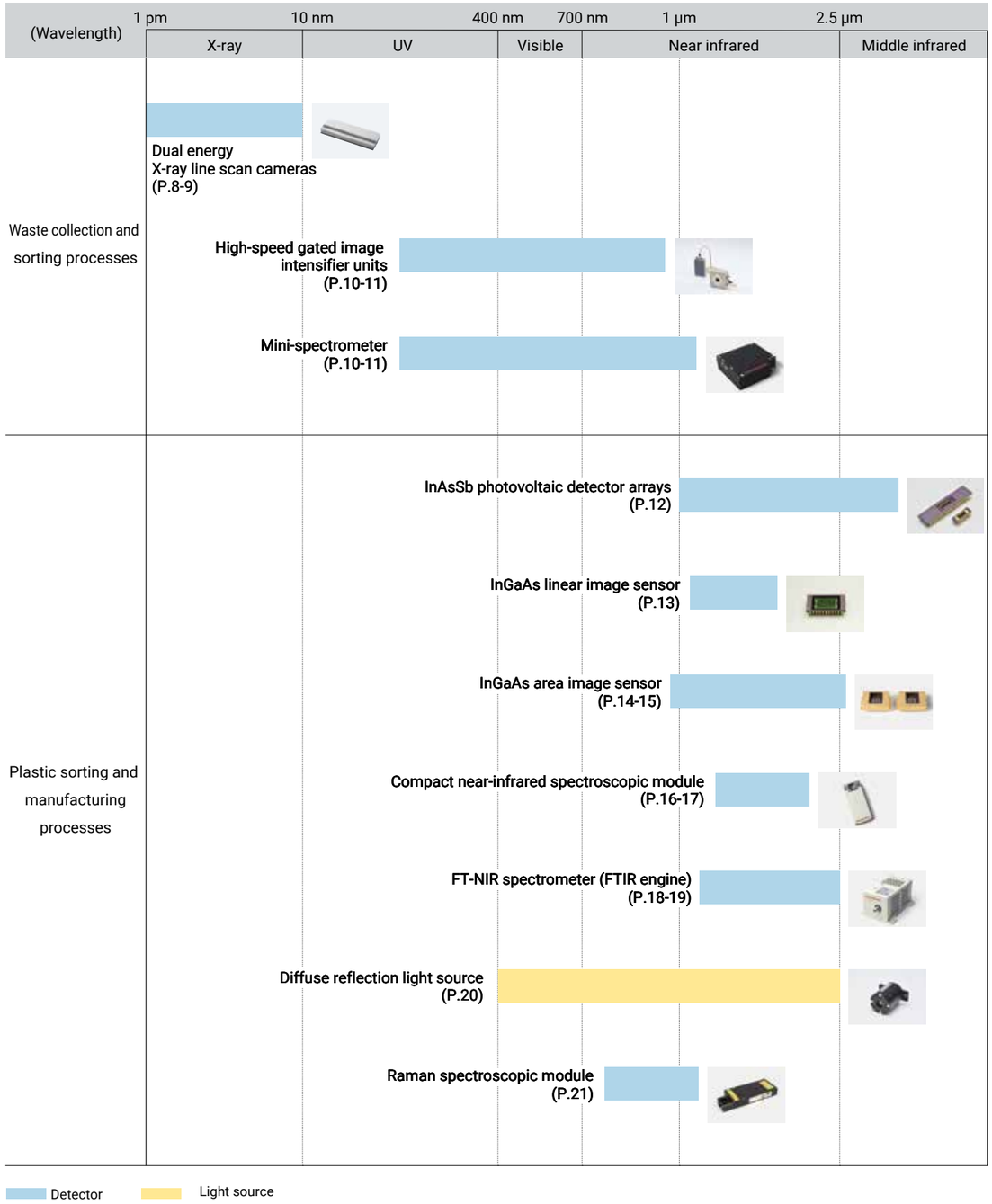
The automobile is one of the most advanced markets in circular design, from product design to the collection, sorting, and resource recycling of end-of-life vehicles, due to the EU's ELV*1 Regulations. In general, automobiles are manufactured using a wide variety of resins, metals, and plastics. In recent years, the diversification of materials has progressed due to factors such as higher functionality, weight reduction, and the shift to EVs, making it no longer possible to achieve high-precision recycling using conventional metal-centered recycling methods. Against this backdrop, higher sorting accuracy and improved uniformity in recycled material quality are required.

Small home appliances

The small home appliance market is subject to the EU's WEEE*2 Directive, which requires producers to take responsibility for the collection, sorting, and reuse of waste electrical and electronic equipment. Compared with automobiles, small home appliances generate larger waste volumes and have lower collection rates, while containing significant amounts of rare metals, precious metals, and hazardous substances. Therefore, efficient collection and reuse is essential both for securing resources and for reducing environmental impact. Against this backdrop, identification for accurately sorting a wide variety of mixed waste materials is required.

