MEMS Sensors with Chemically Selective Coatings of Ionic Liquids

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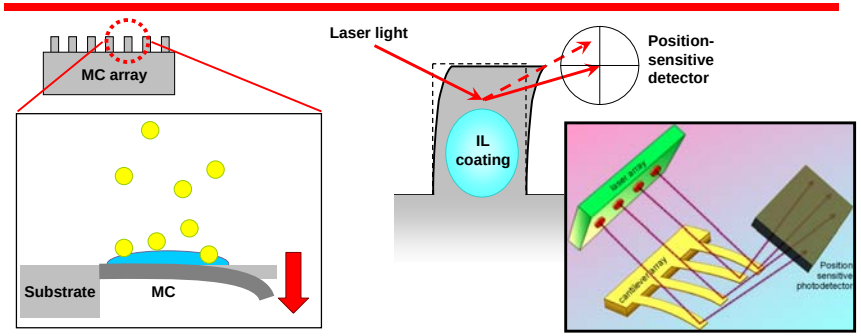
Introduction and Objective

Introduction: Microcantilevers (MCs) are used as chemical sensors. As a result of differences in surface stress between the two sides of MCs, they bend following sorption of a target analyte. Bending and oscillation frequency changes of MCs are detected using reflected laser light. Some ionic liquids are considered to have strong affinities for selected chemical species. Sensors comprising multiple MCs, each with a different ionic-liquid coating, not only can detect targeted analytes, but can also help in chemical speciation.

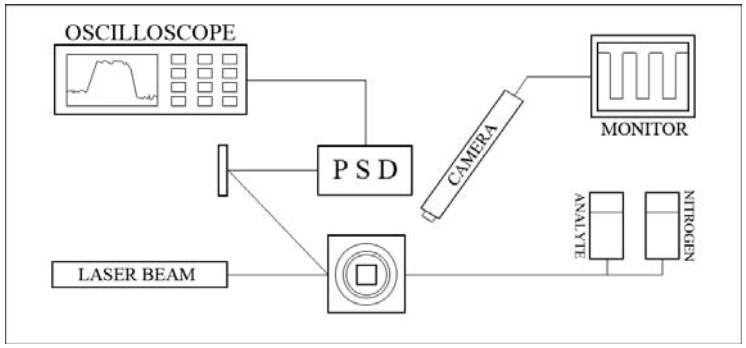
Objective: The objective of this SEED project is to investigate the detection of gas- and liquid-phase analytes with ionic-liquids (ILs) coated MC sensors.

Microcantilevers with Asymmetric Surfaces



Asymmetric MCs have one side coated with a thin chemical film that sorbs target analytes. While the opposite side of the cantilever is passive, the surface tension of the chemically treated side changes due to interactions with analytes. A laser beam is focused onto the cantilever tip, and the position movement of the reflected spot is monitored by a position-sensitive detector.

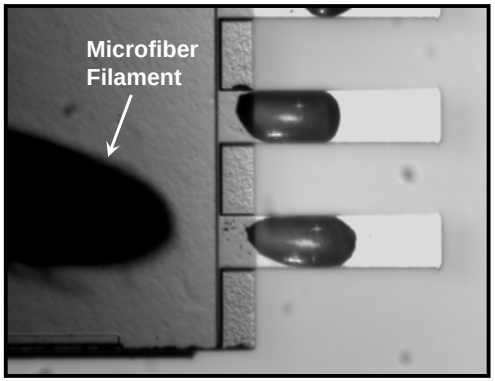
Experimental Arrangement



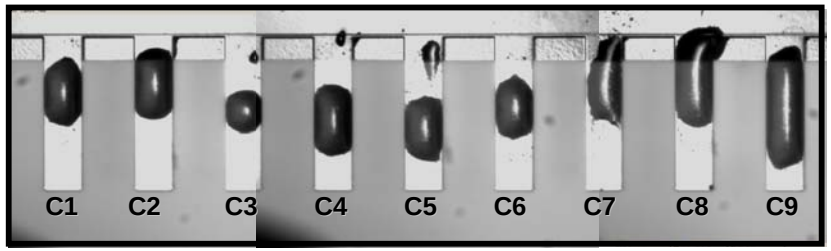
The analyte delivery system consists of an analyte-containing syringe and a nitrogen gas tank. The position-sensitive detector (PSD) is connected to an oscilloscope for direct observation of the signal and a computer for data acquisition.

Ionic-Liquid Coating

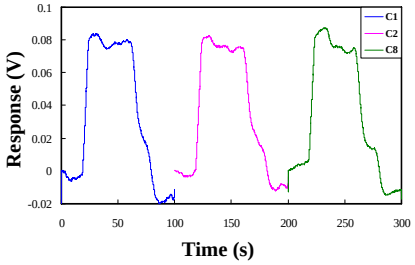
The ionic liquid used is $P_{666,\ 14}$ LABs (or tributyltetradecyl-phosphonium dodecylbenzene-sulfonate), which has a sulfonate anion. This is a water insoluble ionic liquid. The IL was deposited on a cantilever using a microspotting technique, where an appropriate amount of IL is transferred onto a cantilever simply by painting it with a microfiber filament.



