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Raman Microspectroscopy for the Characterisation of Inorganic Additives in Plastic Consumer Products

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While plastics themselves can pose health risks, such as when they are in the form of microplastics, it is not as widely recognised that plastics can contain potentially harmful inorganic substances. The same element can play different roles. For instance, antimony (Sb) can be present as it is intentionally added (*e.g.* as antimony trioxide as flame retardant in some products) or remains as a residue from synthesis in PET bottles due to its use as a catalyst.

Titanium oxides (TiO_2) have been extensively used in various products, especially as pigments. Their uses also include toothpaste, cosmetics and food colourings. Although TiO_2 has generally been considered safe, in 2022 the European Commission banned its use as a food additive due to growing concerns about its effects on human health. Therefore, the amount of TiO_2 used in different applications, such as plastics, is important information that should be shared with the public. However, this information is rarely disclosed by manufacturers.

To address this, we investigated how Raman microspectroscopy and X-ray fluorescence spectrometry (XRF) can be combined to detect and characterize TiO_2 in plastics. XRF is well known for its sensitivity to characterize the concentration of titanium in plastics. In combination, Raman microspectroscopy can speciate in which form TiO_2 is present (*e.g.* anatase or rutile). The main advantage of microspectroscopy over conventional Raman spectroscopy is that the laser is focused on a volume determined by the diffraction limit of light (typically less than one µm), which increases the signal-to-background ratio. This means that a tiny Raman signal from nanoscale objects can be captured without being hidden by background signals. As demonstrated in Fig. 1, it is possible to characterize the polymorph of TiO_2 in a sample containing Ti element in concentrations as low as 400~500 ppm. We first identified that TiO_2 is present in the form of anatase in consumer cleaning cloths. As we explored a wider variety of consumer plastic products, we realised that TiO_2 can be present in both anatase and rutile forms. In some cases, the reasoning behind the choices is clear, but in others it is not.

One of the key challenges in applying Raman spectroscopy to plastic products is the fluorescence signal due to pigments used for coloring products. This problem can be overcome in some cases by tuning the laser wavelength (*e.g.* using 405 nm as the excitation source)[1] or by controlling the signal detection timing.

By enabling detailed characterisation of additives such as TiO_2, Raman microspectroscopy can provide information for safer product design, regulatory monitoring and improved plastic recycling strategies.

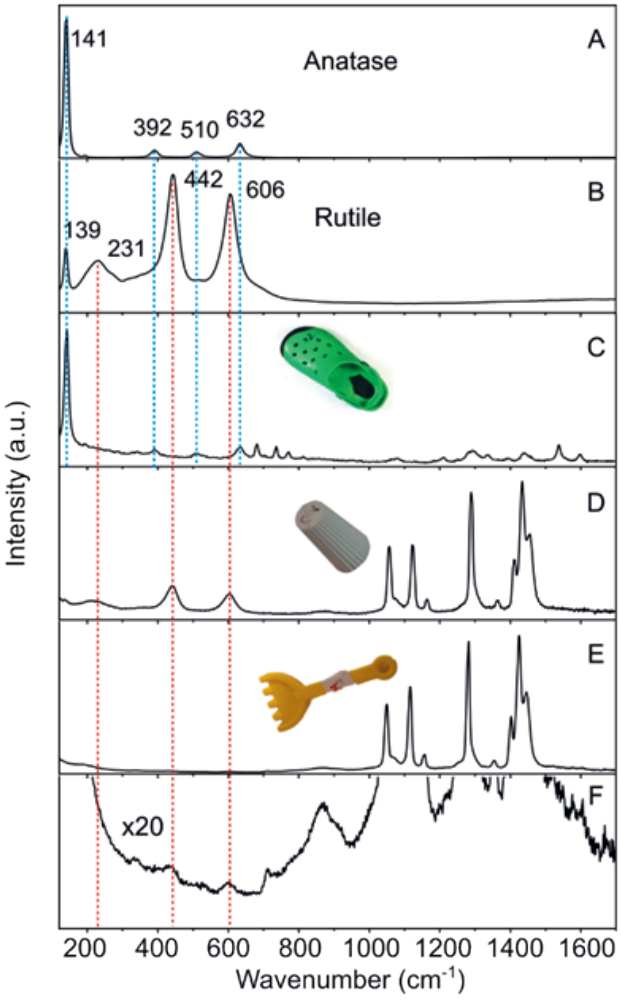

Fig.1. Raman spectrum of TiO_2 reference (A-B) and TiO_2 in consumer plastic products (C-F). Panel F is the 20x scaled spectrum of panel E.

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[1] J. Brazard, T. B. M. Adachi, A. Turner, M. Filella, *Microchem. J.* **2025**, *208*, 112391. https://doi.org.10.1016/j.microc.2024.112391.

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