*1: End-of-Life Vehicle (used vehicles)
*2: Waste Electrical and Electronic Equipment (a system/regulation for the collection and recycling of waste electrical and electronic equipment in the EU)

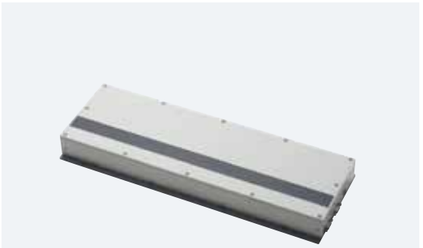
Product Lineup



Waste Collection and Sorting Processes

X-ray Imaging

Dual energy X-ray line scan camera C11800-08U/-09U



X-ray line scan camera suitable for removing foreign objects contained in plastics

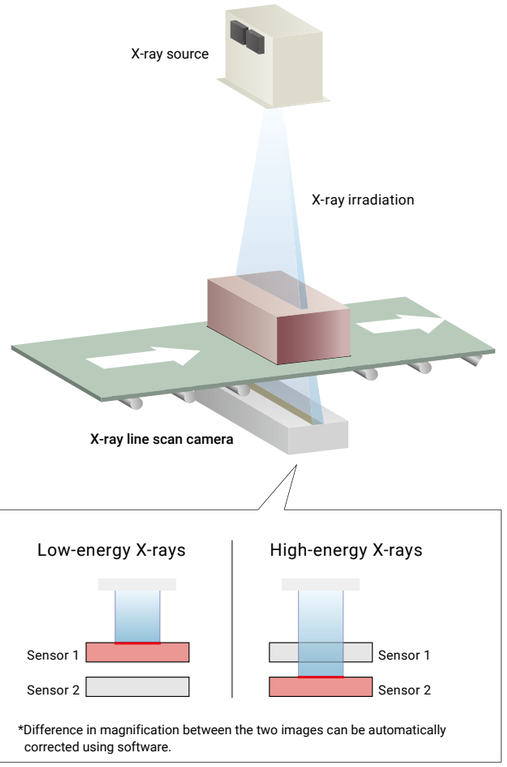
The dual energy X-ray line scan camera, which enables the separation of different materials, measures the X-ray absorption of two energy levels (high and low) and enhances contrast based on differences in the measurement samples. In plastic sorting, it is ideal for detecting composite plastics containing metal scraps, brominated flame retardants, and glass fibers that get mixed in as foreign objects.

Type no.	C11800-08U	C11800-09U	Unit
Camera type	Dual energy X-ray line scan camera		—
Effectuve X-ray tube voltage	Approx. 25 to 160		kV
Semsor element pitch	0.4		mm
Detection width	409.6	460.8	mm
Corresponding line speed	4 to 100		m/minutes
A/D converter	14		bit
External control	USB 3.0		—
Power supply	DC +15 to +24		V

Main features

Technology for enhancing detection “capabilities”
Next-generation X-raydetector equipped with 「DUALXTRAX™」

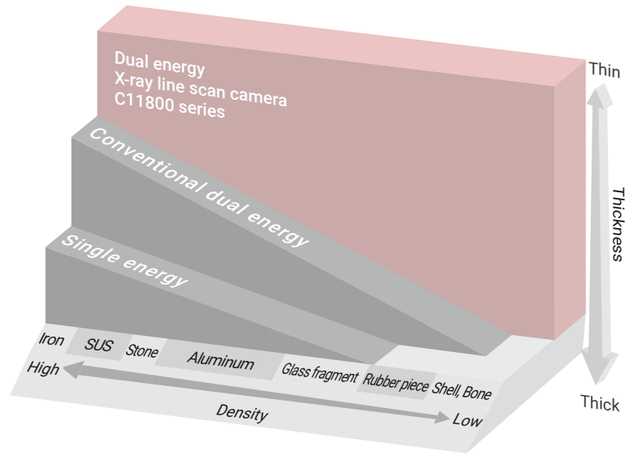
Conventional in-line non-destructive X-ray inspection using single energy detects materials and contaminant by thedifferences in the density of X-ray transmission images. However, in many cases, it is difficult to distinguish contaminant only by the gray level of an actual object because of the complex shape and uneven surfaces (i.e. variation of thickness) of various substances in the object.
This product is equipped with “DualXTRAX®,” a technology that combines a high-sensitivity X-ray detector with the new image processing technology. Computational technology using high hardware performance has greatly improved detection capability with high and low energy images. Furthermore, unnecessary information such as backgrounds, can be removed, resulting in a dramatic enhancement in discrimination performance.
This enables the advanced distinction of low-density and thin objects, which was previously difficult to detect.



*Difference in magnification between the two images can be automatically corrected using software.

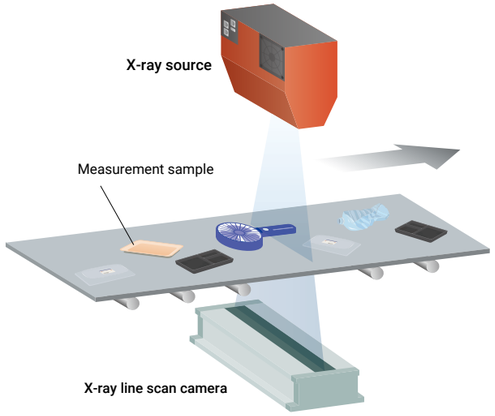
Corresponding containment comparison diagram

Material identification is enabled across a wide range of conditions, from high-density to low-density samples, as well as from thin to thick samples.

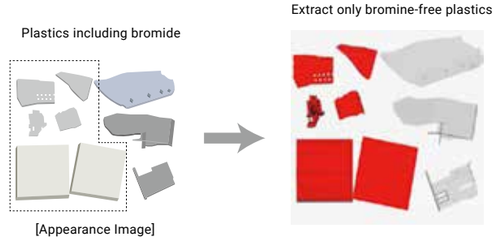


Imaging examples

Plastics that cannot be distinguished in visible images can be sorted based on material composition and displayed in pseudo-color.

