LIQUID CRYSTAL SENSORS FOR DOSIMETRY AND RAPID SENSING OF TOXIC GASES

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Summary

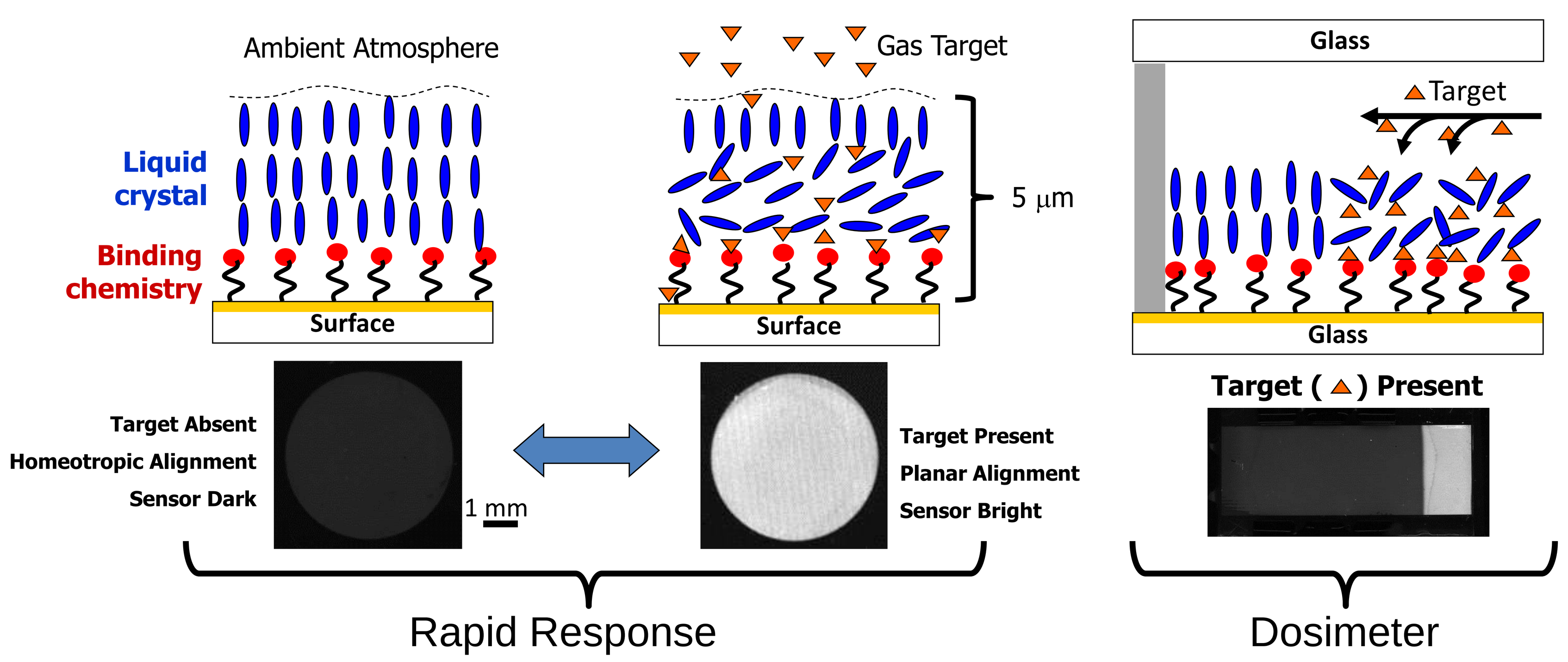
The same liquid crystals (LCs) used in TV and computer screens can also be used for gas sensing. Chemically reactive surfaces are fabricated that (i) align thin films of LC molecules in a specific orientation, and (ii) react with the target gas. Exposure to target gas then disrupts the alignment, and the LC sensors turn from dark to bright.

The ClearSense™ hydrogen sulfide (H_2S) dosimeter, a passive sampling device, detects H_2S more sensitively and with higher specificity than do electrochemical (EC) monitors. The dosimeter can be read with either a zero-power pocket viewer or a USB-powered digital reader. H_2S measurements correlate well with the OSHA-1008 method that pumps air through a sorbent tube, which must be sent to a certified laboratory for analysis. LC dosimeters in contrast provide a sensitive tool for immediate on-site assessment of personal exposure to H_2S, dispensing with the need to wait a week for laboratory analysis.

