Excellence in Science

Fourier Transform Infrared Spectrophotometer

Application News

# Identification of Plastics/Microplastics (MPs) Using FTIR

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## User Benefits

- Plastics (including MPs) can be easily identified by measuring them using an FTIR spectrophotometer and searching spectral libraries.
- Plastics can be identified with higher accuracy by comparing the library search results with the summary of wavenumbers for major peaks of typical plastics (Table 10).
- Additionally using the Library for UV-Degraded Plastics for library searches can be expected to improve the accuracy of identifying plastics (including MPs) in the environment.

## ■ Introduction

The material characteristics of plastics in the environment must be confirmed before they can be used for research, recycling, or other applications. The material characteristics of plastics can be confirmed nondestructively and quickly using Fourier transform infrared (FTIR) spectrophotometry, which measures the vibrational modes originating from molecular functional groups of materials as peaks in infrared spectra[1]. Then the material can be identified by comparing the multiple measured vibrational modes with spectra in a database (spectral library) in software, where identification involves narrowing down the similar candidate substances using indices, such as similarity score, hit quality, and HQI (high quality index) values, with the final decision made by a human. Therefore, by memorizing the major peaks of typical plastics, substances can be identified with higher accuracy. For information about the attribution of peaks, refer to FTIR Talk Letter vol. 42 to 46.

This article describes the results from measuring the infrared spectra of typical plastics before and after UV degradation and comparing the peak wavenumber information for major peaks with other literature.

Fig. 1 IRSpirit™-X +QATR™-S (left) and IRXross™+QATR™10 (right)

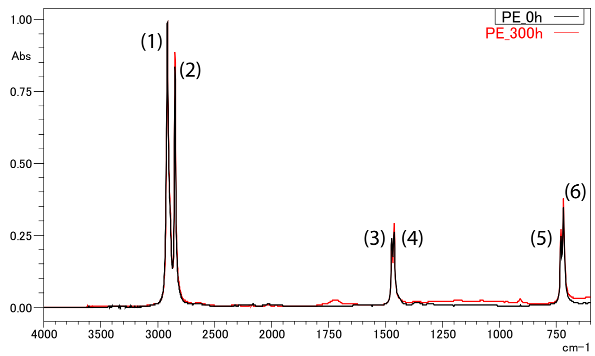


Fig. 2 Infrared Spectrum of Polyethylene (PE)
Black line: Before UV degradation,
Red line: After UV degradation (300 hours irradiation)

Table 1 Wavenumbers of Major Polyethylene (PE) Peaks

| | PE (Polyethylene) | |
|---|---|---|
| | Japanese MOE Guidelines | ISO 16094-2 |
| (1) | 2915 cm$^{-1}$ | 2915 cm$^{-1}$ |
| (2) | 2845 cm$^{-1}$ | 2850 cm$^{-1}$ |
| (3) | 1472 cm$^{-1}$ (High density)<br>1467 cm$^{-1}$ (Low density) | 1472 cm$^{-1}$ |
| (4) | 1462 cm$^{-1}$ | 1461 cm$^{-1}$ |
| (5) | 730 cm$^{-1}$ | |
| (6) | 717 cm$^{-1}$ | 718 cm$^{-1}$ |

## ■ Measurement of Plastics

Nine types of plastics were prepared and measured before and after UV degradation using an ultra-accelerated weathering tester manufactured by Iwasaki Electric Co., Ltd. The measurement results are shown in Fig. 2 to 10, with the major peaks indicated in the figures and listed in Tables 1 to 10. The "Guidelines for River Microplastic Monitoring Methods," issued by the Japanese Ministry of the Environment (MOE), and ISO 16094 Part 2 "Water quality — Analysis of microplastic in water" were referenced[2),3)] to determine the major peaks. The MOE guidelines state that when the hit quality is low, plastics should be identified based on characteristic peaks. According to ISO 16094-2, judgment by an operator is required when the HQI value is within the 60 to 80 % range, presumably using Annex A "List of characteristic wavenumbers for the main polymers" as a reference. In addition to plastics, these references also provide information about major peaks of other substances that are likely to be collected together with MPs in the environment, such as proteins and cellulose, which can be helpful for distinguishing them from plastics. In addition, because environmental MPs may be degraded by UV rays, spectra after UV degradation are shown in each figure for reference.