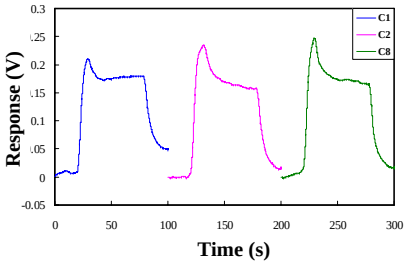
Coating of Cantilever with Ionic Liquid: Response to Water and Acetone



Response to Water Vapor

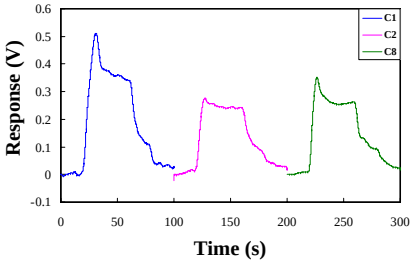


Response to Acetone Vapor

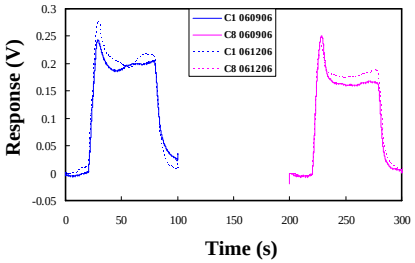


Response to Ethanol Vapor: Reproducibility Test

Response to Ethanol Vapor



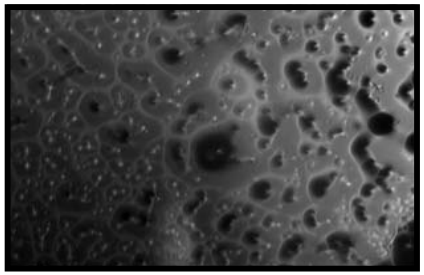
Reproducibility Test

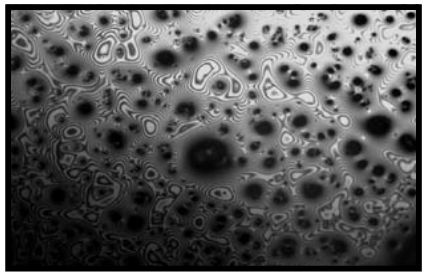


The chemical with highest volatility had the largest response. The reproducibility of response measurements was confirmed by measuring the response of ethyl alcohol in nitrogen after a period of 3 days. Within this period, there was no significant change in the response of the IL-coated cantilevers.

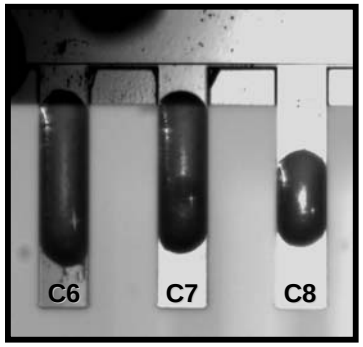
Particle-Mixed IL+ Diluted IL with 2-Propanol

To overcome coating limitations of the smooth-surface cantilever, nano-size powder of aluminum oxide, which is inert and stable, was used to form a suspension with the IL. Because the powder-IL mixture has a higher viscosity, a 10 % dilution of IL with 2-propanol was used to form the powder-IL mixture. When this mixture was applied on a flat silicon plate, a thin IL layer was evenly formed.





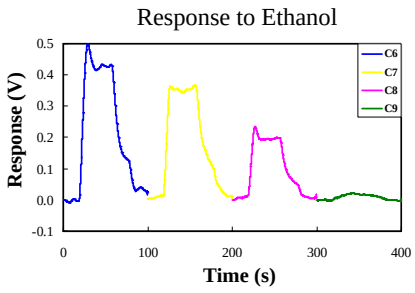
Different Coating Methods

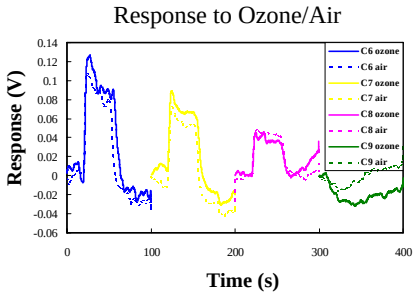


The IL-mixture coating is thick and appeared as a droplet. Due to the presence of particles, an increased total surface area of IL can be generated.