Fast-response LC sensors use similar surface chemistry principles with a distinct sensor design. Following appropriate chemical and physical optimizations, responses in less than 60 seconds to100 ppb of H_2S, NO_2, and NH_3 has been achieved.

The light weight, low power requirements and versatile design formats facilitate application of LC sensors to industrial, environmental and defense monitoring needs. These LC sensing capabilities are also ideal for small unmanned vehicles that cannot accommodate traditional electrochemical (EC) sensors, which are either too heavy or too power-hungry or both.

Liquid Crystal Sensing

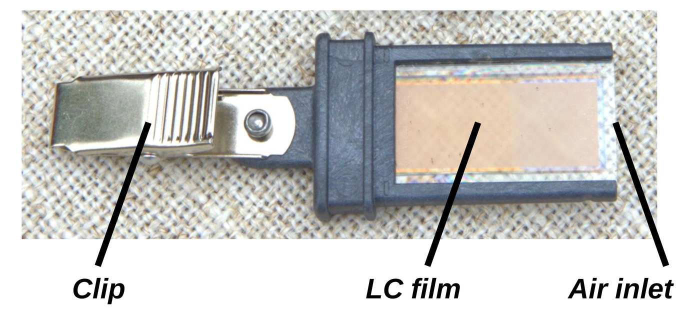


Rapid Response: Gold-coated glass slides are functionalized with reactive chemistries (red) that anchor the LCs (blue bars) in a homeotropic alignment. When viewed through crossed polarizers, the LC sensor appears dark before exposure (left image). When the open-faced sensor is exposed to the target gas, the gas reacts with the surface chemistry, which no longer anchors the LC molecules. As a result, the LC molecules assume a planar orientation and the sensor becomes bright (middle image).

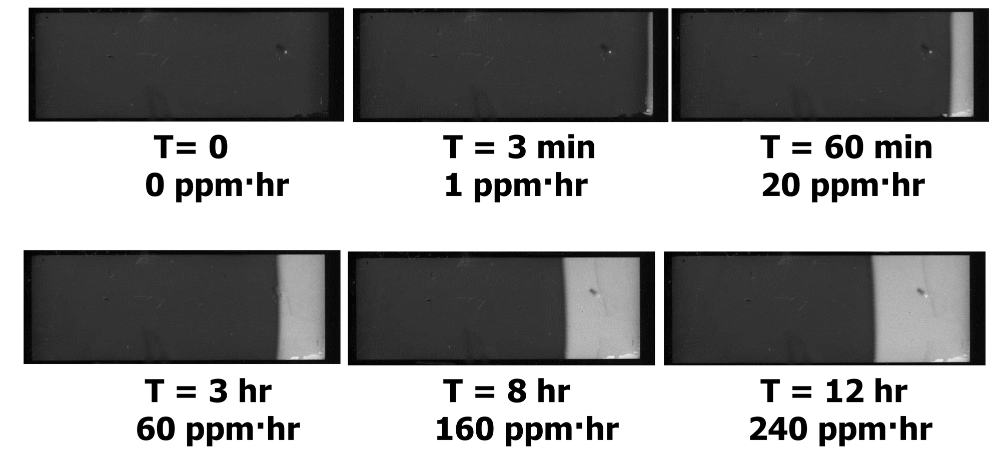
Dosimeter: Using similar surface chemistry, the sensor is enclosed in a housing with only a narrow air inlet that controls diffusion of gas from one end. As the target gas reaches the LCs, the sensor turns bright from the exposed end inwards.