Fig. 2 shows infrared spectra of polyethylene (PE) and the wavenumbers for major peaks. The global production of PE is greater than of any other type of plastic and, because its specific gravity is 0.91 to 0.96, it floats in environmental water, resulting in it often being identified in MP analysis. PE is classified according to its density, with high-density PE used for plastic grocery bags and fishing nets and low-density PE used for garbage bags and cushioning materials. The positions of peaks in infrared spectra vary according to the density (see Table 1). Carbonyl group peaks are also observed at 1750 cm$^{-1}$ due to ultraviolet degradation.

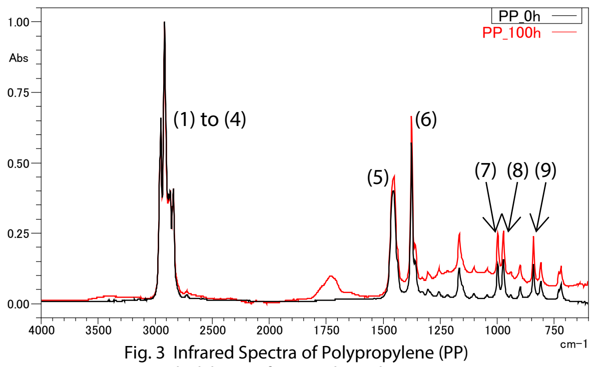


Fig. 3 Infrared Spectra of Polypropylene (PP)
Black line: Before UV degradation,
Red line: After UV degradation (100 hours irradiation)

Table 2 Wavenumbers of Major Polypropylene (PP) Peaks

| PP (Polypropylene) | | |
|---|---|---|
| | Japanese MOE Guidelines | ISO 16094-2*1 |
| (1) to (4) | 4 peaks around 3000 $cm^{-1}$ | 2953 $cm^{-1}$ |
| | | 2919 $cm^{-1}$ |
| | | 2840 $cm^{-1}$ |
| (5) | 1455 $cm^{-1}$ | 1453 $cm^{-1}$ |
| (6) | 1377 $cm^{-1}$ | 1373 $cm^{-1}$ |
| (7) | | 1000 $cm^{-1}$ |
| (8) | | 971 $cm^{-1}$ |
| (9) | | 840 $cm^{-1}$ |

*1 Only confirmed major peaks are listed

Fig. 3 shows infrared spectra of polypropylene (PP) and the wavenumbers of the major peaks. PP is the lightest of the plastics, with a specific gravity of 0.9 to 0.91. It is often used in food containers (Tupperware) and laboratory test tubes. Although PP is generally superior to PE in terms of heat resistance, it is susceptible to UV degradation. Peaks appear at 1750 $cm^{-1}$ even when exposed to ultraviolet light for a shorter time than that for PE.

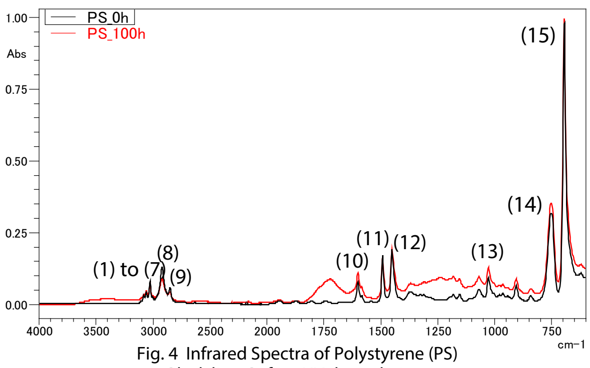


Fig. 4 Infrared Spectra of Polystyrene (PS)
Black line: Before UV degradation,
Red line: After UV degradation (100 hours irradiation)

