Affordable multi-spectral imaging system for the identification and classification of microplastics from the environment.

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Abstract Studies on microplastic pollution commonly use expensive spectroscopic methods such as FTIR spectroscopy or Raman spectroscopy. Alternatively, studies could also employ cheaper methods such as optical microscopes, which are prone to errors. Here, we present an inexpensive and simple multi-spectral imaging system that is based on photoluminescence spectroscopy. The main components are a RGB camera, two light sources that have a wavelength of 365 nm and 405 nm and a set of bandpass filters (with a central wavelength ranging from 380 nm to 440 nm). Our study shows that the spectra acquired with both light sources are sufficient to distinguish plastics from natural materials and identify different plastic types. Considering the simplicity of the proposed system, this could be combined with methods to extract microplastics from the environment.

Keywords:

Microplastics, photoluminescence, spectroscopy, multi-spectral imaging system, affordable system

1. Introduction

Plastic pollution studies have raised socio-political awareness and influenced the use of plastic in the society. Still, a tremendous amount of mismanaged plastic waste is produced (Lebreton and Andrady, 2019) because of the lack of regulations (Garcia and Fang, 2019; Hajbane and Pattiaratchi, 2017), especially in the continents of Asia, South America and Africa (Blettler et al., 2018). Studies on the amount of microplastics worldwide are often lengthy and costly and hence, there is a need for affordable plastic identification systems. Most of the low budget studies rely on analysis with an optical microscope which are prone to errors (Hanvey et al., 2017). A more reliable plastic identification can be achieved with FTIR and Raman spectroscopy, which are time intensive and expensive. In this study, we present an inexpensive multi-spectral imaging system which is based on our previous work (Ornik et al., 2020). We focus on two different sets of emission analysis. For the first one, we excite the sample with a laser that has a wavelength of 405 nm and for the second set, we excite the sample with a LED that emits light with a wavelength of 365 nm. Our goal is to use both sets to distinguish plastics from non-plastic materials and to determine the plastic type of the sample.

2. Materials and methods

2.1. Materials

Our sample set consists of eight different plastics types and eight natural materials. The former consists of high-density polyethylene (HDPE), low-density polyethylene (LDPE), polypropylene (PP), polycarbonate (PC), polystyrene (PS), polyethylene terephthalate (PET) and polyamide (PA), polyvinyl chloride (PVC). All plastic samples are pellet-shaped with a diameter between 2 – 5 mm. For the natural materials we chose samples commonly found in the marine environment: Sea snail (Neverita josephina), sea grass leaf (Posidonia oceanica), sea urchin skeleton (Echinocardium cordatum), eggs of sea snail (Hexaplex trunculus), a piece of wood with teredo, cuttlefish bone (Sepia officinalis), fine-grained quartz sand and cellulose.

2.2. Experimental setup and method

A schematic of the experimental setup is shown in Fig. 1. Two different excitation sources are used to excite the samples and a RGB camera is used to acquire the emitted light from the samples. The sample is placed on a silicon wafer. Since the band gap energy of silicon is 1.12 eV, it does not interfere with the measurement of the spectrum in the visible range (Low et al., 2008).

For the excitation of the sample with the 405 nm laser, the beam is spectrally narrowed by a 10 nm FWHM band-pass filter. To achieve a uniform sample illumination, we place a beam diffuser between the filter and the sample. To block the excitation light from entering the camera, a 420 nm long pass filter is mounted on the filter wheel to detect the sample emission through the inbuilt color filters of the RGB camera.

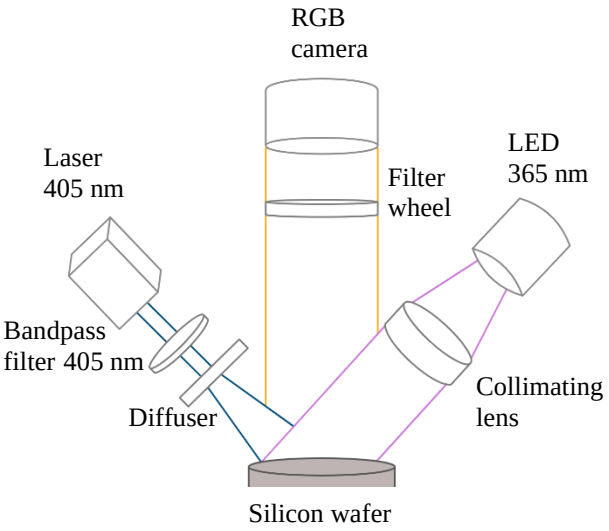

Figure 1. Schematic of the experimental setup used to acquire selected emissions using two different excitation sources.

To analyze the sample emission further in the UV region we excite the sample with a LED that emits at 365 nm. A lens is placed between the LED and the sample to allow for a homogeneous sample illumination. The sample emission is detected on the RGB camera through bandpass filters with central wavelengths of 380 nm, 400 nm, 420 nm, and 440 nm, which are placed in the filter wheel. For the analysis, we calculate two parameters defined as:

$$\mathrm{P1} = \frac{I_{380}}{I_{420}} \text{ and } \mathrm{P2} = \frac{I_{400}}{I_{440}}$$

where $I_{380}, I_{400}, I_{420}$, and I_{440} are the intensities of the emitted light at 380 nm, 400 nm, 420 nm and 440 nm, respectively.

