Application Note

A Validated, Cost-Effective Alternative: Gold-Coated vs. Aluminum-Coated Membranes for LDIR Microplastic Analysis

LHZ analytics

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INTRODUCTION

Microplastics (MPs), plastic particles and fibers ranging from 1 µm to 5 mm, have become a global concern. They have been detected in nearly all of Earth's ecosystems, from deep-sea canyons to polar regions, as well as in various human organs. MPs have also been found in a wide variety of organisms and biota, including samples from different human organs (Codrington et al., 2024; Wright et al., 2013).

The plethora of polymer types (including co-polymers and recyclates), additives, sizes, and shapes makes the development of reliable and standardized analytical methods challenging. The often low concentrations and ubiquitous distribution of MPs in various matrices require highly sensitive and selective detection methods to achieve reliable results (Hansen et al., 2023; Hildebrandt et al., 2022; Vetter et al., 2025). Currently, Raman spectroscopy, Fourier transform infrared spectroscopy (FTIR), and quantum cascade laser (QCL)-based laser direct infrared (LDIR) imaging are widely accepted methods for chemically identifying and characterizing individual MPs down to the lower micrometer range (Ciornii et al., 2025).

Infrared (IR) microscopy techniques require the sample to be prepared on IR-reflective or transparent microscopic slides or filter membranes, depending on the measurement mode (Cabernard et al., 2018; Löder et al., 2015). For several reasons, filter membranes are superior to microscopic slides for MP analysis and are thus considered the current gold standard. They allow the processing of significantly larger sample volumes (e.g. water or air) and a quantitative transfer of MPs, compared to analysis of a small volume on a slide (subsampling error) (López-Rosales et al., 2022; López-Rosales et al., 2025a). In addition the sample preparation directly on the analysed filter can help to minimize sample handling steps, which may cause particle loss. Ideally, filtration leads to a uniform distribution of particles on the membrane surface, which aids systematic examination and reduces the likelihood of particles being overlooked. Furthermore, filter membranes are compatible with various analytical methods, including light microscopy, fluorescence microscopy and scanning electron microscopy.

Over the last six years, the number of scientific publications (including interlaboratory comparison studies) demonstrating the ability of the 8700 LDIR Chemical Imaging System (Agilent Technologies) to accurately analyze MPs in various environmental and biological matrices has grown to more than 100. Both aluminum (Al)- and gold (Au)-coated filter membranes facilitate MP analysis via reflectance-absorbance (transflectance) LDIR imaging (López-Rosales et al., 2025b), though each has distinct advantages and disadvantages. The choice often depends on the specific requirements of the analysis. Several essential requirements of filter membranes for IR imaging include:

- Chemical resistance towards the solvents and reagents used
- Mechanical stability to enable good handling with tweezers (no breaks, bumps or bending)
- Optimal IR reflective properties
- Pore size suitable for the MP size of interest (typically in the micrometer range) without any relevant scattering
- Good coverage of the membrane with pores to enable rapid filtration and low pore size variability
- Smooth and even surface to ensure effective recognition and analysis (good focus) of the particles and fibers.

Beyond technical specifications, financial considerations are critical, especially for routine analysis and future large scale monitoring programs. The aim of this work was to test and validate the suitability of Al-coated polyethylene terephthalate glycol (PET-G)-membranes for MP analysis using LDIR imaging.

EXPERIMENTAL

All preparatory lab work and filtration steps **(Figure 1)** were carried out in laminar flow benches (SuSi, SPETEC; 99.9995% removal of particles ≥ 0.3 µm). Before use, all solutions were pre-filtered through polycarbonate (PC) track-etched filter membranes (d = 47 mm, pore size: 0.45 µm).

Chemical Stability Testing

Figure 1: Sample filtration setup in a laminar flow cleanbench.

Different pH standard solutions (pH: 1.68, 3.00, 4.00 ± 0.01, 5.00, 7.00 ± 0.01, 8.00, 11.00, 12.00 ± 0.01, 13.00), various chemicals with high relevance in the field of MP analysis (30% HCl, 35% H_2O_2, 10% KOH, 1.5% of 2.0 g mL^{-1} $ZnCl_2$ / sodium polytungstate (SPT) solution, seawater, mineral water (with and without (sodium dodecyl sulfate (SDS) and ethylenediaminetetraacetic acid (EDTA)) and a buffered enzyme solution) were filtered through Au- and Al-coated PETG-membranes to test their chemical resistance and impacts on the subsequent MP analysis via LDIR imaging. More detailed information including contact times and used volumes is given in Table 1. The experimental set-up of the filtration is shown in Figure 1. A stainless-steel filtration manifold with 25 mL /250 mL glass funnels (Rocker Scientific Co., Taiwan) was used for all filtrations.