PLATYPUS TECHNOLOGIES

ClearSense™ H_2S Dosimeter

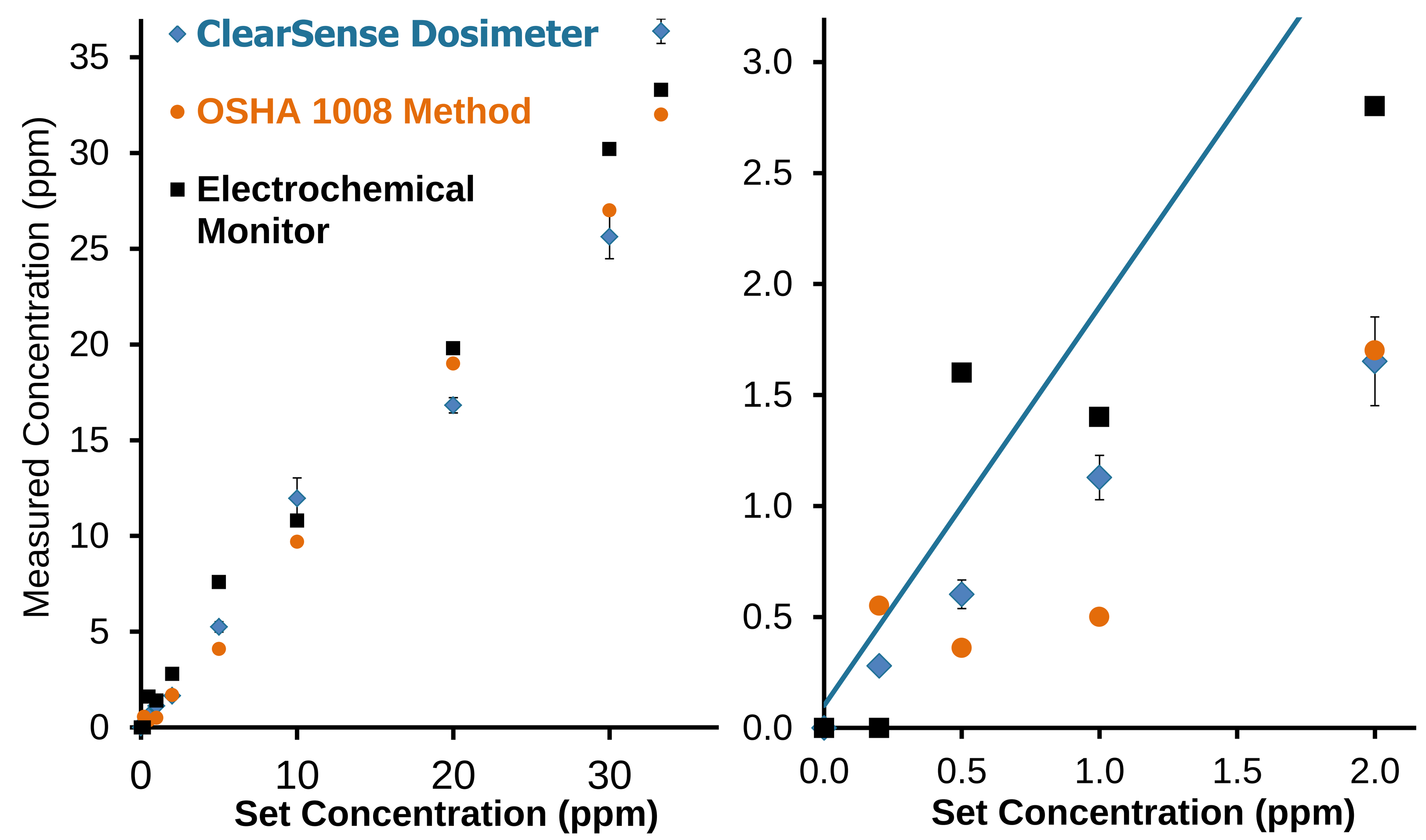


ClearSense™ Dosimeter, cover removed



A series of exposures to 20 ppm H_2S

As gas diffuses across the sensor surface, a bright front lengthens in proportion to the dose of H_2S. Shown above left is a dosimeter with the cover removed. Above right is a series of images of dosimeters exposed to 20 ppm H_2S for 0-12 hr., viewed through crossed polarizers.