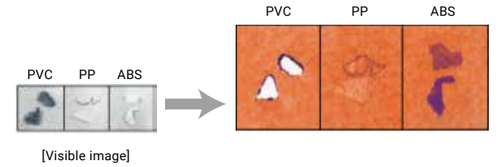


Captured image: Flame-retardant plastic



Captured image: PVC (polyvinyl chloride)

PVC and ABS judgement by pseudo-color
PP is out of judgment



LIBS

Mini-spectrometer C16449MA-02
High-speed gated image intensifier units C14245 series

Product lineup

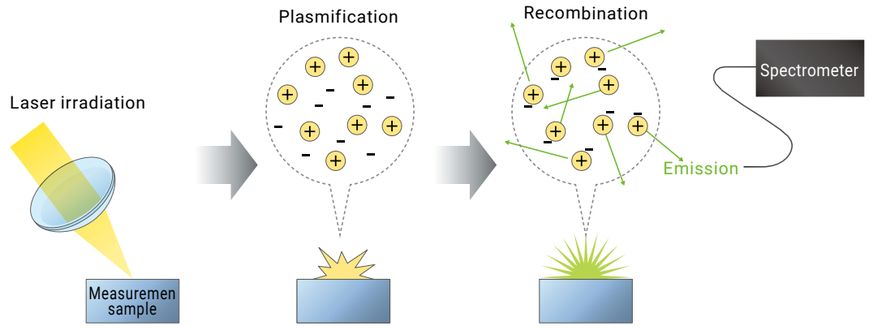
Parameter	Spectrometers	Photosensors
Product name	Mini-spectrometer	High-speed gated image intensifier units
Type no.	C16449MA-02	C14245 series
Product photo		
Operating environment	Inline	Inline
Measurement distance*1	Approx. up to 30 cm	Approx. 4 m to 8 m
Features	● Wide spectral response range ● High resolution ● Built-in high-sensitivity CMOS image sensor ● With trigger function ● No external power supply required (USB bus powered)	● High-speed phenomenon observation ● Enables low-level light imaging ● Supports from UV regions to near-infrared regions ● Can be used as an I-CMOS camera when combined with a CMOS camera (C11440-36U) 

*1: Measurement distance between the measurement unit and the sample. The measurement distance varies depending on the equipment into which the unit is integrated.

Principle of LIBS

LIBS* is a spectroscopic method that analyzes elements in a sample at high speed. High energy laser light is irradiated on to a to turn part of the sample into plasma. The intrinsic spectrum of the contained elements generated during the subsequent recombination is then measured. Since no pretreatment is required regardless of the sample state (gas, liquid, or solid), it is possible to sort a wide range of substances such as plastics (including black plastics), metals, and glass.

* Laser Induced Breakdown Spectroscopy

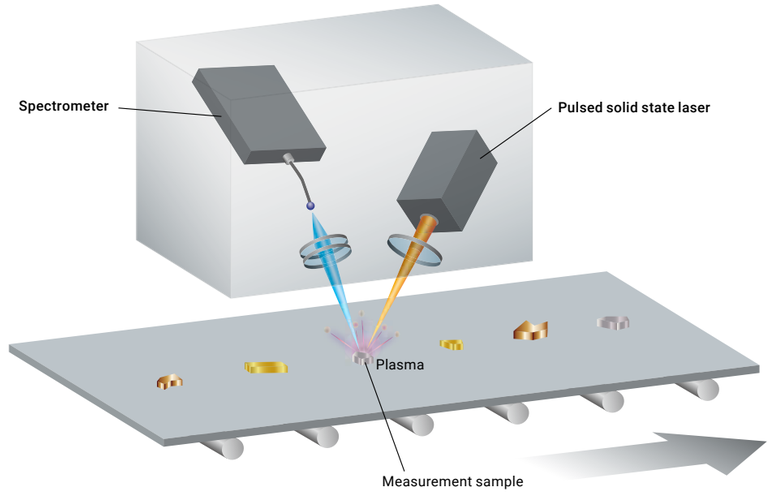


Application examples

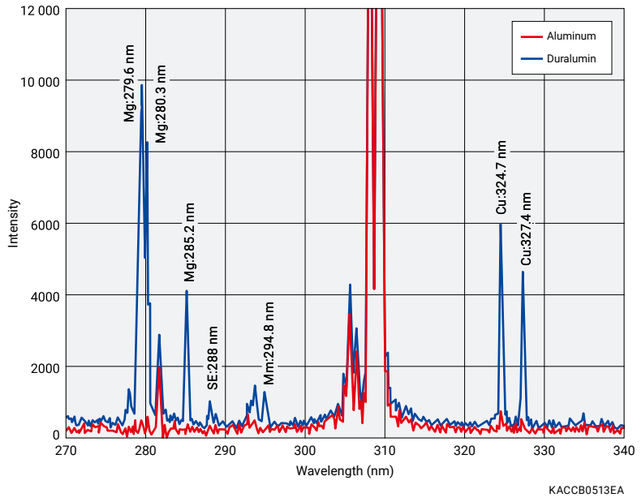
Metal sorting

Sorting equipment using LIBS technology allows for elemental analysis of measurement samples. By focusing on differences in the composition, it is also possible to sort alloys such as aluminum (pure aluminum) and duralumin (aluminum alloy).

■ Measurement image



■ Measurement result



Plastic Sorting and Manufacturing Processes

Mid-Infrared Spectroscopy

InAsSb photovoltaic detector array P15742-016DS, P15742-046DS

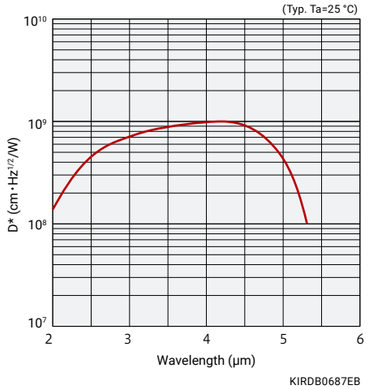
Middle-infrared photosensors capable of sorting black plastics

Since the pigment carbon black contained in black plastics absorbs near-infrared light, it is possible to sort black plastics by using light in the middle infrared region up to 5 µm.