EXPERIMENTAL

Samples doped with MP reference particles and reference material

A filtered seawater sample was spiked with separate suspensions of polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), polyethylene terephthalate (PET), polyurethane (PUR), and acrylonitrile butadiene styrene (ABS) fragments (10–100 µm, EasyMP™, Microplastic solutions, **Figure 2**). The spiked sample was filtered via Au- and Al-coated PETG-membranes prior to LDIR analysis. The reference material EURM®-060 (PET microplastic particles in water; > 30 µm; 1 L) was also filtered through the coated PETG-membranes.

Figure 2: A: EasyMP™ MP reference suspensions. B: EURM®-060.

Spectroscopic analysis and data evaluation

All tested membranes were visually inspected using the Agilent 8700 LDIR Chemical Imaging System's (high magnification) vis camera. All spectroscopic analyses were conducted using an Agilent 8700 LDIR Chemical Imaging System.

The LDIR, a name derived from its mode of operation, laser direct infrared imaging, utilizes a QCL as the source that enables the spectroscopic analysis in the light wavenumber region from 1800 cm^{-1} to 975 cm^{-1}. The scanning mode was first used to scan the sample area at a wavenumber of 1442 cm^{-1}. The resulting IR image in conjunction with vis images is used to both locate particles on the membranes and analyse their size and shape. Once located, the LDIR automatically moved to each particle and acquired an IR spectrum in the covered wavenumber range (sweep mode). Once a spectrum was acquired from a particle, it was compared (real-time processing) to a MP spectral library. The best match (cosine similarity) for the spectrum was determined and reported for each particle. The library was derived from well-established sources and included a variety of IR spectra of synthetic polymers and natural materials relevant to the analysis of MP in marine water-derived samples. The library has been expanded as described in Vetter et al. (2025). The data exports were further processed using a custom-written Python script and an Excel spreadsheet containing macros.

RESULTS & DISCUSSION

Chemical Stability Testing

The chemical resistance and analytical suitability of aluminum (Al)- and gold (Au)-coated PETG membranes was tested with various reagents and solutions relevant to MP analysis (**see Table 1**). The Au-coated membrane demonstrated chemical resistance to nearly all tested substances, including aggressive chemicals and solutions across a wide pH range (1.68 to 13.00). Indeed, some commonly used chemicals like 30% HCl solution, 10% KOH solution or ≥ 30% H_2O_2 might require matrix-dependent testing, since different process parameters, e.g., contact times and applied temperatures, can influence the chemistry acting on the membrane, as well as the coating. In some cases, we have observed a slight small-scale deposit on the Au coating when concentrated H_2O_2 was filtered.

Chemical Stability Testing

To better prepare real-world samples for analysis, pre-filtering them through a resistant, large-pore membrane like PTFE or stainless-steel mesh is a beneficial step before the transfer to the gold filter. In general, however, the gold coating exhibits a high chemical resistance. In contrast, the Al-coated membrane may experience visual corrosion when exposed to strongly acidic solutions (pH ≤ 3.00) and strongly basic solutions (pH ≥ 12.00), 30% HCl, 10% KOH, 35% H_2O_2, and a 1.5% 2.0 g mL^{-1} $ZnCl_2$ solution. Visual corrosion caused by 30% HCl and 10% KOH on Al-coated membranes compared to Au-coated membranes is shown in **Figure 3**. For both membrane types, filtration of a $ZnCl_2$ solution resulted in a significant amount of precipitate, which could be successfully removed by rinsing with a 1.3% HCl solution. Using an SPT solution for density separation can solve this problem.

