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Nanoscale infrared spectroscopy-based technique to detect and quantify micro- and nanoplastics in aqueous solutions

SARA BELONTZ[1] AND GERARDO DOMINGUEZ[2]

[1]California State University, San Marcos

[2]California State University San Marcos

Presenting Author: sbelontz@csusm.edu

Microplastics have been detected in almost every environmental compartment, however, the fate and behavior of nanoplastics are not extensively studied due to the difficulty of detecting them in the natural environment. Conventional infrared (IR) imaging, considering the gold standard for identifying microplastics, is unable to resolve particles smaller than the wavelength of the IR photons (~10 mm). This limitation makes it difficult to identify much less understand how microplastics degrade in the natural environment. Here we present a method for the chemical identification and quantification of small micro- (<30 mm) and nanoplastic (1 nm- 1 mm) particles in aqueous samples using an atomic force microscope based infrared spectroscopy (AFM-IR). AFM-IR achieves sub-diffraction limited infrared spectroscopy using a combination of tunable IR sources and metal-coated AFM-tips. The absorption of IR photons, particularly at a resonance frequency, leads to the thermal expansion of the material. The AFM-tip allows the thermal expansion of the material directly underneath the AFM-tip to be recorded as a function of IR wavelength, yielding the equivalent of an infrared spectrum of the material. Using a relatively simple sample preparation technique, we used AFM-IR to estimate the number of micro- and nano-particles in bottled, tap, and saltwater samples. Our preliminary work with bottled water found ~163,000 polyethylene terephthalate (PET) particles less than 4 microns in a single 10 mL drop. These particles tended to appear as thin films and ranged in size from approximately 683 nm to 3.6 mm, with an average maximum diameter of ~1.9 mm (See Figure 1). These results suggest that one 500 mL plastic bottle could contain roughly 8 billion PET particles. This implies that the consumption of bottled water could expose humans to billions of nanoplastic particles. Our preliminary results demonstrate that AFM-IR is a suitable method for characterizing nanoplastic abundances and size distributions in aqueous environments. Ongoing work is focused on developing sample preparation techniques to determine nanoplastic abundances in natural water samples. This technique development work was sponsored by the California State University Council on Ocean Affairs, Science & Technology (CSU COAST) through the State Science Information Needs Program (PI: Dominguez).

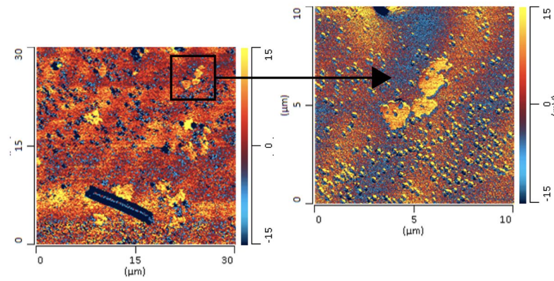

Figure 1: (Left) 30x30 micron AFM-IR image of evaporated water drop on Au surface (1199 cm^{-1}). (Right) 10x10 micron zoom in of nano-films present in aqueous water sample.