ABSTRACT

Author: Laster, Jennifer S. PhD
Institution: Purdue University
Degree Received: December 2017
Title: Design of Microstructured Conducting Polymer Films for Enhanced Trace Explosives Detection
Major Professors: Stephen P. Beaudoin and Bryan W. Boudouris

The detection of trace amounts of explosive material is critical to national security. Ion mobility spectrometer (IMS)-based contact sampling continues to be a common method employed for the detection of explosives in high security checkpoint applications, such as airport security. In this process a surface of interest, such as a passenger's hands or luggage, is probed by a swab or particle trap to collect and transfer residue to an IMS for analysis. The collection of residue on a sampling swab has been shown to be a limiting step in this detection process. As such, there is significant need to develop new materials with increased adhesion to explosive analytes and with superior particle removal abilities.

Here, the design of novel sampling swabs is presented for the enhanced collection of trace explosive residue from surfaces. First, the influence of the swab microstructure on the ability to remove particles from representative substrates is demonstrated. Free-standing microstructured polypyrrole (PPy) films of a variety of dimensions and form factors are fabricated using a templated electropolymerization process. The removal of polystyrene fluorescent particles from an aluminum substrate of varying surface roughness is examined as a function of the polymer microstructure. PPy microstructured films display enhanced particle removal abilities compared to PPy non-structured and current commercial films. This increase in particle removal is attributed to the increased particle-swab contact from the microstructured films.

Next, the influence of the surface chemistry of sampling swabs on the collection of a representative explosive analyte, trinitrotoluene (TNT) is explored. The surface chemistry of PPy films is modified by electropolymerizaton of an N-substituted pyrrole monomer. The surface chemistries examined include a methyl, carboxylic acid, and amino-phenyl functionality. The vapor deposition of TNT on the surface of the functionalized PPy films is quantified through ultraviolet-visible (UV-vis) absorption and compared to commercial swabbing materials of varying chemistry and surface roughness. The PPy modified films with potential sites for hydrogen bonding display the highest deposition of TNT, while the Teflon coated commercial films display the lowest interaction with TNT.

Finally, the desorption and release of TNT from sampling swabs is studied as an effect of temperature and of applied bias. For successful analyte detection within an IMS, the residue collected on a sampling swab must be released from the swab, typically through a thermal desorption process. In this work the release of TNT from sampling swabs is determined through solid-phase microextraction-gas chromatography mass spectrometry (SPME-GCMS). The results of this thesis provide important information on the design considerations for the development of novel particle sampling swabs with increased performance.