Reagent	Volume [mL]	Contact time [min]	Suitable for Au-coated membrane	Suitable for Al-coated membrane	Findings / comments
30% HCl solution	15	Direct filtration	(YES)*	NO	*Aggressive chemicals might require matrix-dependent testing, contact times are very important
10% KOH solution	15	Direct filtration	(YES)*	NO	*Aggressive chemicals might require matrix-dependent testing, contact times are very important
35% H_2O_2 solution	15	Direct filtration	(YES)*	NO	*Aggressive chemicals might require matrix-dependent testing, contact times are very important
Fenton solution (H_2O_2 + Fe^{2+}) (Tagg et al., 2017)	15	Direct filtration	((YES))*	NO	* Aggressive chemicals might require matrix-dependent testing, contact times are very important
*p*H = 1.68	15	5	YES	NO	Mild corrosion of Al-coating
*p*H = 3.00	15	5	YES	(NO)*	Very mild corrosion of Al-coating
*p*H = 4.00 ± 0.01	15	5	YES	YES	-
*p*H = 5.00	15	5	YES	YES	-
*p*H = 7.00 ± 0.01	15	5	YES	YES	-
*p*H = 8.00	15	5	YES	YES	-
*p*H = 11.00	15	5	YES	YES	-
*p*H = 12.00 ± 0.01	15	5	YES	NO	Mild corrosion of Al-coating
*p*H = 13.00	15	5	YES	NO	Corrosion of Al-coating
1.5% 2.0 g mL^{-1} $ZnCl_2$ solution	15	5	YES*	NO	Rinsing with 1.3% HCl solution required for Au-coated membranes; Strong corrosion of Al-coating
1.5% 2.0 g mL^{-1} SPT solution	15	5	YES	YES	-
Proteinase K (buffered, *p*H = 8.5)	15	~ 15	YES	YES	-
Seawater	100	~ 15	YES	YES	-
Mineral water with EDTA and SDS	100	~ 15	YES	YES	-

Table 1: Chemicals and reagents used to test the resistance and suitability of Al- and Au-coated PETG-membranes for MP analysis.

RESULTS & DISCUSSIONS

Chemical Stability Testing

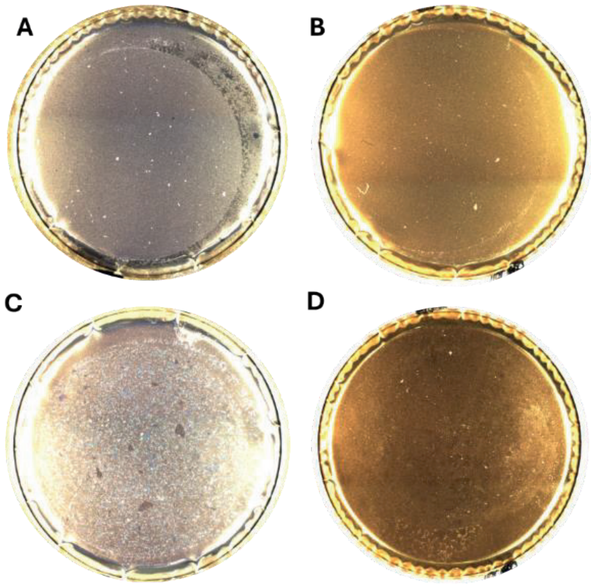

Figure 3: Visual images of Al-membrane (A) and Au-membrane (B) after filtration of 30% HCl and Al-membrane (C) and Au-membrane (D) after filtration of 10% KOH.

Spectral Quality

Despite some chemical limitations, Al-coated membranes proved highly effective for the analytical detection of MPs via LDIR imaging. **Figure 4** shows a false-color LDIR image of an Al-coated membrane that was used to filter seawater spiked with EasyMP™ MP reference particles.

The system successfully identified particles of PE, PP, PS, PVC, PET, and polyurethane PUR, with high-quality spectra confirming their chemical identity as shown in **Figure 4**.