Type no.	P15742-016DS	P15742-046DS	Unit
Number of elements	16	46	—
Element size	0.45 × 0.7	0.2 × 0.7	mm
Package	18-pin ceramic DIP	48-pin ceramic DIP	—
Cutoff wavelength	5.3 typ.		µm

■ Spectral response

High sensitivity in the middle infrared region



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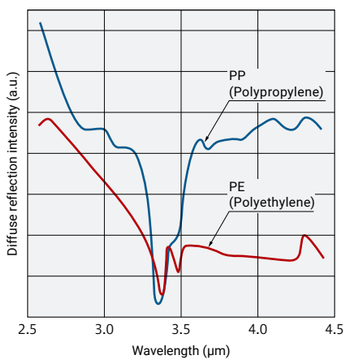
■ Measurement example

Absorption spectra of black plastics (PP, PE)



Data provided by Professor Hirofumi Kawazumi (Research fellow, Institute of Systems, Information Technologies and Nanotechnologies (ISIT))

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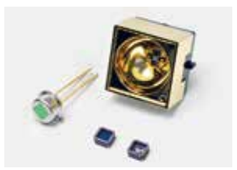
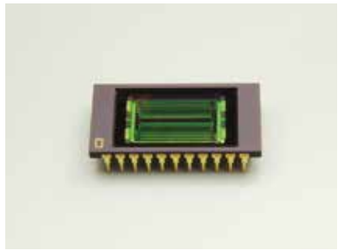


Mid-Infrared LEDs L15893 / L15894 / L15895 series

By combining multiple wavelengths, they covers the wide spectral range required for plastic sorting. It is being considered for utilization in black plastics sorting by integrating into middle infrared hyperspectral imaging.

Near Infrared Spectroscopy

InGaAs linear image sensor G14006-512DE



Near-infrared image sensor capable of sorting single plastics

This near-infrared image sensor achieves high sensitivity and high-speed readout in the near infrared region of 1.12 µm to 1.9 µm. By removing plastics other than the specific plastics (dissimilar plastics) from a mix of multiple types of plastics, sorting single plastic material is possible.

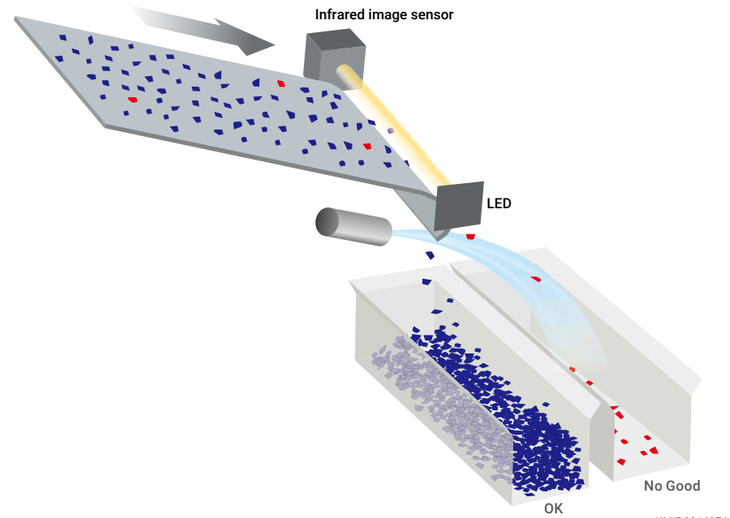
Parameter	Specification	Unit
Spectral response range	1.12 to 1.9	µm
Pixel pitch	25	µm
Number of total pixels	512	pixels
Dark current	10 max.	pA
Line rate	8150 max.	lps

Application example

Sorting different plastics with near-infrared spectroscopy

Plastics are irradiated with light, and foreign objects are detected by analyzing the transmitted light. The detected foreign objects are then removed with a high-pressure air jet.

■ Measurement image



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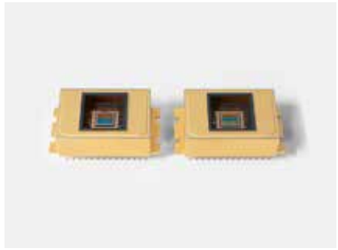
Near Infrared Spectroscopy

InGaAs area image sensors G16561-0909T, G16562-0909T, G17242-0808T,G17243-0808T



Near-infrared image sensors capable of sorting multiple types of plastics

These InGaAs area image sensors cover a wavelength range of 0.9 µm to 2.55 µm and realize a high frame rate of up to 503 fps in full-pixel readout. They are possible to sort plastics that are difficult with visible images by equipping these sensors in a hyperspectral camera and analyzing near-infrared images.