Table 3 Wavenumbers of Major Polystyrene (PS) Peaks

| PS (Polystyrene) | | |
|---|---|---|
| | Japanese MOE Guidelines | ISO 16094-2 |
| (1) to (7) | 6 or 7 peaks around 3000 $cm^{-1}$ | 3027 $cm^{-1}$ |
| | | |
| | | |
| (8) | | 2918 $cm^{-1}$ |
| (9) | | 2850 $cm^{-1}$ |
| (10) | 1601 $cm^{-1}$ | 1600 $cm^{-1}$ |
| (11) | 1492 $cm^{-1}$ | 1495 $cm^{-1}$ |
| (12) | | 1450 $cm^{-1}$ |
| (13) | 1027 $cm^{-1}$ | 1027 $cm^{-1}$ |
| (14) | | 756 $cm^{-1}$ |
| (15) | 694 $cm^{-1}$ | |

Fig. 4 shows the infrared spectra of polystyrene (PS) and the wavenumbers of the major peaks. PS has a specific gravity of 1.04 to 1.07, making it the next lightest material after PE and PP. Though PS is widely used as polystyrene foam, which is produced by using a blowing agent, polypropylene and polyethylene are also available in expanded (foam) form. PS is also degraded relatively quickly by ultraviolet light, with peaks at 1750 $cm^{-1}$ after 100 hours of ultraviolet irradiation. Styrene copolymerizes with other monomers, so it has a spectrum similar to that of SBR and ABS.

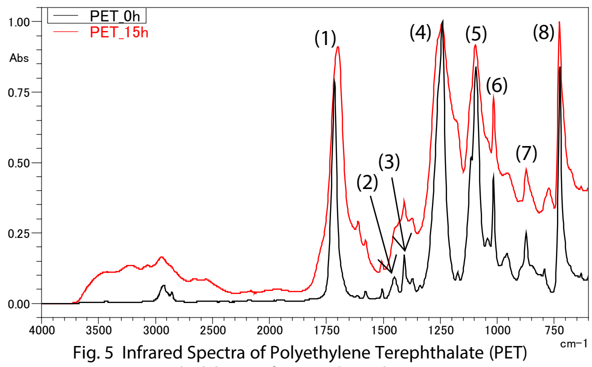


Fig. 5 Infrared Spectra of Polyethylene Terephthalate (PET)
Black line: Before UV degradation,
Red line: After UV degradation (15 hours irradiation)

Table 4 Wavenumbers of Major Polyethylene Terephthalate (PET) Peaks

| PET (Polyethylene Terephthalate) | | |
|---|---|---|
| | Japanese MOE Guidelines | ISO 16094-2 |
| (1) | 1713 $cm^{-1}$ | 1715 $cm^{-1}$ |
| (2) | | 1410 $cm^{-1}$ |
| (3) | | 1342 $cm^{-1}$ |
| (4) | 1241 $cm^{-1}$ | 1250 $cm^{-1}$ |
| (5) | 1094 $cm^{-1}$ | 1105 $cm^{-1}$ |
| (6) | | 1017 $cm^{-1}$ |
| (7) | | 871 $cm^{-1}$ |
| (8) | 720 $cm^{-1}$ | 722 $cm^{-1}$ |

Fig. 5 shows the infrared spectra of polyethylene terephthalate (PET) and the wavenumbers of the major peaks. PET is commonly used for plastic beverage containers and is actively recycled. PET is heavy and sinks in environmental water due to a specific gravity of 1.27 to 1.40. PET degrades very easily, with various peaks broadening and hydroxyl group peaks appearing around 3500 cm-1 after exposure to ultraviolet light for about 15 hours. If peak (3) in the infrared spectra is smaller, it is known as non-crystalline PET[4)].

