Non-proximate, Handheld Probe with Positional Feedback for Real-time Analysis of Three-dimensional Object Surfaces

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Abstract

Non-proximate desorption photoionization mass spectrometry (NPDPI-MS) was recently designed to analyze large, intact objects whose bulk requires positioning far from the instrument inlet. The first system used a rigid transport tube and detached, heated gas jet probe to identify dyes, plasticizers, and other organic molecules from convex surfaces ≥1 meter across. Neutral desorbed analytes were transported to a custom photoionization system. The rigidity of the transfer tube, however, required that the object be positioned in the desorption zone with sub-millimeter precision: a slow and unwieldy process when analyzing a large artwork or cultural heritage item. A new, flexible transfer tube design is implemented here to make analysis faster and more versatile. The 2-4 m transfer line is based on custom gooseneck tubing which satisfies multiple requirements: flexibility; stainless steel construction with inert coating; heating to minimize adsorption; and large inner diameter for analyte collection and carryover purging. An integrated desorption/suction probe suitable for manual use is built around the non-proximate end of the transfer line. The probe can be used on objects one-handed, while the other hand operates an integrated control module.

The sampling probe is designed for maximum efficiency, collecting desorbed analyte without loss so that heat exposure to a sample surface is minimized. A shaped inlet attachment slides along the end of the transfer line terminal, indicating by LED when the probe is in optimal position. Piezo sensors arrayed around the probe also signal physical contact, helping the user to avoid inner walls when probing inside a concave object. When the positioning is satisfactory, the user triggers a pulse from a 190 °C, 1 L/min nitrogen jet to desorb analyte from a 9 mm^2 area. Desorbed analyte is drawn into the transfer line at 4.8 L/min, where it is doped with anisole by an in-line permeation device and ionized in real time.

Irregularly-shaped objects on a stationary tabletop were sampled for demonstration purposes without moving them, using extractive solvent, or causing discernable physical damage. Caffeine was observed from a coffee stain at the base of an intact coffee mug; multiple compounds were observed from food paste residue at the bottom on an even deeper clay pot. Peppermint gum flavoring agents were observed from the semi-rigid rubber sole in between the cleats of an athletic shoe. The probe was also adjusted for analysis without pressing against a surface to sample from the soft surface of a citrus fruit. When analyte signal persisted after the gas jet pulse, the flow system was purged at 20 L/min to return to baseline signal levels.

Biography - G. Asher Newsome

G. Asher Newsome is a Physical Scientist and mass spectrometrist at the Smithsonian Museum Conservation Institute. Much of his current research involves developing ambient sampling techniques for cultural heritage and conservation science applications, with a particular interest in analyzing intact objects too precious for micro-sectioning, too fragile to be moved to the laboratory, too large to be positioned immediately adjacent to a typical mass spectrometer, and/or with other complex requirements. He frequently works closely with curators, conservators, and cultural representatives to determine an acceptable level of “invasiveness” for analysis. He holds a PhD in Analytical Chemistry from UNC-Chapel Hill.

Keywords

Photoionization, Thermal desorption, Accessibility, Practicality