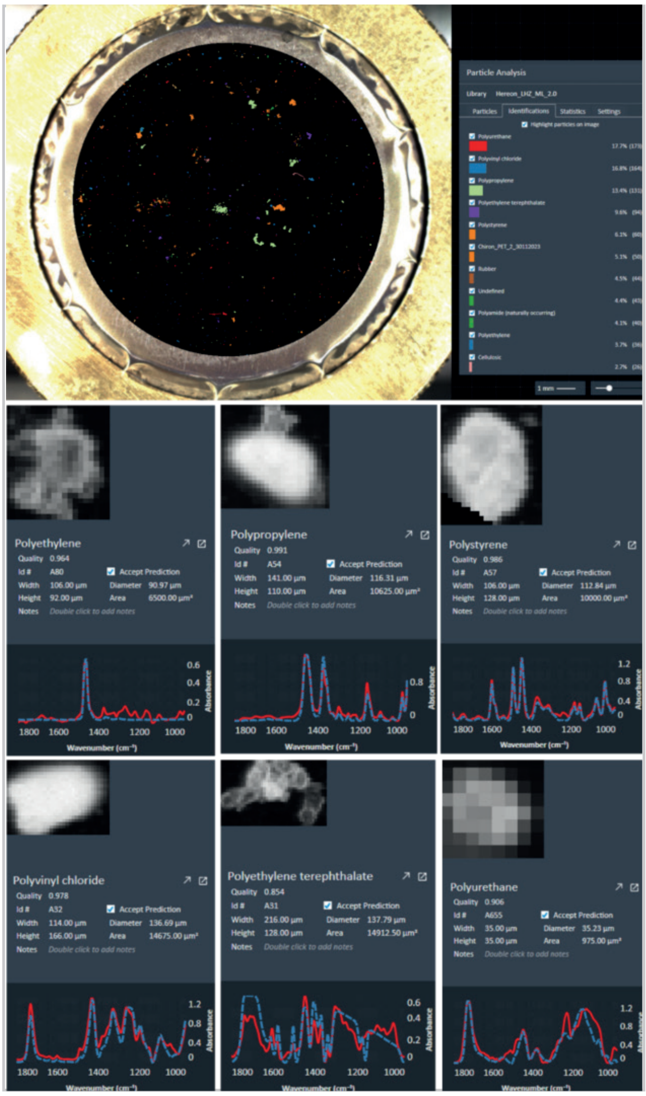

Figure 4: A false color image displaying the LDIR analysis of the Al-coated membrane through which seawater spiked with PE, PP, PS, PVC, PET and PUR fragments (EasyMP™) was filtered. LDIR spectra with good HQI values as acquired in the automated analysis are also shown.

RESULTS & DISCUSSIONS

Spectral Quality

The analytical performance was quantitatively assessed using the hit quality index (HQI), which measures the similarity between a particle's spectrum and the best library match. A comparison of HQI values for PET particles ≥ 30 µm of the reference material EURM®-060 (PET particles in water) analyzed on both Al and Au-membranes showed no significant difference, with the average HQI for the Al-coating (0.937/1) being slightly higher than for the Au-coating (0.931/1) as shown in **Figure 5**.

Spectral Quality

HQI values regarding the EasyMP™ MP reference particles (ABS, PE, PET, PP, PS, PU, PVC) spiked to filtered seawater were very similar for Al and Au-membranes as shown in **Table 2**. The comparatively low HQIs for ABS, PUR (< 0.80), and PET (< 0.90) are a result of using a library not yet trained with EasyMP™ standards, a deliberate choice to avoid prior data manipulation. Meanwhile, the ABS, PUR and PET spectra have been added to the database, enabling HQI values of over 0.90 for all relevant synthetic polymer types using Al and Au-membranes.

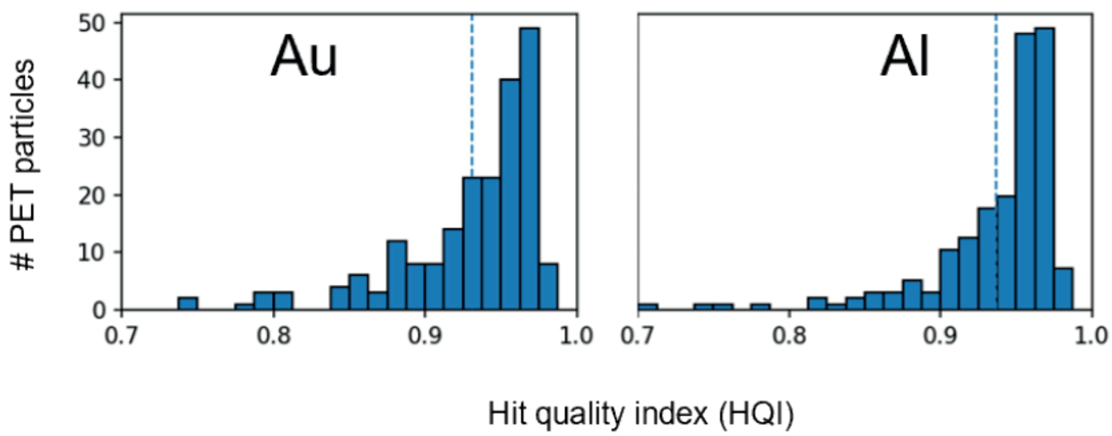

Figure 5: HQI values of the reference material EURM®-060 (PET particles in water) analyzed on Au- and Al-coated membranes via LDIR imaging in the automated mode. The average HQI values (dashed lines) for the PET MPs do not differ significantly between the different coatings.