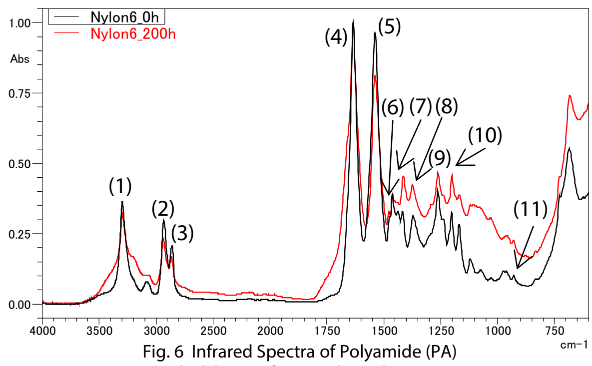


Fig. 6 Infrared Spectra of Polyamide (PA)
Black line: Before UV degradation,
Red line: After UV degradation (200 hours of irradiation)

Table 5 Wavenumbers of Major Polyamide (PA) Peaks

| Nylon, PA (Polyamide) | | |
|---|---|---|
| | Japanese MOE Guidelines | ISO 16094-2 |
| (1) | 3298 $cm^{-1}$ | 3298 $cm^{-1}$ |
| (2) | 2932 $cm^{-1}$ | 2922 $cm^{-1}$ |
| (3) | 2858 $cm^{-1}$ | 2857 $cm^{-1}$ |
| (4) | 1634 $cm^{-1}$ | 1631 $cm^{-1}$ |
| (5) | 1538 $cm^{-1}$ | 1539 $cm^{-1}$ |
| (6) | | 1464 $cm^{-1}$ |
| (7) | | 1414 $cm^{-1}$ |
| (8) | | 1373 $cm^{-1}$ |
| (9) | | 1271 $cm^{-1}$ |
| (10) | | 1200 $cm^{-1}$ |
| (11) | | 932 $cm^{-1}$ |

Fig. 6 shows the infrared spectra of nylon/polyamide (PA) and the wavenumbers of the major peaks. In general, nylon is a type of polyamide, with specific types of nylon, such as nylon 66, also types of polyamide. PA is heavy, with a specific gravity of 1.35 to 1.42, so it sinks in environmental water, similar to PET. It is commonly used in clothing and other fibers. PA is relatively resistant to degradation, but degradation causes broader peak bases. Peak (11) in the infrared spectra, which is caused by crystallization, is relatively tall in nylon 66[4)].

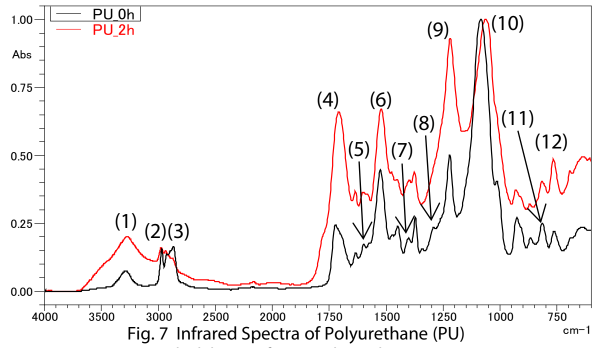


Fig. 7 Infrared Spectra of Polyurethane (PU)
Black line: Before UV degradation,
Red line: After UV degradation (2 hours irradiation)

Table 6 Wavenumbers of Major Polyurethane (PU) Peaks

| | PU (Polyurethane) | |
|---|---|---|
| | Japanese MOE Guidelines | ISO 16094-2*1 |
| (1) | 3291 $cm^{-1}$ | |
| (2) | 2938 $cm^{-1}$ | |
| (3) | 2858 $cm^{-1}$ | |
| (4) | 1734 $cm^{-1}$ | 1700 $cm^{-1}$ |
| (5) | | 1600 $cm^{-1}$ |
| (6) | 1538 $cm^{-1}$ | 1528 $cm^{-1}$ |
| (7) | | 1414 $cm^{-1}$ |
| (8) | | 1312 $cm^{-1}$ |
| (9) | | 1223 $cm^{-1}$ |
| (10) | 1109 $cm^{-1}$ | 1071 $cm^{-1}$ |
| (11) | | 817 $cm^{-1}$ |
| (12) | | 769 $cm^{-1}$ |