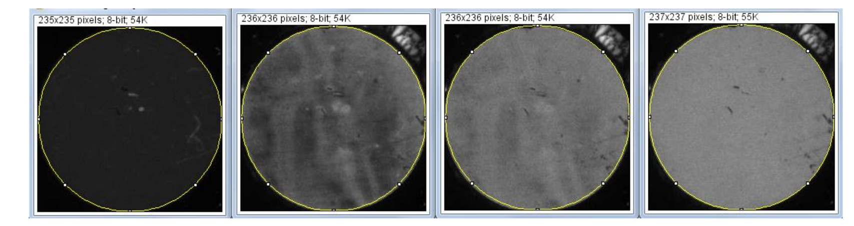
***Laboratory validation of ClearSense™ Dosimeters**. Five dosimeters each were exposed to nine different concentrations (0.2 to 33.3 ppm) of H_2S for different durations (15 min. to 12 hr.) at 60% RH. Using an algorithm, the concentrations were determined and compared with the concentrations measured using an EC Monitor and the OSHA-1008 method.*

The ClearSense™ dosimeter response correlates well with OSHA-1008 measurements and with real-time EC monitor data, and below 5 ppm its linearity is superior to both. The OSHA method requires a sample tube, a calibrated pump, express shipment to a certified lab, and a week's wait for results, while the ClearSense™ dosimeter can be read immediately on site.

The dosimeter clips onto clothing (left) for personal monitoring and can be read in ambient light with the zero-power Pocket Viewer (middle), or with the ClearSense™ USB reader (right) connected to a computer.

Fast-Response Sensors

Fast-response sensors are fabricated as 5-mm LC discs on glass substrates. For exposure the LC surface is completely open to the air. Gas exposures are monitored in real time, collecting camera images every ten seconds.



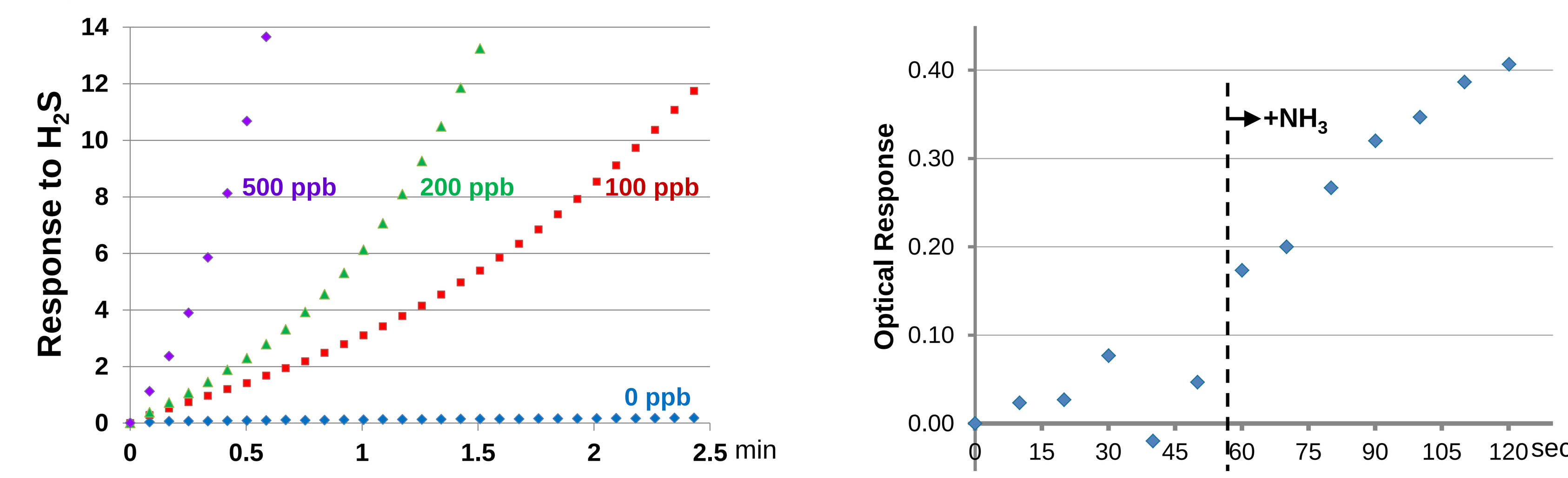
As the sensors respond to target gas mixed with air, they become brighter over time when viewed through crossed polarizers.

Increasing Sensitivity and Response Times

In order to generate faster responses than dosimeters, the surface chemistry underlying the LCs was modified and optimized, along with other fabrication steps, and LC film thickness was reduced from 5 µm to 1-2 µm.