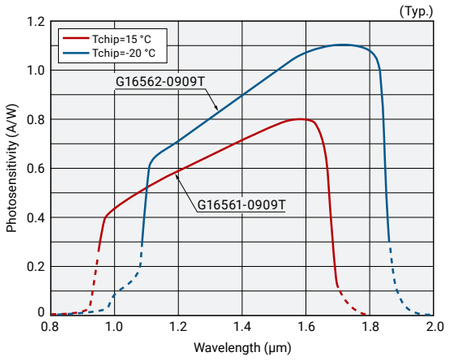
Type no.	G16561-0909T	G16562-0909T	G17242-0808T	G17243-0808T	Unit
Spectral response range	0.95 to 1.69	1.12 to 1.85	0.9 to 2.15	0.9 to 2.55	µm
Pixel size	20 × 20				µm
Number of total pixels	640 × 512		320 × 256		pixels
Dark current	0.03 typ.	0.3 typ.	0.01 typ. (1.7 µm area)	0.01 typ. (1.7 µm area)	pA
			3.0 typ. (2.2 µm area)	3.0 typ. (2.2 µm area)	
				30 typ. (2.6 µm area)	
Frame rate*2	116 max.		503 max.		fps

*2 : At full-pixel readout

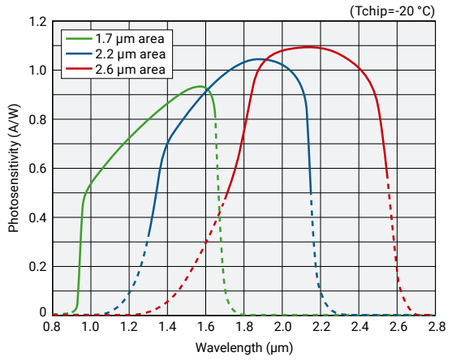
Main features

● Product lineup with sensitivity up to 2.55 µm

Spectral response of G16561-0909T and G16562-0909T



Spectral response of G17242-0808T and G17243-0808T



InGaAs area image sensor module C16090 series

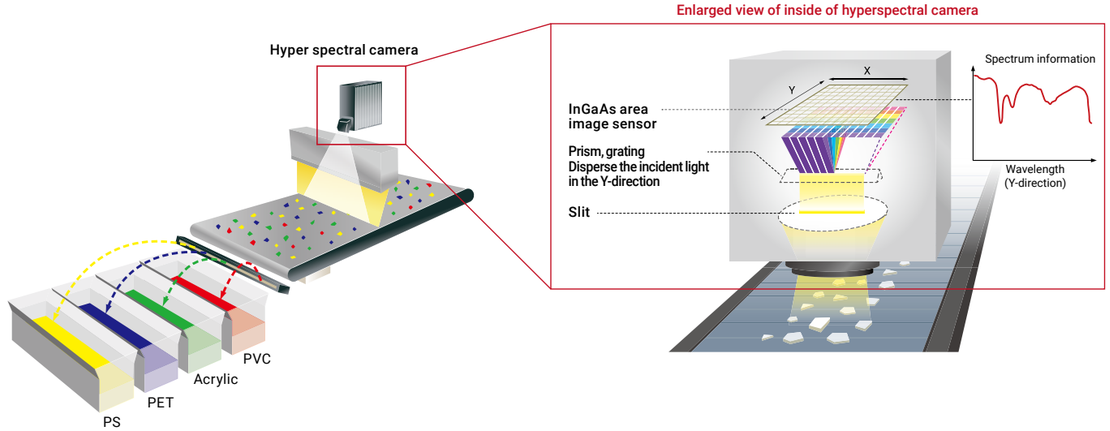
This module is equipped with an InGaAs area image sensor. It consists of a driver circuit, a temperature controller, and a high-speed communication controller,etc. It outputs analog video signals from an InGaAs area image sensor as digital output.

Application examples

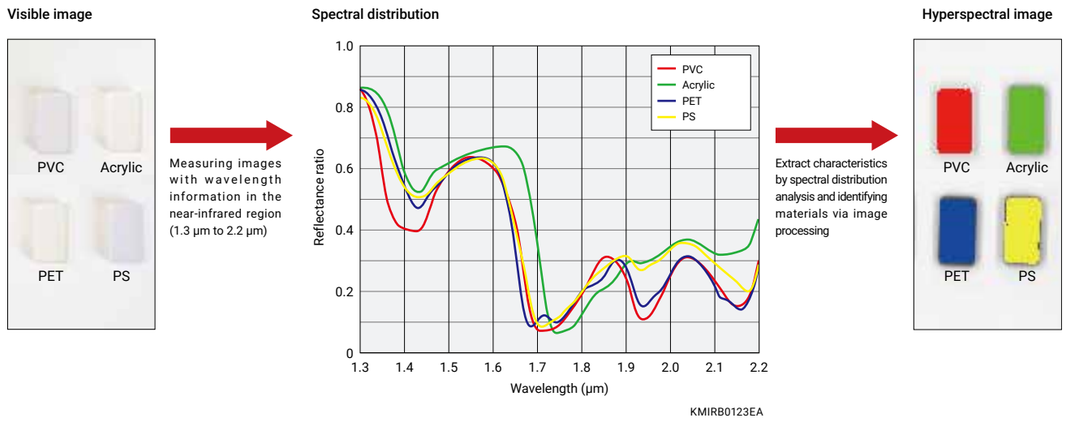
Plastic Sorting Using Hyperspectral Imaging

Hyperspectral imaging is a method in which pixel-level spectrum information is acquired simultaneously when capturing images of the measurement sample. It is a useful method to identify and classify materials that are difficult to distinguish visually.
Similar to a normal line scan camera, scanning is performed by moving the measurement samples (or the camera). The input light passes through a slit, is dispersed by a prism and a grating into the Y-axis direction of the sensor, and is measured by an area image sensor. Since plastics exhibit characteristic spectra in the near-infrared region, highly accurate identification becomes possible by using a hyperspectral camera incorporating a near-infrared area image sensor.

■ Measurement image



■ Measurement results (measurement comparison of 4 types of plastics)



Near Infrared Spectroscopy

Compact near-infrared spectroscopic module C17553

Compact spectroscopic module capable of simple plastic sorting

This compact spectroscopic module has a built-in light source, control circuit, and MEMS-FPI* spectrum sensor consisting of a MEMS-FPI tunable filter and an InGaAs PIN photodiode. It is expected to be incorporated into portable equipment that makes it possible to check on the spot whether items such as food trays and PET bottles in collection boxes are sorted properly by plastic type.