*1 Only confirmed major peaks are listed

Fig. 7 shows infrared spectra of polyurethane (PU) and the major peak wavenumbers. Because PU is highly elastic like rubber, it is also called polyurethane elastomer. PU is heavy, with a specific gravity of 1.2, and sinks in environmental water. It is highly susceptible to UV degradation, which results in broadening of various peaks. The peaks around 3300 cm-1 are attributable to N-H bonds.

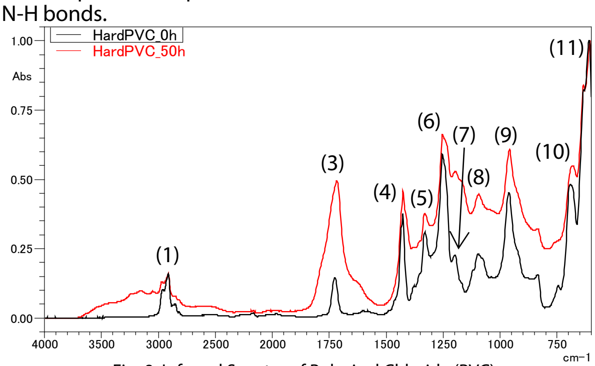


Fig. 8 Infrared Spectra of Polyvinyl Chloride (PVC)
Black line: Before UV degradation,
Red line: After UV degradation (50 hours irradiation)

Table 7 Wavenumbers of Major Polyvinyl Chloride (PVC) Peaks

| | PVC (Polyvinyl Chloride) | |
|---|---|---|
| | Japanese MOE Guidelines | ISO 16094-2 |
| (1) | 2911 $cm^{-1}$ | 2919 $cm^{-1}$ |
| (2) | 2862 $cm^{-1}$ | |
| (3) | | 1729 $cm^{-1}$ |
| (4) | 1426 $cm^{-1}$ | 1430 $cm^{-1}$ |
| (5) | | 1332 $cm^{-1}$ |
| (6) | 1254 $cm^{-1}$ | 1254 $cm^{-1}$ |
| (7) | | 1193 $cm^{-1}$ |
| (8) | | 1098 $cm^{-1}$ |
| (9) | | 965 $cm^{-1}$ |
| (10) | 694 $cm^{-1}$ | |
| (11) | 637 $cm^{-1}$ | |

Fig. 8 shows infrared spectra of polyvinyl chloride (PVC) and the major peak wavenumbers. Soft PVC is used for agricultural plastic sheets and coatings for electric wires and cables, whereas hard PVC is used for water pipes. The difference between soft and hard PVC, which can be confirmed from the infrared spectrum, is the intensity of peak (3) (around 1730 $cm^{-1}$), which is higher for soft PVC. These peaks are derived from phthalate esters, which are plasticizers. The specific gravity is 1.30 to 1.58 for soft and 1.16 to 1.35 for hard PVC. Due to the susceptibility to UV degradation, various peaks become broader and peaks for hydroxyl groups appear around 3500 $cm^{-1}$.

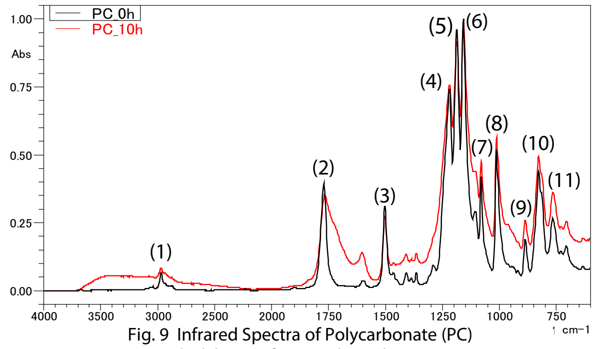


Fig. 9 Infrared Spectra of Polycarbonate (PC)
Black line: Before UV degradation,
Red line: After UV degradation (10 hours