- 2-propanol 90% + ionic liquid 10%
- particle + ionic liquid
- particle + 2-propanol + water

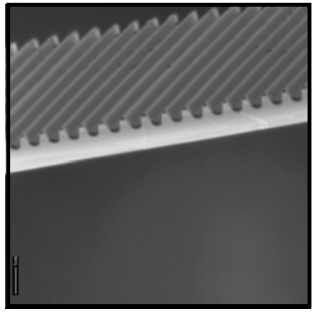
Results of Different Coating Methods with Ethanol and Ozone/Air

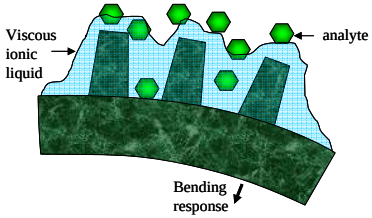




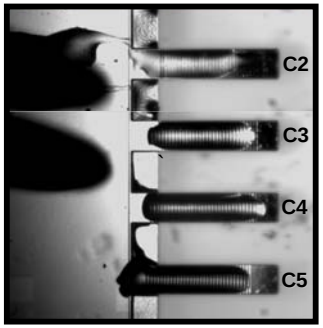
The higher surface area led to a higher response with ethanol vapor. The cantilever response with ozone was lower than that with other analytes, like ethanol. The response patterns were similar with that of air, indicating that this particular ionic liquid is not appropriate for ozone detection.

Structured Cantilever

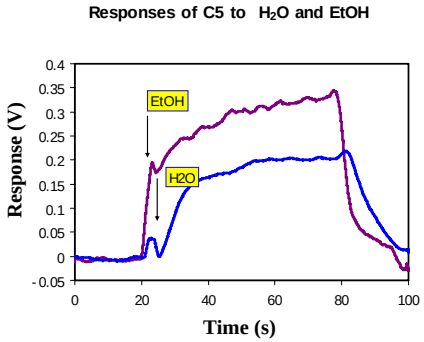


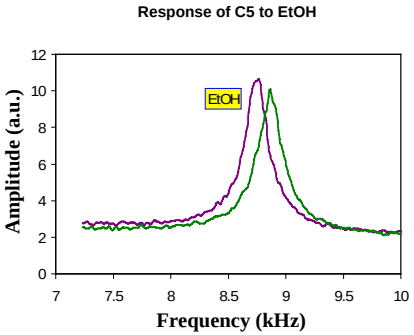


To achieve a uniform, thin coating of IL on the cantilever surface, a nanostructure was applied on the surface of MCs using focused ion beam (FIB) milling.



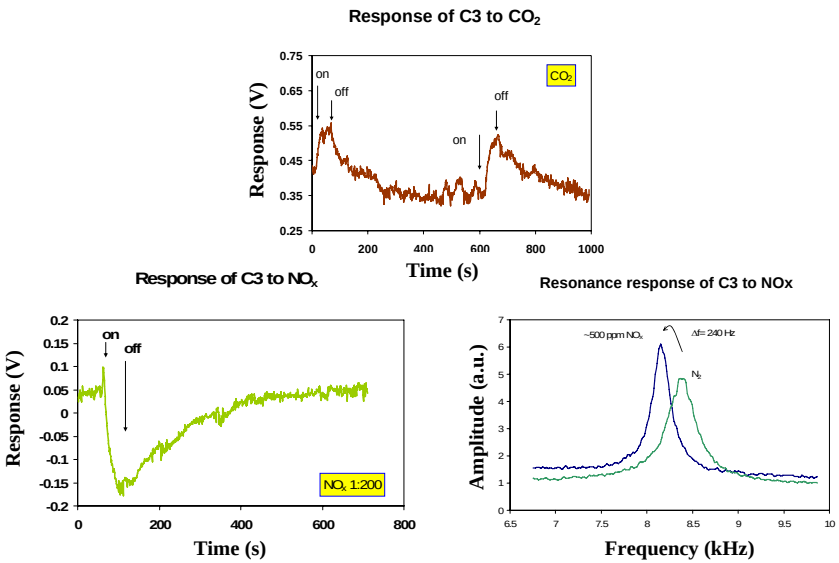
Response of Cantilever to Various Gas-phase Analytes



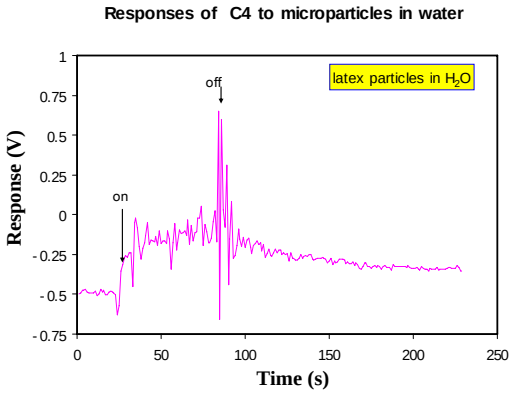


Responses in both bending and oscillation frequency shift were obtained.

Response of Cantilever to Relevant Gas-Phase Analytes



Response of Cantilever in Aqueous Phase



The size of latex particles are about 300 nm.

Summary and Conclusions

- IL-coated MCs showed good responses for water, acetone, ethanol, and NOx.
- The IL coating was stable and the response was reproducible for several days.
- A coating made from a mixture of aluminum oxide particles in a 10% concentration of IL in 2-propanol was evenly distributed on the MC surface.
- The particle-mixed IL coating increases the magnitude of the response.
- The coated ILs on grooved cantilevers showed different results for different-depth grooves.
- ILs have been proven as good coatings for MC sensors.