Engineers Develop Biowarfare Sensing Elements That Permit Mass Production of Highly Sensitive Nerve-Gas Detectors

February 10 2005

A sensing device tailored for mass production of highly sensitive and stable nerve-gas detectors has been developed by a research group led by a mechanical engineer at The University of Texas at Austin.
The new sensor technology, which was more sensitive and much more stable than its predecessors, was featured on this week's cover of Applied Physics Letters. The researchers' highlighted study demonstrated the sensor's potential ability to detect a single molecule of the nerve gas, sarin, the most toxic of biological warfare agents.

The researchers, led by Dr. Li Shi, designed and tested a nanometer-thin crystal of tin oxide sandwiched between two electrodes. When a built-in micro-heater heated the super-thin device, the tin oxide reacted with exquisite sensitivity to gases.

Shi's group experimented with a non-toxic gas, dimethly methylphosphonate (DMMP) widely used to accurately mimic sarin and other nerve agents. The sensor element responded to as few as about 50 molecules of the DMMP in a billion air molecules.
Both the nano-sizing of the metal-oxide and the unique micro-heater element of the sensor gave the detector its high sensitivity, stability and low power consumption, said Shi, assistant professor of mechanical engineering.

The thinner a metal-oxide sensor becomes, the more sensitive it becomes to molecules that react with it. In addition to improved sensitivity, the group found its single-crystal metal-oxide nanomaterials allowed the detector to quickly dispose of previously detected toxins and accurately warn of new toxins' presence.

Shi's engineering collaborator, Zhong Lin Wang from Georgia Institute of Technology, provided single crystals of tin oxide as thin as 10 nanometers, and with the ability to rapidly recover from chemical exposure. The researchers found that the sensor was refreshed immediately after the DMMP molecules were purged from the small flow-through chamber where the sensor element was tested in. By contrast, previous polycrystalline metal oxide thin film sensors could not recover automatically after being exposed to toxic or flammable gases, an effect known as sensor poisoning.

Co-author and collaborator Wang is the first to grow the ribbon-like, single crystals of tin oxide used for sensing DMMP. Other sensors of this type consist of crystals with many imperfections, and recover slowly because molecules previously detected can become trapped in these imperfections.

Shi constructed the accompanying sensor components using traditional computer chip design and fabrication techniques. Specifically, he used microelectromechanical systems (MEMS) fabrication methods.

For instance, MEMS was used to fabricate the platinum electrodes, one of which links to a
microfabricated heating element and thermometer to elevate the nano sensor's temperature to a constant 932 degrees Fahrenheit (500 degrees Celsius) with a power consumption of only 3-4 milliwatts. These components allow the sensor to be operated using a battery so that it can be used as a wearable device. To minimize heat loss, Shi's group isolated the silicon nitride membranes attaching the electrodes using trapeze-like

strands of microfabricated silicon nitride.

The sensor requires the high temperature to activate the reaction between DMMP molecules and the tin-oxide sensor element. That reaction changes the electrical current across the crystal, which indicates a nerve agent is present.

The paper was based on the dissertation research of the lead author, Choongho Yu. Yu received a doctor's degree in mechanical engineering from The University of Texas at Austin last year, and is a post-doctoral fellow at Lawrence Berkeley National Laboratory.

Shi's group is continuing to develop methods to integrate nanomaterials with MEMS devices more efficiently in order to microfabricate better, lower-cost sensors. Multiple sensor elements would then be packaged together to produce a commercial sensing device that acts as an electronic nose for detecting different toxic and flammable molecules.

Citation: Engineers Develop Biowarfare Sensing Elements That Permit Mass Production of Highly Sensitive Nerve-Gas Detectors (2005, February 10) retrieved 26 April 2024 from https://phys.org/news/2005-02-biowarfare-elements-mass-production-highly.html