Table 8 Wavenumbers of Major Polycarbonate (PC) Peaks

| | PC (Polycarbonate) |
|---|---|
| | ISO 16094-2*1 |
| (1) | 2969 $cm^{-1}$ |
| (2) | 1773 $cm^{-1}$ |
| (3) | 1500 $cm^{-1}$ |
| (4) | 1217 $cm^{-1}$ |
| (5) | 1193 $cm^{-1}$ |
| (6) | 1159 $cm^{-1}$ |
| (7) | 1081 $cm^{-1}$ |
| (8) | 1013 $cm^{-1}$ |
| (9) | 888 $cm^{-1}$ |
| (10) | 830 $cm^{-1}$ |
| (11) | 766 $cm^{-1}$ |

*1 Only confirmed major peaks are listed

Fig. 9 shows the infrared spectra of polycarbonate (PC) and the major peak wavenumbers. Due to its strong impact resistance and high transparency, PC is used for window materials in transportation equipment. PC is heavy, with a specific gravity of 1.2, and sinks in environmental water. UV degradation is rapid, with broadening of various peaks and hydroxyl groups appearing at around 3500 $cm^{-1}$.

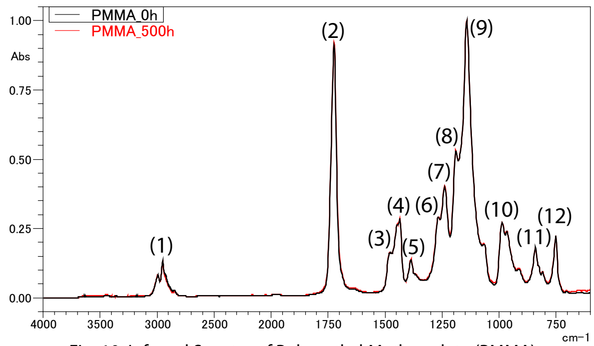


Fig. 10 Infrared Spectra of Polymethyl Methacrylate (PMMA)
Black line: Before UV degradation,
Red line: After UV degradation (500 hours irradiation)

Table 9 Wavenumbers of Major Polymethyl Methacrylate (PMMA) Peaks

| | PMMA (Polymethyl Methacrylate) |
|---|---|
| | ISO 16094-2 |
| (1) | 2952 $cm^{-1}$ |
| (2) | 1722 $cm^{-1}$ |
| (3) | 1478 $cm^{-1}$ |
| (4) | 1437 $cm^{-1}$ |
| (5) | 1390 $cm^{-1}$ |
| (6) | 1271 $cm^{-1}$ |
| (7) | 1240 $cm^{-1}$ |
| (8) | 1186 $cm^{-1}$ |
| (9) | 1142 $cm^{-1}$ |
| (10) | 990 $cm^{-1}$ |
| (11) | 847 $cm^{-1}$ |
| (12) | 749 $cm^{-1}$ |

Fig. 10 shows infrared spectra of polymethyl methacrylate (PMMA) and the wavenumbers of the major peaks. Due to its particularly high transparency, PMMA acrylic is commonly used in aquarium tanks. PMMA has a specific gravity of 1.17 to 1.20 and sinks in environmental water. The results confirmed that there is almost no degradation due to ultraviolet rays.