Surface chemistry optimzation centered on (i) screening diverse chemicals for responses to each gas, and (ii) reducing the surface density of LC binding sites.

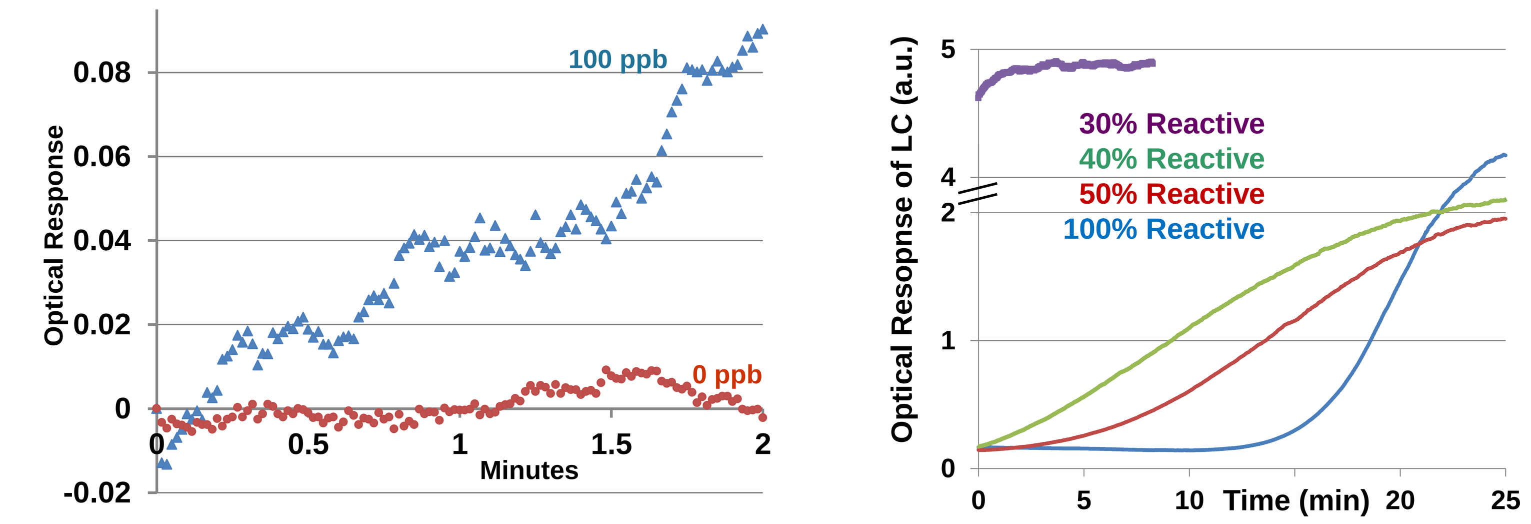
Hydrogen Sulfide & Ammonia



***Fast Response Sensors**: Left, H_2S sensor responses to 0-500 ppb target. Concentrations down to 100 ppb are detected within a minute, and response rates are a function of target concentration, i.e. the sensors are quantitative. Right, NH_3 sensor response to 100 ppb target again is measurable within a minute.*

Nitrogen Dioxide

NO_2 sensor testing was done at 45% relative humidity in nitrogen rather than air since ambient air contains NO_2 levels from 10 - 50 ppb.



***Fast Response NO_2 Sensor**: Left, NO_2 sensor response to 100 ppb target within a minute. Right: How the proportion of surface binding sites impacts sensor responses to 1 ppm NO_2. As the reactive species is reduced, less energy is available to align the LC molecules, so the target gas more readily disrupts the alignment, generating a more sensitive response. Below a threshold level of reactive species, the LC molecules are not aligned at all and the sensor is bright to begin with.*

Acknowledgements

We thank Nicholas Abbott, Jacob Hunter and Marco Bedolla (University of Wisconsin); and Kurt Kupcho, Laura Bremer, Matthew Gajeski and Anthony Moore (Platypus Technologies) for advice and assistance. This work was supported by contract W911SR-11-C-0025 from the US Army Edgewood Contracting Division, contract W911NF-13-P-0030 from the Army Research Office, SBIR Phase I award 1214980 from the National Science Foundation and Research Grant 1R21OH010116-01A1 from the National Institute of Occupational Safety and Health.

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