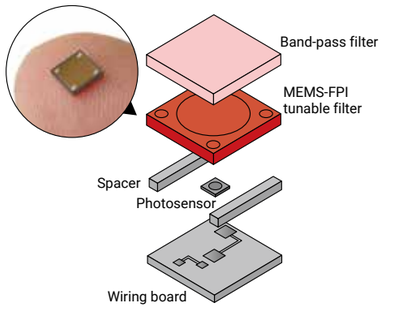
* FPI : Fabry-Perot interferometer

Parameter	Specification	Unit
Sensor	MEMS-FPI spectrum sensor	—
Spectral response range	1.55 to 1.92	μm
Spectral resolution (FWHM)	21 max.	nm

Structure (MEMS-FPI spectrum sensor)

Though this is a spectrum sensor, it uses a single-element photosensor and does not require expensive multichannel photosensors (photodiode arrays or image sensors). The MEMS-FPI tunable filter and the photosensor are arranged on the same axis as the direction of incident light, making it a simple configuration. Another advantage is high optical throughput because the aperture size can be made larger.

■ Internal structure



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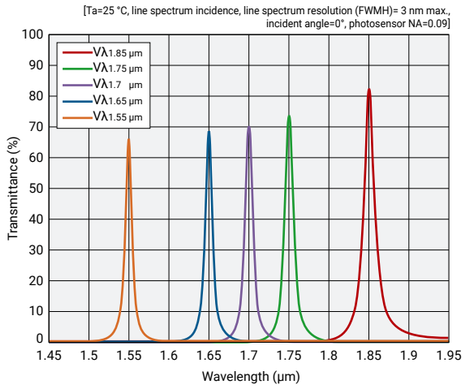
■ MEMS-FPI tunable filter transmittance vs. wavelength



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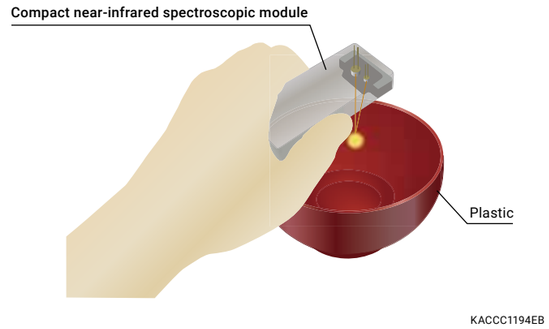
Application examples

Light from a tungsten lamp is irradiated on the plastic and the reflected light is detected by the compact near-infrared spectroscopic module.

■ Measurement image



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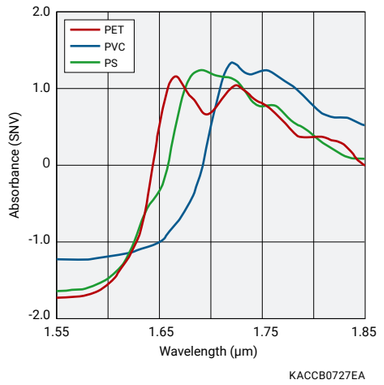
■ Measurement of white plastics (PET, PVC, PS)

This is a measurement example of different types of white plastics (PET: polyethylene terephthalate, PVC: polyvinyl chloride, PS: polystyrene).



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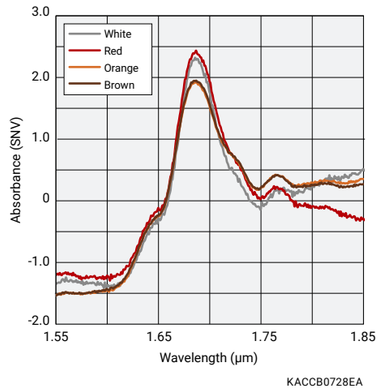
■ Measurement of colored plastics for food (PS)

This is a measurement example of the same plastic (PS) with different colors (white, red, orange, and brown).



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White Red Orange Brown

Near Infrared Spectroscopy

FT-NIR spectrometer (FTIR engine) C16511-01

Near-infrared spectrometer capable of sorting plastics containing additive compounds

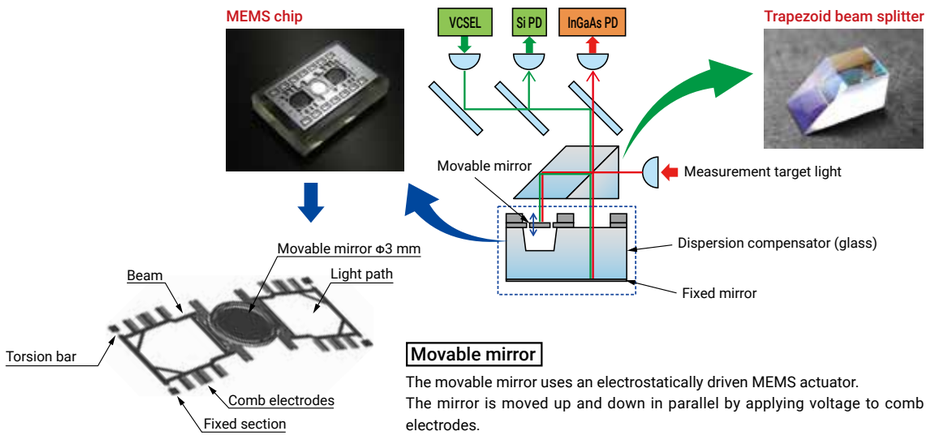
Many plastics contain flame retardants and reinforcing agents to prevent ignition or increase strength, and they are widely used in home appliances and other products.
The FT-NIR spectrometer C16511-01 is a palm-sized Fourier-transform spectrometer which covers the near-infrared region up to 2.5 µm.
Since it can detect up to around 2.4 µm, where spectral differences appear depending on the presence or absence of flame retardants, it enables the sorting of plastics containing flame retardants.

