Integrated TiO_2 Nano-sensor Package for Detecting Fugitive Volatile Organic Compound Emissions

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Volatile organic compounds (VOCs) are associated with adverse health effects. They are also precursors to ozone and secondary aerosol formation. Benzene, toluene, and ethanol are common VOCs, which are also indicators of petrochemical emissions. Benzene is a human carcinogen, and toluene can cause neurotoxicity. Industrial facilities and chemical plants are large sources of fugitive VOC emissions. Current strategies for detecting fugitive VOCs involve periodic passive sampling (collected at 2-week intervals and post-analysis in a laboratory) or the use of expensive handheld VOC detectors. However, passive sampling strategies often mean that a facility will only learn of its VOC releases weeks or months after the event occurs. Hence, there is a need for more effective methods to detect low concentrations of fugitive VOCs emissions.

Metal oxide semiconductor-based nano-sensors make for a promising choice for gas sensing, owing to their high sensitivity, quick response time, relatively inexpensive nature and simple sensing mechanism. This study presents the development of an electrochemical TiO_2 nanotube-based sensor array that has a high surface area and is highly sensitive for the detection of fugitive VOCs (benzene, toluene, and ethanol). TiO_2 nanotubes were synthesized through electrochemical anodization in an electrolytic solution of ammonium fluoride (NH_4F)-ethylene glycol ($C_2H_6O_2$) and oxygen annealed at 500°C for 8 hours.

The response of the sensor was measured using an amperometric technique (change in current over time) at room temperature. This study evaluated arrays of TiO_2 sensors operating at different combinations of bias voltages to determine concentrations of individual VOC species. The operating voltage of the sensor determines its selectivity towards the particular VOC. Preliminary results showed that when exposed to benzene at a bias voltage of +1.5 V, the sensor consistently exhibited a decrease in current that was proportional to benzene concentration, and benzene had an oxidizing effect on the TiO_2 surface. However, toluene and ethanol had a reducing effect on the TiO_2 surface at the same bias voltage. This provides a proof of concept that this type of inexpensive sensor can identify individual VOC compounds.