Microplastic identification in sea water by optical transmittance

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INTRODUCTION

Microplastics have become a worrisome source of pollution in our oceans due to their potential to enter the food chain at all levels and cause harm to marine lifeforms by their tendency to accumulate waterborne toxins due to their large surface/volume ratio [1-3]. These microplastic particles are widespread and ubiquitous in the oceans and enter the marine environment from the breakdown of larger plastic pieces or clothing or directly in the form of plastic granules used as scrubbers in cosmetic products and air-blasting.

Recent publications have studied the ecologic impact on aquatic species of relevant concentrations of microplastics. It was found that even average concentrations of plastic microparticles had a significant effect on birth, growth and survival ratios of the species under study. [4]

Appropriate monitorization of microplastic concentration's spatial and temporal trends is needed to gather the information necessary to evaluate and address the problem [5,6]. Specifically, the challenges and impact presented by each type of plastic should be evaluated. Such monitorization should include the study of characteristics such as the localization of each type of plastic in the water column, the evaluation of their degradation rate and degradation-induced changes in their density and characteristics.

In this work, a measurement strategy based on optical transmission is proposed for implementation in a low-cost sensor to identify the base material of the microplastic pieces. In order to avoid costly components and time-consuming processing, only specific, carefully selected wavelengths will be used. Two basic difficulties encountered in such a measurement are, on the one hand, the modifications introduced in the transmittance spectrum of the base material by the addition of additives such as colorants, and on the other, the fact that the identification must be invariant with the thickness and/or geometrical shape of the plastic pieces.

DISCUSSION

A large spectral database in the near UV – Vis range has been created for the plastics most commonly found in the industry, especially in single-use applications; Polypropylene (PP), Polystyrene (PS), Polyethylene Terephthalate (PET) and Polyethylene (PE). [7]

The optical transmittance spectrum of each material has been measured for a wide range of different plastic pieces obtained from commercially available products (such as food and beverage packaging). Spectral characteristics common to each plastic type have been extracted to make up the characteristic signature of the base material, regardless of specific additives. Instead of relying on absolute transmission values, relative variations in the spectra have been used, ensuring that the identification of the plastic will be independent of the fragment thickness and geometry.

Figure 1 shows four representative transmission spectra for the four materials object of this study, measured in uncolored samples.

Both PS and PET show clear absorption thresholds in the measured range, whereas PP and PE transmission spectra do not present any such threshold, only the continuation of their slow, monotonous decrease. Between the two thresholds, that of PS is the most abrupt.

Another promising aspect of these spectra is that these absorption thresholds of PS and PET happen at a much longer wavelength than the typical absorption thresholds for silicates, implying the possibility of easily differentiating between plastic microparticles and grains of sand.

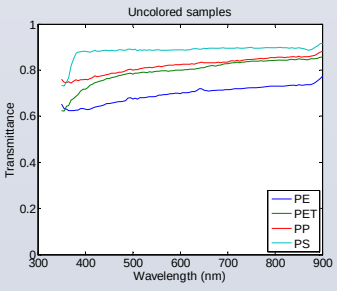

Figure 1. Transmission spectra in the 350-900 nm range, for samples of PE, PET, PP and PS

Once the differences between the uncolored materials have been established, we proceed to study the impact of coloring additives on the transmission spectra. Figure 2 presents the transmission spectra for different PET samples, with colors ranging from pink to dark green.

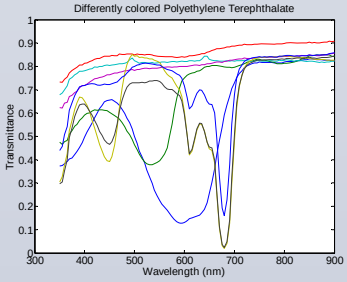

Figure 2. Transmission spectra in the 350-900 nm range for PET samples with different coloring

The differences between the transmission spectra of the different samples are very clear. The variations in the visible range are so great that identification would be impossible. However, the absorption threshold around 400 nm is similar for most samples, implying that this wavelength region is indeed the most promising for identification purposes.

Figure 3 shows a close up view of the optical transmission spectra in the 350-400 nm wavelength range, for different samples of each material.

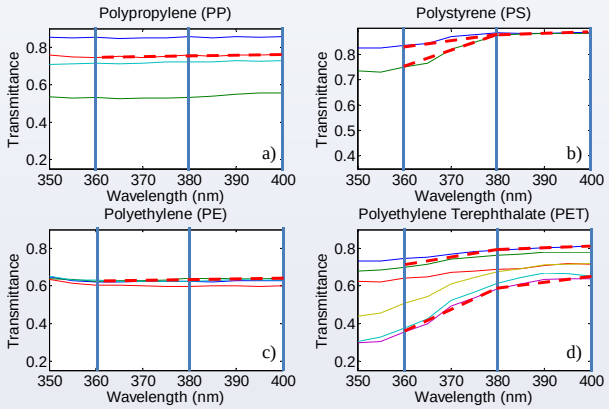

Fig 3. Optical transmission spectra in the 350-900 nm range for a) PP samples, b) PS samples, c) PE samples and d) PET samples. Blue lines mark the proposed measurement wavelengths (360 nm, 380 nm and 400 nm)

Even though the absorption thresholds of both PS and PET are located at the same wavelength, the change in the transmission slope is very different for both materials. The relative slope variation γ, calculated as the relative variation between the UV slope ($\mathbf{s}_{UV}$) and the visible slope ($\mathbf{s}_{VIS}$), is in the range of 1-10 for PET and 50-300 for the PS.

$$\gamma = \frac{\Delta \mathbf{s}}{\mathbf{s}} = \frac{(\mathbf{s}_{UV} - \mathbf{s}_{VIS})}{\mathbf{s}_{VIS}}$$

This difference is sufficiently significant to enable differentiation between both types of plastics. For implementation in a low cost sensor we therefore propose the measurement of the optical transmittance at 360 nm, 380 nm and 400 nm, followed by the calculation of γ. Such a sensor would easily differentiate between grains of sand, PET, PS and PP-PE. We propose to identify a fourth wavelength, deeper in the UV region, to be able to differentiate between PP and PE.

CONCLUSIONS

A measurement strategy is proposed for implementation in low-cost sensors to identify the base material of microplastic pieces floating at sea from among the most commonly found types of plastics. This measurement strategy relies on the measurement of the optical transmittance at a small number of discrete wavelengths, in the near UV-VIS range. These wavelengths have been determined by a careful study of a large transmittance database of plastic packaging obtained from off-the-shelf products, in order to account for spectral changes induced by additives like colorants. The results show that it is possible to identify easily PET and PS, while PP and PE are metameres in this range of illumination. Further studies are being performed to extend the wavelength range further into the UV zone in order to break the metamerism between these two materials

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