Parameter	Specification	Unit
Spectral response range	1.1 to 2.5	µm
Optical interferometer	Michelson interferometer (Φ3 mm movable mirror installed)	—
Photodetector	InGaAs PIN photodiode	—
Light input method*3	Optical fiber input type (with SMA connector)	—
Interface	Ethernet communication (GigE Vision)	—
Dimensions (W × H × D)	124 × 68 × 66 (excluding Protrusions)	mm
Spectral resolution (FWHM)*4	5.7	nm
Signal-to-noise ratio	10000:1	—
Weight	580	g

*3: Optical fiber (core diameter: 600 µm, NA: 0.22)
*4: λ=1533 nm

Structure

Interference light occurs when measurement target light (incident light) is split by a beam splitter, reflected by a movable mirror and a fixed mirror respectively, and then recombined. The intensity of the interference light, which varies depending on the position of the movable mirror, is detected by a photodetector (InGaAs PIN photodiode), and then the signal is subjected to arithmetic processing (Fourier transform) to obtain the optical spectra. By measuring the position of the movable mirror within the same interferometer using a photodetector (Si PIN photodiode) and a semiconductor laser (VCSEL), it is possible to obtain optical spectra with high wavelength reproducibility.



Movable mirror

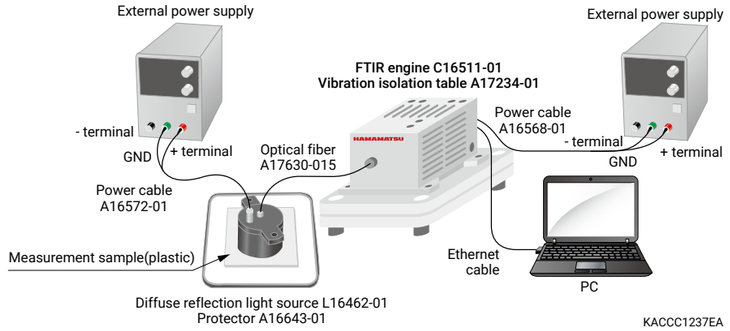
The movable mirror uses an electrostatically driven MEMS actuator.
The mirror is moved up and down in parallel by applying voltage to comb electrodes.

Measurement example

Sorting of plastics containing flame retardants

Flame retardants contained in plastics can be sorted by identifying differences in the spectra in the 1.4 µm to 2.5 µm band.

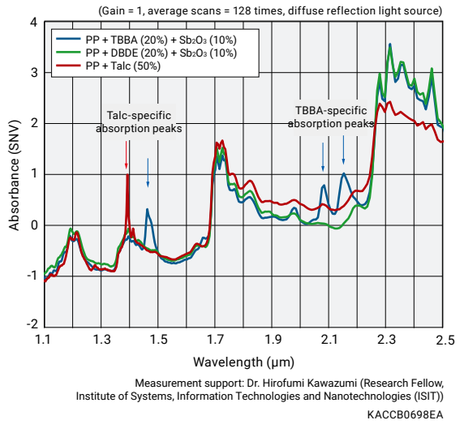
■ Measurement system



[Sorting of white plastics (PP: Polypropylene)]

The figure below shows the absorption spectra of flame retardants TBBA (tetrabromobisphenol A) and DBDE (decabromodiphenyl ether), and Talc. Since there is a peak around 1.4 µm, the red spectrum can be inferred to be a Talc-specific component. Although TBBA and DBDE have similar spectra, it is possible to infer each component from the difference in the peaks around 2.1 µm.

■ Measurement result

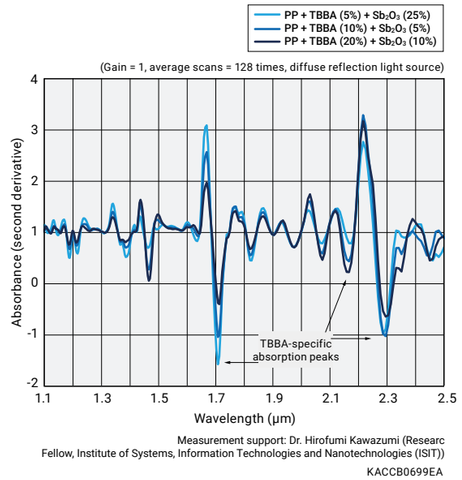


Measurement support: Dr. Hirofumi Kawazumi (Research Fellow, Institute of Systems, Information Technologies and Nanotechnologies (ISIT))
KACCB0698EA

[Estimation of concentration levels]

The figure below shows the absorption spectra of white plastics containing different concentrations of the additives of TBBA (tetrabromobisphenol A) and Sb_2O_3 (antimony trioxide). The concentration of TBBA can be estimated from the differences in absorbance at 1.7 µm, 2.2 µm, and 2.3 µm.

■ Measurement result



Measurement support: Dr. Hirofumi Kawazumi (Researc Fellow, Institute of Systems, Information Technologies and Nanotechnologies (ISIT))
KACCB0699EA

Near Infrared Spectroscopy

Diffuse reflection light source L16462-01

Near-infrared spectroscopic light source suitable for bioplastic sorting

The diffuse reflection light source L16462-01 is a compact light source designed for use with a near-infrared spectrometer. Its integrated structure, which combines a tungsten lamp for irradiation and an optical fiber for light guiding, enables the near-infrared spectrometer to efficiently detect light reflected from the sample. It can be used for sorting bioplastics.

