

Polymer identification using a NIR fiber probe with compact NIR spectrometers

Rapid and reliable identification of polymer materials is essential in modern industrial settings, whether for quality control, recycling, sorting, or in-line production monitoring. Near-infrared (NIR) spectroscopy has become a go-to technology for these tasks thanks to its speed, non-destructive nature, and suitability for analyzing bulk materials in-situ. With the growing demand for compact solutions, different NIR spectrometer technologies have emerged, each offering distinct wavelength ranges, sensitivities, form factors, and cost levels. To help customers choose the right technology for their needs, it is important to understand how these different spectrometers perform when used with a standard fiber-optic setup.

In this application note, we demonstrate that our diffuse-reflection fiber probe is fully compatible with two following spectrometer architectures (non-cooled options): a conventional slit spectrometer, based on grating dispersion and InGaAs detector, and a spectrometer based on a tunable MEMS Fabry-Pérot optical filter. Both devices have been tested using the same probe, the same polymer samples, and identical measurement procedures. This shows the versatility of our fiber-probe solution and helps clarify which fiber-based spectrometer better fits end-user applications.

The following spectrometers were used:

- “Fabry-Pérot based” spectrometer with a Fabry-Pérot MEMS Filter and a single element extended InGaAs detector with a wavelength range of 1550-1950 nm and typical resolution of 15-21 nm. This design allows for a very compact form factor and robust performance in industrial environments.
- “Grating-based” conventional slit spectrometer is a compact, grating-based NIR spectrometer covering the 950–1700 nm range with a 256-pixel InGaAs detector array (non-cooled, 30µm slit) and typical resolution of 8 nm. It uses a traditional slit and diffraction grating design, delivering high-resolution spectra suitable for analytical applications.

All measurements were performed using a **NIR diffuse-reflection fiber-optic probe (model AP12490, art photonics GmbH, Germany)**. The probe contains six illumination fibers and one detection fiber housed in a 6 mm stainless-steel shaft with a sapphire window at the tip, ensuring low straylight levels (Fig. 1). The light source was a broadband halogen lamp.

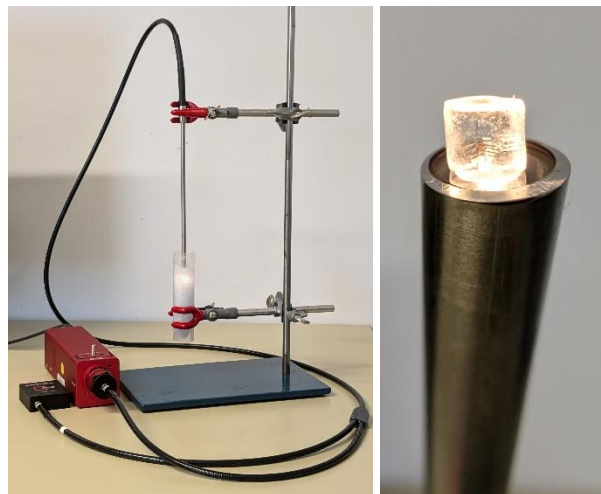


Figure 1. Experimental setup for: bulk measurements (left) and single granule measurements (right).

Six common polymers were tested:

- ABS (acrylonitrile butadiene styrene)
- LPE (linear low-density polyethylene)
- PA6 (polyamide)
- PC (polycarbonate)
- PPR (polypropylene)
- PTF (polyethylene terephthalate)

A 100% reflectance Spectralon® standard was used as a reference sample. The measurements on polymers were carried out in two modes (Fig. 1). In the first experiment three separate granules (3-5 mm in diameter) of each polymer were measured in three different positions, i.e. 54 spectra in total (Fig. 2).

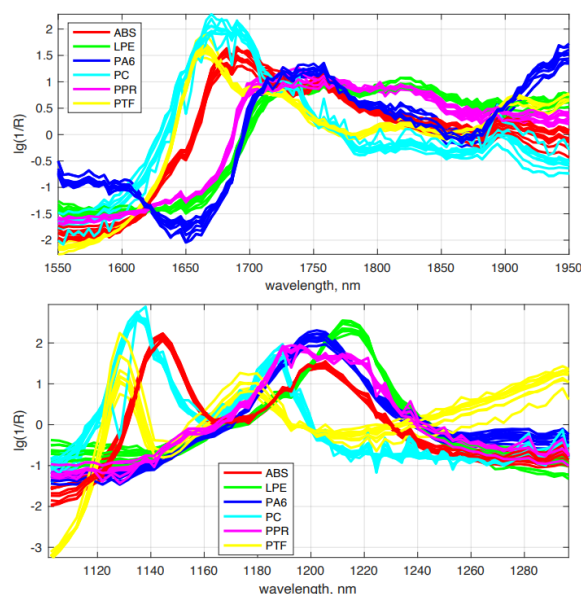


Figure 2. SNV-normalized spectra of six polymers obtained using Fabry-Pérot based (top) and grating-based (bottom) spectrometers.

In the second experiment the probe was immersed in a vessel with a polymer, which mimics the bulk material. The bulk measurements were repeated three or five times (for Fabri-Pérot and grating-based spectrometers, respectively) to investigate the reproducibility of results. Between the measurements the probe was pulled out of the vessel and inserted in again.