For both excitation sources each sample includes three to eight samples from each sample type, and five images per sample are acquired using the RGB camera. The emission with 405 nm excitation is analyzed based on the average pixel counts acquired from each sample using the built in red, blue and green channels. In the case of the 365 nm excitation, since the emission beyond 440 nm is not evaluated, we consider the sum of the average pixel counts of only the blue and green channels.

3. Results and discussion

As reported by Ornik et al., 2020, the emission maxima of most of the polymers with 405 nm excitation fall below 460 nm. From this observation, we expect that we can separate the polymers from natural materials using solely the pixel counts obtained from blue and green channels using only the 405 nm excitation.

Fig. 2 shows the intensity ratio of the blue channel to the green channel. From the comparison between the datasets for plastic and non-plastic materials we can see that both types can be separated from each other except

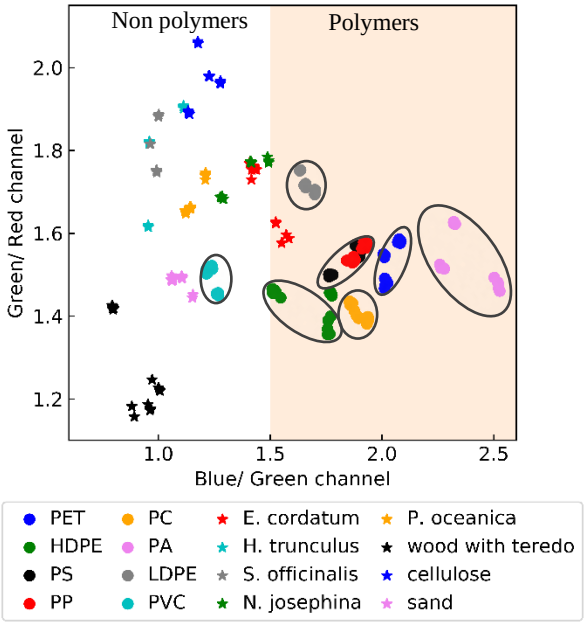

Figure 2. Categorization of polymers (circles) and natural materials (stars) with 405 nm excitation. The scatter plot shows ratio of pixel counts extracted from blue and green channel on the x-axis and green/ red channel on the y-axis.

for PVC. Each datapoint that belongs to a single plastic type forms a cluster. Additionally, we observe that the datapoints for PP and PS overlap. Consequently, a light source with a wavelength of 405 nm allows us to separate the different plastic types from each other except for PP and PS.

To investigate the separation of the plastic types further, we evaluated the spectra acquired with an excitation wavelength of 365 nm. Figure 3 shows a scatter plot of the parameters P1 and P2 (see methods). Compared to the previous result in Figure 2, all plastic types can be now separated from each other.

The possibility to further separate polymer clusters with more precision is portrayed in Fig. 3. Besides, it can be inferred that the emission band for polymers with 365 nm excitation seems to be distinguishable from each other. Moreover, the overlapping cluster of PP and PS in case of 405 nm excitation (Fig. 2) are now well separated.

There is large variance in clusters of samples and moreover a few data points fall out of their clusters. This could be due to those irregularly shaped pellets which were not subjected to uniform illumination. Nevertheless, the average variance of the outliers lies below 20%, which seems reasonable for a preliminary work. Further investigation is necessary to compensate for these variations in pixel counts.

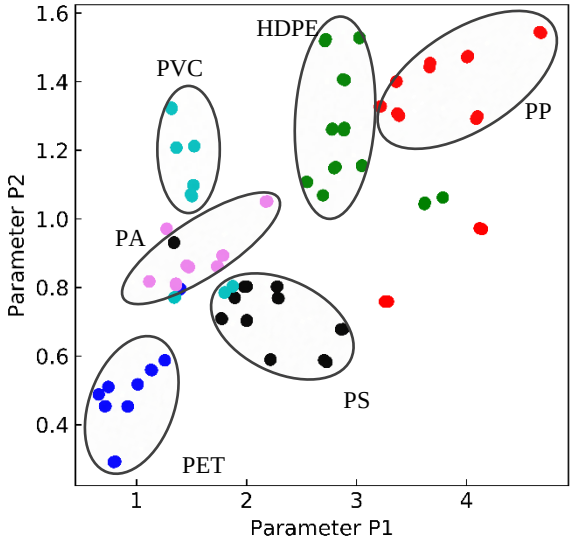

Figure 3. Categorization of polymers with 365 nm excitation using multiple bandpass filters. Parameter P1 is the ratio of intensities detected with the filters centered at 380 nm and 420 nm. P2 is the ratio of intensities detected with the filters 400 nm and 440 nm. The intensity of each sample is the sum of pixel counts extracted from the blue and green channels.

4. Conclusion

We showed that a RGB camera and an excitation source with a wavelength of 405 nm are sufficient to separate plastic from non-plastic samples. A separation between the different plastic types can be achieved by using a light source with a wavelength of 365 nm. Going forward the experimental setup will need to be further optimized to reduce the scattering between the data points of a single plastic type.

Based on our study, we suggest a two-step process: First, an excitation at 405 nm to separate plastics from natural materials and then an excitation at 365 nm with multiple bandpass filters to further separate the polymers.

5. References

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