

Multi-Transducer Arrays for Determination of Organic Vapor Mixtures

Chunguang Jin and Edward T. Zellers

In most applications of microfabricated sensor arrays to multi-vapor analysis, the devices employed operate on the same transduction principle. It stands to reason that arrays incorporating sensors that operate on different transduction principles should enhance response diversity by probing different aspects of the vapor-interface interaction, thereby improving vapor discrimination. This study explored and compared capabilities for vapor recognition and quantification with polymer-coated single-transducer (ST) and multi-transducer (MT) arrays. The picture at the right shows an MT array chip (7mm x 7mm) consisting of three different transducers, all with on-chip signal processing circuitry, produced by collaborators P. Kurzawski and A. Hierlemann at ETH, Zurich. Each chip has one cantilever (CAN), one capacitor (CAP), and one calorimeter (CAL), coated with the same polymer. Data from five chips, each with a different polymer layer, were pooled for this study. The primary data set consisted of experimentally derived sensitivities for 11 organic vapors obtained from these 15 microsensors. These were used in Monte Carlo simulations coupled with principal component regression models to assess expected performance. Recognition rates for individual vapors and for vapor mixtures of up to four components were estimated for single-transducer (ST) arrays of up to 5 sensors and MT arrays of up to 15 sensors. Our findings are fourfold. First, recognition rates are not significantly improved by including more than 5 sensors in an MT array for any specific analysis, regardless of difficulty. Second, optimal MT arrays consistently outperform optimal ST arrays of similar size, and with judiciously selected 5-sensor MT arrays one-third of all possible ternary vapor mixtures are reliably discriminated from their individual components and binary component mixtures, whereas none are reliably determined with any of the ST arrays. Third, a “universal” MT array consisting of eight sensors was defined, which provides the best possible performance for all analytical scenarios. Accurate quantification is predicted for correctly identified vapors. Lastly, quaternary mixtures could not be analyzed effectively with any of the arrays. ■

Comparison of 5-sensor ST CAP, CAN, and CAL arrays to 5-sensor MT arrays for recognition of a) 11 individual vapors, b) 55 binary mixtures, and c) 165 ternary mixtures. In a), the 5-sensor MT array is the best selected from 3003 different 5-sensor combinations. In b) and c), a different (optimal) 5-sensor MT array is chosen for each mixture. The confidence interval around the mean recognition rate is shown for each array type, along with the range (minimum to maximum) of recognition rates.

