PLATYPUS TECHNOLOGIES

Bringing Science to the Surface™

Liquid Crystal-based Sensors for Biological and Chemical Detection

National Need

A broad range of US military missions have an immediate need for situational awareness that provide information about the environment. Paradoxically, as the need for such information increases the logistic burden must be reduced. Sensors that have a small foot print, with no power or instrumentation requirements, and that passively sample the environment to detect and warn of chemical and biological agents, can offer minimal logistics burden while providing immediate relevant information to the warfighter. Additionally, monitoring systems that operate in real-time, are sensitive and specific, quick to respond, simple to operate, environmentally robust, and low cost will be broadly useful in the military arena. No sensor currently exists which meets these stringent requirements.

A number of military applications are envisaged for the sensor that is being developed using liquid crystal (LC) detection technology (see **Figure 1**). The nature of the application will dictate any additional components that may be integrated with the sensor. In its simplest form, the technology will provide the basis of visual displays (read by the naked eye, see **Figure 2**) of local environments. Such devices could be displays attached to face shields and badges worn on uniforms of first responders and warfighters or as indicators of the integrity of protective garments. With the addition of electronic components, the sensor can be incorporated into robotic equipment, wall mounted in buildings or located on the outside of vehicles to report the presence of targeted toxic chemicals and biological pathogens using electronic signals and activate a remote visual (flashing lights) or audible signal (alarm). The LC-based sensors can operate in chemically complex environments and will have the following features and benefits:

Figure 1. Platypus Technologies Sensor Applications

- Miniature footprint (5 mm) & negligible weight → Reduced logistical burden to warfighter
- Flexible readout options → Mission selectable passive display, active alarm and remote monitoring
- Sensor surface accessible to analyte diffusion → Fast response time
- Selective → Few false positives, simplified analysis
- Resistant to environmental conditions → Broad applications
- Simple to manufacture → Inexpensive

The Technology

Daunting technical challenges of sensitivity, response time, operational simplicity, specificity, environmental robustness and cost pose barriers to the development of real-time biological and chemical monitoring systems that will be broadly useful to the government and the private sector. Future exposure to hazardous agents in the air that we breathe and the water that we drink, whether accidental or intentional, is a frightening certainty. We are addressing these challenges by developing sensors that employ patented *Platypus Technology®.*

Platypus Technology combines chemically functionalized interfaces with LCs to provide the basis of a sensor platform offering a remarkable range of features, including a small footprint (< 5 mm diameter) for portability, a reversible response for real-time monitoring and constant surveillance, direct visual indication or easy integration into optical and/or electronic reporting systems, ease of operation and low manufacturing costs. These properties make possible a range of applications that are prohibited by the cost or complexity of other technologies. Our propriety technology relies on the fact that the molecular orientation and thus the optical characteristics of a film of LC in contact with an interface is highly sensitive to the molecular-level structure of the adjacent interface. Binding events that occur at the interface between the solid surface and LC or between an overlaying liquid and LC, as illustrated in **Figure 2,** lead to changes in the molecular-level structure of the interface and drive transitions in the orientation of the LC film. This process results in the amplification of sub-nanometer-scale processes associated with molecular recognition into measurable outputs that can be optically or electrically interrogated.

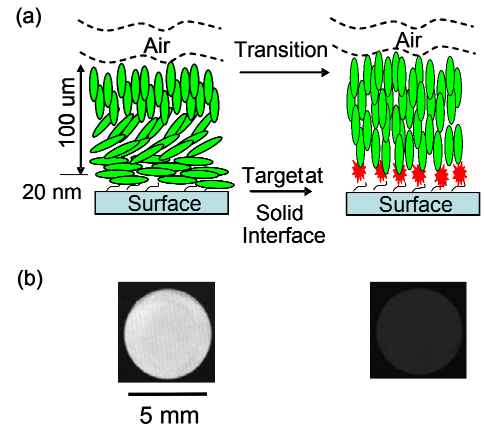

Figure 2. Schematic illustration and images of LC-based sensors for detection of analytes at interfaces. A film of liquid crystal is supported on a surface that is chemically treated to align LCs in a prescribed orientation. (a) Target molecules present in a vapor phase diffuse through the liquid crystal and compete with the LC for a receptor on the surface. The binding event affects a change in the LC alignment at the LC/solid interface and the change is communicated through the bulk. (b) The images, as viewed through crossed polarizers, show the appearance of the sensor (left) before and (right) after exposure to the target.

LC detection technology has been used for detection of low molecular weight, vapor-phase compounds (Shah and Abbott, 2001), proteins (Gupta et al, 1998; Luk et al, 2003), cells (Luk et al, 2004), viruses (Tercero et al, 2004) nucleic acids (Price and Schwartz, 2008) and lipids (Brake et al, 2003). LC sensors are tolerant to non-targeted compounds, can be tuned for specificity (e.g., to differentiate between molecules possessing common functional groups), and permit the real-time monitoring of environments without intervention from an operator. The sensing element is compact, thus reducing the logistics burden. It can be prepared using established processes that are amenable to high throughput manufacturing and from low-cost materials that make it affordable for wide implementation in the field. The optical output of visible light from the sensor can be directly observed (see **Figure 2**) or quantified, e.g., use of a light emitting diode (LED) and a photodiode detector. Integrated with simple electronics, the sensor output can also be quantified by measuring changes in capacitance. We have employed LC sensors to detect a range of targets including: warfare simulants, toxic industrial chemicals, organophosphates, biologically relevant gases, enveloped viruses, antibodies directed against pathogens and components of gram negative bacteria.