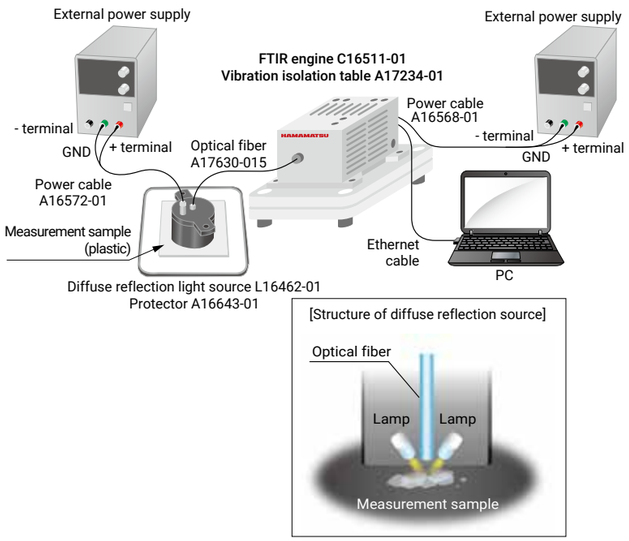
Parameter		Specification	Unit
Dimensions (excluding protrusions)		Φ28 × 35.5	mm
Built-in lamp (Tungsten lamp)	Number of lamps	4	pcs
	Recommended supply voltage	+5	V
	Average lifetime	7000	hr

Measurement example

Sorting of biodegradable bioplastics

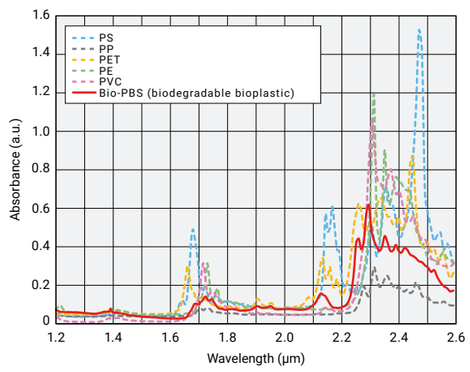
Biodegradable bioplastics have attracted attention as materials that can significantly reduce the burden on the global environment. By sorting biodegradable plastics from non-biodegradable plastics, efficient recycling becomes possible, and a reduction in plastic waste disposal is expected.

■ Measurement system



KACCC1176EB

■ Measurement result



Measurement support: Hamamatsu Central Research Laboratory

KACCB0730EC

Near Infrared Spectroscopy

Spectroscopic module C15471

Raman spectroscopic module capable of sorting black plastics

Raman spectroscopy is less affected by pigment carbon black contained in black plastics compared with near-infrared light, enabling composition analysis of black plastics. Since the absorption spectrum peaks appear clearly, highly accurate sorting becomes possible, and its application to sorting high-performance resins used in products such as lenses is being considered.

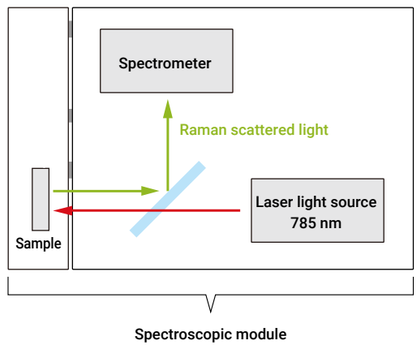
Parameter	Specification	Unit
Spectral range	200 to 2500	cm^{-1}
Resolution	10	cm^{-1}
Dimensions (W × H × D)	130 × 20 × 60	mm

Measurement example

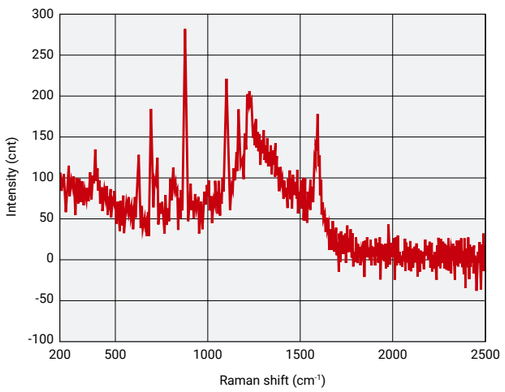
Measurement of black plastic (PC)

This is an example of measuring the Raman scattered light spectrum of black plastic (PC: polycarbonate) with the spectroscopic module C15471.
The black plastic sample is irradiated with a 785 nm laser, and the Raman scattered light is detected by the spectroscopic module.

■ Structure



■ Measurement result



Measurement support: Dr. Hirofumi Kawazumi (Research Fellow, Institute of Systems, Information Technologies and Nanotechnologies (ISIT))

KOTHB0128EA

Related Information

Test imaging

As a preliminary evaluation in response to customers' requests for non-destructive inspection, we perform test imaging using various X-ray sources, sensors, and cameras. In addition to proposing the most suitable devices, we also provide optimal solutions that include tips and know-how for imaging. Please feel free to contact us.

https://www.hamamatsu.com/all/en/inquiry/input.html/content/hamamatsu-photonics/global-web/all/en/applications/non-destructive-testing.html

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- The content of this document is current as of September 2026. Product specifications are subject to change without prior notice due to improvements.
- When installing and using this product, carefully read and strictly observe the precautions and prohibitions described in the instruction manual and other related documents.

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www.hamamatsu.com

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