Since no single wavelength in Fig. 2 could unambiguously separate all polymer classes, a non-supervised multivariate class separation was performed using principal component analysis (PCA). Results for the spectra of separate granules (Fig. 2) are presented in Fig. 3.

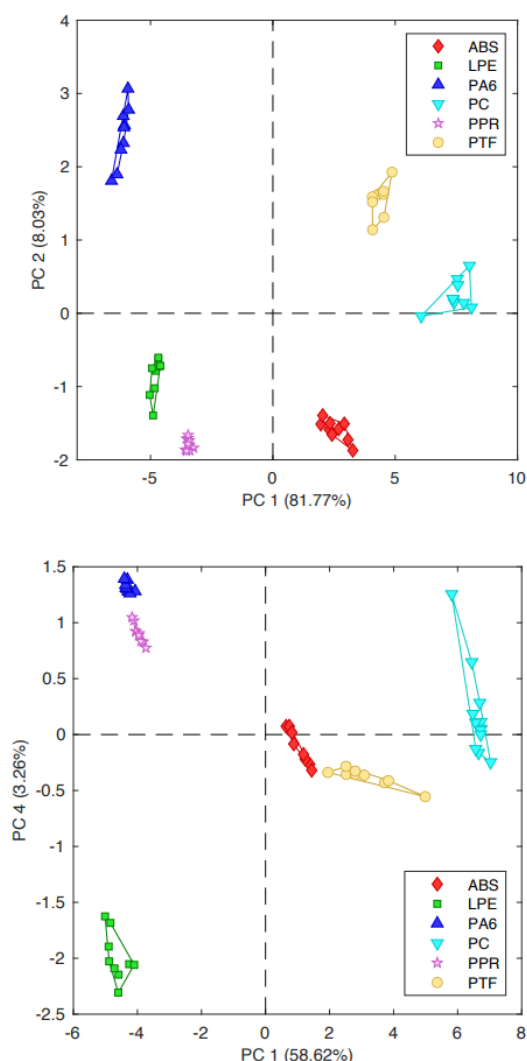


Figure 3. PCA scores plots for the single-granule spectra shown in (Fig. 2): Fabri-Pérot based (top) and grating-based (bottom) spectrometers data.

The PCA score plots in Fig. 3 demonstrate that both spectroscopic methods can clearly discriminate among the six polymer classes. Data obtained from spectral region covered by Fabri-Pérot based spectrometer provide somewhat better class resolution using a simpler PC-space (PC1–PC2) compared to the four-

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factor model for spectral data obtained within range covered by grating-based spectrometer.

Similar results were obtained in the bulk measurement experiments (Fig. 4). Excellent separation of classes is achieved in both experiments at the same PCA-model complexities. The improved class separation in bulk data is attributed to the averaging of scattering effects, while spectra from individual granules show greater intensity variability.

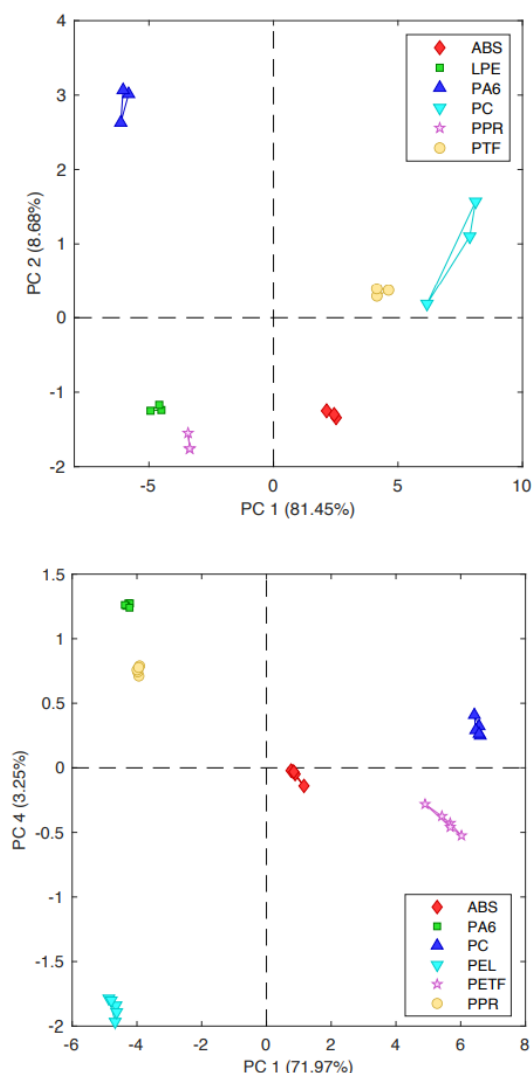


Figure 4. PCA scores plots for the bulk spectra of the polymers: Fabri-Pérot based (top) and grating-based (bottom) spectrometers data.

The obtained results have proved the feasibility of investigated spectroscopic methods including different spectrometers and spectral regions to distinguish between six most common polymers using a diffuse reflectance fiber probe by art photonics GmbH. Successful class separation was illustrated both on separate polymer granules and using bulk measurements with the probe. While Fabri-Pérot based spectrometer results in simpler models, traditional slit spectrometer is faster and better suits for rapid analysis during process control.