Polymer type	Seawater spiked with EasyMP™ fragments (PE, PP, PS, PVC, PET and PUR)			
	HQI value		Recovery* [%] (*n* = 2)	
	Au-coating	Al-coating	Au-coating	Al-coating
ABS	0.780	0.813	74	76
PE	0.940	0.935	79	88
PET	0.879	0.846	92	89
PP	0.958	0.957	94	91
PS	0.967	0.962	72	84
PUR	0.784	0.784	65	62
PVC	0.924	0.916	85	86

Table 2: Left: HQI values for seawater spiked with EasyMP™ fragments (PE, PP, PS, PVC, PET and PUR) analyzed on Au- and Al-coated membranes via LDIR imaging. Right: Recovery rates of EasyMP™ fragments for the same solution analyzed on Au- and Al-coated membranes via LDIR imaging. * Extrapolated to the total filter area, semi-automated mode: aggregates were manually measured.

RESULTS & DISCUSSIONS

Recovery Experiments

Filter seawater spiked with known particle concentrations of EasyMP™ MP reference particles, as well as the reference material EURM®-060 were analyzed on both Al and Au-membranes for particle recoveries (**see Table 2**). The MP particles (EasyMP™ spiked into seawater and EURM®-060) tended to aggregate (**Figure 6**). Thus, the individual particles could not be quantitatively detected in the automatic LDIR mode. Instead, aggregates were measured manually in semi-automatic mode and the results were extrapolated to the total filter area. Recoveries between 62 and 94 % were achieved for EasyMP™ ABS, PE, PET, PP, PS, PU and PVC MPs (20 -100 µm) as shown **Table 2**. Recoveries > 80 % were achieved for EURM®-060 PET particles for both Al and Au-membranes.

For all reference MPs, no significant differences were observed between Al- and Au-membranes regarding either recovery rates or spectral quality. These results in conjunction with the resistance data indicate that for typical drinking water and seawater samples, the Al-coated membranes facilitate LDIR analysis with an accuracy that is equivalent to the more expensive Au-coated membranes.

Recovery Experiments

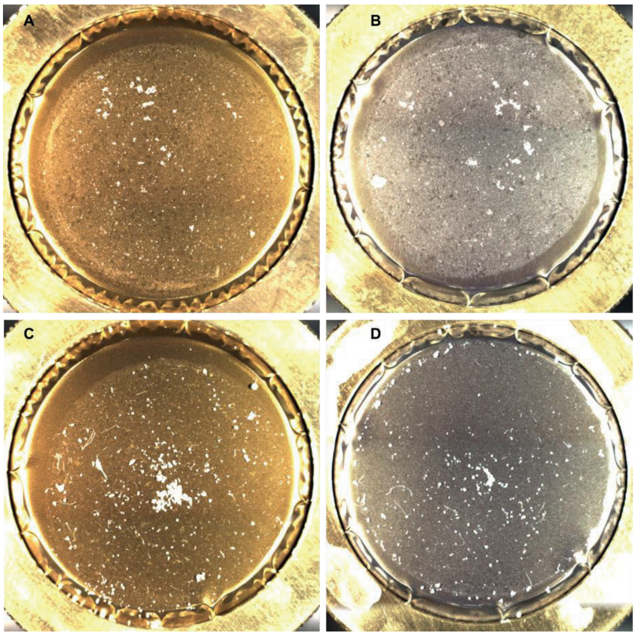

Figure 6: A and B: Al- and Au-coated membranes used to filter the reference material "EURM®-060: Polyethylene terephthalate (PET) microplastic particles in water" (equivalent diameter ≥ 30 µm). C and D: Al- and Au-coated membranes used to filter seawater spiked with PE, PP, PS, PVC, PET and PUR fragments (EasyMP™, equivalent diameter: 10 – 100 µm).

CONCLUSION

This study demonstrates that Al-coated PETG membranes are a highly effective substrate for the analysis of MPs in various aqueous samples using LDIR imaging. The analytical accuracy, measured by the HQI values for MP reference standards, is excellent and fully comparable to that achieved with Au-coated membranes across multiple polymer types. However, the Al-coating is susceptible to corrosion from aggressive reagents, including strong acids and bases.

This makes it unsuitable for protocols requiring harsh chemical treatments. Nevertheless, Al-coated membranes are suitable for enzymatic or mild saline solutions, as well as natural waters. Therefore, for routine monitoring of MPs in near-neutral samples like seawater or mineral water, Al-coated membranes offer a reliable and cost-effective alternative to their gold-coated counterparts. Indeed, pre-tests are recommended for more specific applications.

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