Table 10 Wavenumbers of Major Polycarbonate (PC) Peaks

PE (Polyethylene)

| | Japanese MOE Guidelines | ISO 16094-2 |
|---|---|---|
| (1) | 2915 cm$^{-1}$ | 2915 cm$^{-1}$ |
| (2) | 2845 cm$^{-1}$ | 2850 cm$^{-1}$ |
| (3) | 1472 cm$^{-1}$ (High density)<br>1467 cm$^{-1}$ (Low density) | 1472 cm$^{-1}$ |
| (4) | 1462 cm$^{-1}$ | 1461 cm$^{-1}$ |
| (5) | 730 cm$^{-1}$ | |
| (6) | 717 cm$^{-1}$ | 718 cm$^{-1}$ |

PP (Polypropylene)

| | Japanese MOE Guidelines | ISO 16094-2*1 |
|---|---|---|
| (1) to (4) | 4 peaks<br>around 3000 cm$^{-1}$ | 2953 cm$^{-1}$ |
| | | 2919 cm$^{-1}$ |
| | | 2840 cm$^{-1}$ |
| (5) | 1455 cm$^{-1}$ | 1453 cm$^{-1}$ |
| (6) | 1377 cm$^{-1}$ | 1373 cm$^{-1}$ |
| (7) | | 1000 cm$^{-1}$ |
| (8) | | 971 cm$^{-1}$ |
| (9) | | 840 cm$^{-1}$ |

PS (Polystyrene)

| | Japanese MOE Guidelines | ISO 16094-2 |
|---|---|---|
| (1) to (7) | 6 or 7 peaks<br>around 3000 cm$^{-1}$ | 3027 cm$^{-1}$ |
| | | |
| | | |
| (8) | | 2918 cm$^{-1}$ |
| (9) | | 2850 cm$^{-1}$ |
| (10) | 1601 cm$^{-1}$ | 1600 cm$^{-1}$ |
| (11) | 1492 cm$^{-1}$ | 1495 cm$^{-1}$ |
| (12) | | 1450 cm$^{-1}$ |
| (13) | 1027 cm$^{-1}$ | 1027 cm$^{-1}$ |
| (14) | | 756 cm$^{-1}$ |
| (15) | 694 cm$^{-1}$ | |

PET (Polyethylene Terephthalate)

| | Japanese MOE Guidelines | ISO 16094-2 |
|---|---|---|
| (1) | 1713 cm$^{-1}$ | 1715 cm$^{-1}$ |
| (2) | | 1410 cm$^{-1}$ |
| (3) | | 1342 cm$^{-1}$ |
| (4) | 1241 cm$^{-1}$ | 1250 cm$^{-1}$ |
| (5) | 1094 cm$^{-1}$ | 1105 cm$^{-1}$ |
| (6) | | 1017 cm$^{-1}$ |
| (7) | | 871 cm$^{-1}$ |
| (8) | 720 cm$^{-1}$ | 722 cm$^{-1}$ |

Nylon, PA (Polyamide)

| | Japanese MOE Guidelines | ISO 16094-2 |
|---|---|---|
| (1) | 3298 cm$^{-1}$ | 3298 cm$^{-1}$ |
| (2) | 2932 cm$^{-1}$ | 2922 cm$^{-1}$ |
| (3) | 2858 cm$^{-1}$ | 2857 cm$^{-1}$ |
| (4) | 1634 cm$^{-1}$ | 1631 cm$^{-1}$ |
| (5) | 1538 cm$^{-1}$ | 1539 cm$^{-1}$ |
| (6) | | 1464 cm$^{-1}$ |
| (7) | | 1414 cm$^{-1}$ |
| (8) | | 1373 cm$^{-1}$ |
| (9) | | 1271 cm$^{-1}$ |
| (10) | | 1200 cm$^{-1}$ |
| (11) | | 932 cm$^{-1}$ |

PU (Polyurethane)

| | Japanese MOE Guidelines | ISO 16094-2*1 |
|---|---|---|
| (1) | 3291 cm$^{-1}$ | |
| (2) | 2938 cm$^{-1}$ | |
| (3) | 2858 cm$^{-1}$ | |
| (4) | 1734 cm$^{-1}$ | 1700 cm$^{-1}$ |
| (5) | | 1600 cm$^{-1}$ |
| (6) | 1538 cm$^{-1}$ | 1528 cm$^{-1}$ |
| (7) | | 1414 cm$^{-1}$ |
| (8) | | 1312 cm$^{-1}$ |
| (9) | | 1223 cm$^{-1}$ |
| (10) | 1109 cm$^{-1}$ | 1071 cm$^{-1}$ |
| (11) | | 817 cm$^{-1}$ |
| (12) | | 769 cm$^{-1}$ |