Potential Application for Water Quality Monitoring

The ability to quickly and accurately monitor water supplies for the presence of harmful bacteria is central to effective daily management in military missions; it provides a tool to immediately assess the integrity of the water source and storage system, and ensures that the mission of the highly trained and well-equipped unit will not be rendered ineffective by tainted water supplies. The LC-based sensor could be formatted as visual displays embedded in dipsticks, present on sampling tubes, integral to water delivery and storage tanks or attached to water bottles of warfighters or integrated with electronic components for incorporation into robotic equipment, purification systems, or installations.

The development of LC-based sensors, suitable for assessing the presence of bacteria in water, employs patented *Platypus Technology*. For bacteria sensors, this technology exploits the properties of LCs to rapidly amplify nanoscopic binding events involving lipid-containing moieties at surfaces into easily detectable optical signals (see **Figure 2**). Since the LCs can respond directly to the presence of the lipid A, a component of bacterial endotoxin (no fluorescence, enzymatic or other labels are needed), it should provide an immediate indication of water quality as it relates to gram negative bacteria. Exploiting this unique ability of LCs to interact directly with lipids, Platypus Technologies is focusing on development of specific applications of our technology for military and civilian applications. Using chemically functionalized substrates developed for LC-based gas sensors we have shown the ability of LCs to detect lipopolysaccharide (LPS), commonly referred to as endotoxin and a component of gram negative bacteria, in water samples. Such a sensor will be useful to indicate the presence of undesirable microbial organisms in water and alert troops that their drinking water is unsafe. Our approach to this system is extremely simple. We fabricate a sensor by chemically functionalizing a substrate and depositing a thin film of LC onto it. Next, we place a drop of test water on the sensor. In the absence of LPS the sensor appears bright when viewed between crossed polarizing filters. However, in the presence of LPS, an indicator of harmful bacteria, the LCs align and when viewed between crossed polars the sensor appears dark. Representative data and images of sensors exposed to bacterial LPS/endotoxin are provided in **Figure 3** where responses of the positive and negative samples were unequivocally differentiated 9 minutes after sample delivery.

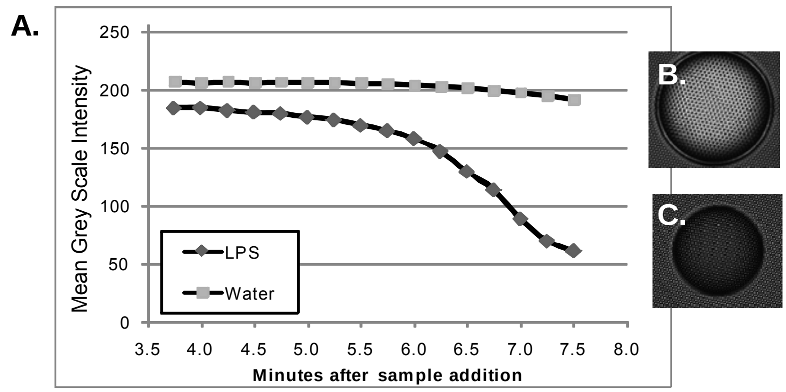

Figure 3. LC sensor response to bacterial LPS. Droplets of water and *E. coli* LPS (0.5 ul) were spotted onto separate areas of the same 5 mm diameter LC sensor. Images were collected by video microscopy and analyzed for light intensity. Approximately 9 minutes after sample addition images show that the presence of water alone resulted in a LC orientation that allowed light to pass through the sensor (B) while the presence of LPS resulted in LC alignment that prevented the passage of light (C).

Advantages of *Platypus Technology* for Monitoring Bioburden in Drinking Water

The characteristics of compactness, simple operation and fast response make the LC-based sensor well-suited to monitor water quality. The main commercial assay for endotoxin is the limulus amoebocyte lysate (LAL) test in which lysate, from the blood of the horseshoe crab, is mixed with the test sample. When endotoxin is present it engenders a clotting cascade such that the sample coagulates. Three types of commercial kits are available that use gel-clot, chromogenic, or turbidometric LAL methods. Based on manufacturer's instructions, these methods require approximately 1 hour to perform, an assay time that is substantially longer than our LC-based assay. In addition, since the LAL test relies on enzyme activity, problems arise when test conditions interfere with the enzymatic reactions. The LAL assays are expensive, time consuming, and require specialized equipment and trained personnel; prohibiting their widespread application and frequency of use. Finally, it is very unlikely that advances in the existing technologies over the coming decade will yield the combination of properties provided by our LC-based technology.

The successful development of LC-based sensors integrated with water storage and sampling regimens whether at military installations or in the field will greatly advance biological and chemical awareness and safeguard our troops by providing immediate feedback of water integrity.

We are very excited about our LC sensor technology. This platform technology has broad applications that enable its use in a variety of settings. We look forward to the opportunity to explore your areas of interest.

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