SELF-ASSEMBLED NANOFIBERS SNIFF OUT EXPLOSIVES

Improvised explosive devices (IEDs) are not just a threat to military troops but to civilians as well. While certainly less frequent, serious IED attacks do occur off the battlefield, such as the IED incident that killed three people and injured about 264 others at the 2013 Boston marathon. Thwarting these attacks will require many measures, one of which is improved screening technologies.

Currently, screening for explosives at airport security checkpoints employs swabbing randomly selected passengers' hands and analyzing the swabs with an ion-mobility spectrometer, which detects trace levels of explosive compounds. Ion-mobility spectrometers, however, are large and expensive — preventing their widespread use. In addition, these spectrometers are not sufficiently portable and therefore cannot be used by hazmat teams called upon to investigate unknown substances in the field.

Vaporsens, a Univ. of Utah spin-off company, is developing a sensor that could meet the need for a portable, inexpensive explosives-screening device. The sensor includes intertwined nanofibers coated onto interdigitated electrode pairs. The coated electrodes are placed on an integrated circuit card (3 in. by 3 in.), which is connected to a handheld electronic device. The nanofibers trap explosive molecules like a spider web catches insects. The presence of explosives alters the fibers' electrical conductivity, and the change in conductivity is quantified to indicate the amount of explosives present. In performance tests at the Naval Research Laboratory, Vaporsens successfully demonstrated that the sensor can detect trinitrotoluene (TNT) vapors at the parts-per-trillion level.

▲ Vaporsens has developed this handheld, portable device that senses explosive compounds down to parts-per-trillion levels. The sensor materials have a shelf life of over one year, and the sensor array has been tested over a period of 15 days of continuous sampling without exhibiting any significant change in performance. When the sensing element does need to be replaced, the process is as simple as replacing a secure digital (SD) card in a camera. Image courtesy of Dan Hixon, Univ. of Utah College of Engineering.

"We're developing a novel, portable vapor-analysis device capable of detecting trace amounts of explosives and chemicals with greater sensitivity, speed, and selectivity than has been possible in such a small package," says Ben Rollins, CEO of Vaporsens.

The new sensor is made of tiny fibers of perylene tetracarboxylic diimide. The nanofibers are prepared via self-assembly of perylene diimide molecules with side groups that are customized to have a strong affinity for the explosive compounds of interest. The synthesis relies on previous work conducted by Ling Zang, a professor at the Univ. of Utah and the inventor of the technology. The fibers are then coated onto interdigitated electrodes.

Perylene diimides were chosen as the building block for the fibers because they have several properties that are ideal for sensors. Self-assembled fibers of these molecules have many adsorption sites, which allows for high sensitivity. In addition, the side groups of perylene diimides can be modified to create fibers that are sensitive to different molecules without changing the electronic properties of the central conjugation part of the compound. This is a unique quality, as the electronic properties of a molecule often change with a change in side groups. Vaporsens has developed more than 30 different highly sensitive fibers, each uniquely optimized for detecting a specific class of chemicals.

Here's how the sensor works: The coated nanofibers form a porous structure that captures targeted molecules (*e.g.*, explosives) from the air through molecular diffusion and surface adsorption. Then the nanofibers either withdraw electrons from the target molecule or donate electrons to it, causing an increase or decrease in observed current. Because they are conductive, the nanofibers form an electrical circuit with the electrodes, and changes in the current can be monitored to detect target molecules.

Because of the nanofibers' large surface area, the sensors are highly sensitive to target molecules. The sensors also exhibit exceptional detection speed (milliseconds). The company attributes this to the strong intermolecular electronic interaction within the nanofibers, enabling the electrons from the target chemical to be transported rapidly along the nanofibers — a key feature that minimizes the loss of electrons by charge recombination.

Vaporsens is now working to develop a sensor that can detect multiple chemicals by combining several different fibers into an array. Such a chip-scale sensor array is small and flexible, and can be incorporated into a handheld (or wearable) detector or mounted on unmanned vehicles. The company plans to have a working prototype ready for field testing some time this year.

This technology was funded through the NSF Small Business Innovation Research Program.

This article was prepared by the National Science Foundation in partnership with *CEP*.