CALIFORNIA STATE SCIENCE FAIR
2011 PROJECT SUMMARY

Name(s)
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S0603

Project Title
Development of a Novel Optical Sensor for Simultaneous Detection of Total and Specific Volatile Organic Compounds

Abstract

Objectives/Goals
Volatile organic compounds (VOCs) represent significant health and environmental safety hazards. Sensors for VOCs exist, but are limited, due to cost and size constraints. We aimed to create a small and cost-effective, yet highly sensitive and selective sensor for VOCs.

Methods/Materials
Our sensor was fabricated by growing a thin-film, metal-organic framework (MOF) comprised of zeolitic imidazolate framework 8 (ZIF-8) on a porous silicon Fabry-Pérot layer. The MOF layer facilitated size-based discrimination between similar compounds, while also increasing sensitivity. Hexane and cyclohexane were used as model compounds, due to their similar molecular weights and chemical properties, but different shapes. Optical reflectance measurements involving analysis of Fabry-Pérot interference spectra were used to collect data.

Results
A ten-fold increase in sensitivity to hexane and significant ability to distinguish between the two vapors were demonstrated. Further, a novel way of analyzing the data allows for simultaneous quantitation of total VOCs and a specific VOC of interest from a single optical measurement, representing a significant improvement over current sensors. Preliminary studies show a 24% increase in sensitivity to natural gas, with this as yet unoptimized system. Thermal renewability, a new feature, increases the sensor's versatility.

Conclusions/Discussion
With these results, we have demonstrated the potential of this dual sensing system as a sensitive, selective, and renewable technology for VOC detection. This novel system has potential applications in a wide range of fields, including health and environmental safety and military and defense operations. Miniaturization and implantation of devices in fabrics allow for instant, on site sensing in settings, such as mines and combat areas. The large number of MOFs currently available allow for customization of this sensor to detect chemicals in virtually any size range.

Summary Statement
A novel sensor for simultaneous detection and quantitation of total and specific volatile organic compounds was developed using thin-film metal-organic framework layers on porous silicon photonic crystals.

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