PVC (Polyvinyl Chloride)

| | Japanese MOE Guidelines | ISO 16094-2 |
|---|---|---|
| (1) | 2911 cm$^{-1}$ | 2919 cm$^{-1}$ |
| (2) | 2862 cm$^{-1}$ | |
| (3) | | 1729 cm$^{-1}$ |
| (4) | 1426 cm$^{-1}$ | 1430 cm$^{-1}$ |
| (5) | | 1332 cm$^{-1}$ |
| (6) | 1254 cm$^{-1}$ | 1254 cm$^{-1}$ |
| (7) | | 1193 cm$^{-1}$ |
| (8) | | 1098 cm$^{-1}$ |
| (9) | | 965 cm$^{-1}$ |
| (10) | 694 cm$^{-1}$ | |
| (11) | 637 cm$^{-1}$ | |

PC (Polycarbonate)

| | ISO 16094-2*1 |
|---|---|
| (1) | 2969 cm$^{-1}$ |
| (2) | 1773 cm$^{-1}$ |
| (3) | 1500 cm$^{-1}$ |
| (4) | 1217 cm$^{-1}$ |
| (5) | 1193 cm$^{-1}$ |
| (6) | 1159 cm$^{-1}$ |
| (7) | 1081 cm$^{-1}$ |
| (8) | 1013 cm$^{-1}$ |
| (9) | 888 cm$^{-1}$ |
| (10) | 830 cm$^{-1}$ |
| (11) | 766 cm$^{-1}$ |

PMMA (Polymethyl Methacrylate)

| | ISO 16094-2 |
|---|---|
| (1) | 2952 cm$^{-1}$ |
| (2) | 1722 cm$^{-1}$ |
| (3) | 1478 cm$^{-1}$ |
| (4) | 1437 cm$^{-1}$ |
| (5) | 1390 cm$^{-1}$ |
| (6) | 1271 cm$^{-1}$ |
| (7) | 1240 cm$^{-1}$ |
| (8) | 1186 cm$^{-1}$ |
| (9) | 1142 cm$^{-1}$ |
| (10) | 990 cm$^{-1}$ |
| (11) | 847 cm$^{-1}$ |
| (12) | 749 cm$^{-1}$ |

*1 Only confirmed major peaks are listed

## ■ Conclusion

In this study, the infrared spectra of representative plastics before and after UV degradation were measured and major peaks were identified. Mainly literature related to MPs was referenced. Although the attribution of respective peaks was not discussed, it is expected that confirming those characteristic peaks would be helpful for identification after library searches. Shimadzu has improved the accuracy of using the optional UV-degraded plastics library in the software database to identify plastics (including MPs) in the environment.

### References


1) FTIR Talk Letter vol. 37 and vol. 42–46
2) Ministry of the Environment, Japan, “Guidelines for River Microplastic Monitoring Methods”, April 2026
https://www.env.go.jp/content/900543325.pdf
(Refer to information from June 23, 2026)
3) ISO 16094-2 Water quality — Analysis of microplastic in water — Part 2: Vibrational spectroscopy methods for waters with low content of suspended solids, including drinking water
4) The Japan Society for Analytical Chemistry Symposium on Polymer Analysis and Research, Polymer Analysis Handbook New Edition, Asakura Publishing Co., Ltd., 382-593, 2008


### Related Applications

1. Analysis of Ultraviolet-Degraded Plastic by Plastic Analyzer, Application News No. A647
2. Analysis of Resin Using FTIR and Thermal Analysis – “Silent Change” -, Application News No. T154
3. Prescreening of Phthalic Esters Contained in PVC Products by FTIR, Application News No. A602



01-01189-EN First Edition: Aug. 2026

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