ABSTRACT
MONITORING HYDROCARBONS IN AIR USING ADAPTIVE MULTIVARIATE SENSOR SIGNAL PROCESSING AND ANALYSIS OF HUMIDITY EFFECTS

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Volatile organic hydrocarbons such as BTEX (benzene, toluene, ethylbenzene, xylenes), commonly released into the ambient environment from sources such as gasoline or household products, are known to be hazardous to human health. As a result, real-time monitoring of such compounds in ambient environments is required for safety. Gas sensors with high sensitivity, sufficient selectivity, and fast response times are needed for effective monitoring of the environment. This dissertation addresses some challenges in environmental monitoring using gas sensors, especially with multi-analyte mixtures in the presence of humidity.

This work uses sensor arrays with multivariable sensing parameters (sensitivity and response time constant) with three different polymer-plasticizer blend coatings, each partially selective to BTEX compounds. Using multivariable sensor parameters drastically increases the probability of detection and accuracy of quantification while decreasing the probability of misidentification. Adaptive multivariate sensor signal processing was used to extract recognition and concentrations from the rapid transient sensor response to multi-analyte mixtures. The approach combines principal component analysis (PCA) and Levenberg-Marquardt (LM) modified exponentially weighted-recursive least squares estimation (EW-RLSE) algorithm for analyte identification and quantification (down to 3 µg/L for all target analytes) from the mixture responses. A slightly higher detection limit was obtained for benzene due to its high vapor pressure. Using PCA, excellent cluster separation for single analytes was achieved, and with the LM modified EW-RLSE, correct identification of target analytes (including common interferents) was obtained from mixtures. Accurate concentration estimations also require a minimum data sampling rate. A sampling time of no more than 1 s resulted in concentration errors of approximately ±5% for BTEX analyte mixtures, with up to 6 compounds, using the proposed algorithm.

In real-world applications, changes in humidity pose a challenge to the functionality of most sensor systems. This dissertation also investigates the effect of humidity on the coated shear-horizontal surface acoustic wave (SH-SAW) sensor on analyte detection. Addressing this challenge is key to efficient design of the proposed polymer-plasticizer blend coated gas sensor systems. For single analytes and multi-analyte mixtures, the LM modified EW-RLSE algorithm resulted in accurate concentration estimation in a relative humidity range up to 65%.