10.1117/2.1201002.002660

Opto-electronic nose sniffs out toxic gases

Kenneth S. Suslick

A newly developed detector for toxic industrial chemicals is highly sensitive, simple, fast, and inexpensive, and it works by visualizing odors.

Chemists have no equivalent of the physicists' radiation badge. There is no readily available method to easily measure the low levels of personal exposure that workers may receive to the diverse range of volatile, toxic industrial chemicals (TICs) used in laboratories, manufacturing facilities, or general-storage areas. Thus, there remains a pressing need for rapid, portable, and highly sensitive identification of toxic gases and vapors. Potential applications include use in the industrial chemical workplace, security monitoring, and more general epidemiological studies.

We have developed an artificial nose for the general detection of poisonous gases and deadly toxins that is highly sensitive, simple, fast, and inexpensive. It works by changing colors.[1,2] This sensor array (resembling a polka-dotted postage stamp) could be useful in detecting high exposures to chemicals that pose serious health risks in the workplace or through accidental exposure. Our device is simply a digital, multidimensional extension of litmus paper. It consists of an array of 36 different nanoporous pigments whose colors change depending on their chemical environment. The pattern of the color change is a unique molecular fingerprint for any toxic gas and also tells us its concentration. By referring to a library of color fingerprints, we can identify and quantify the relevant TICs in a matter of seconds.

To create the sensor array, we print a series of tiny colored dots—each a different pigment—on an inert backing layer such as paper, plastic, or glass (see Figure 1). The array is then digitally imaged before and after exposure to an odor-producing substance. Unlike other electronic-nose technologies that have been tried in the past, our colorimetric sensors are not affected by changes in relative humidity.

To test the application of our chemical sensor, we chose 20 representative examples of TICs. We included chemicals such as ammonia, chlorine, nitric acid, and sulfur dioxide at concentrations known to be immediately dangerous to life or health. We have improved the array's sensitivity and can now distinguish among those 20 TICs at levels a hundred times lower, generally down to 5% of the permissible exposure levels. Our laboratory studies used inexpensive flatbed scanners for imaging but we have developed a fully functional prototype handheld sniffer (see Figure 2). The latter uses inexpensive white LED illumination and an ordinary electronic camera, which makes the entire process more portable, sensitive, faster, and less expensive. It will eventually be similar to a card-scanning device.

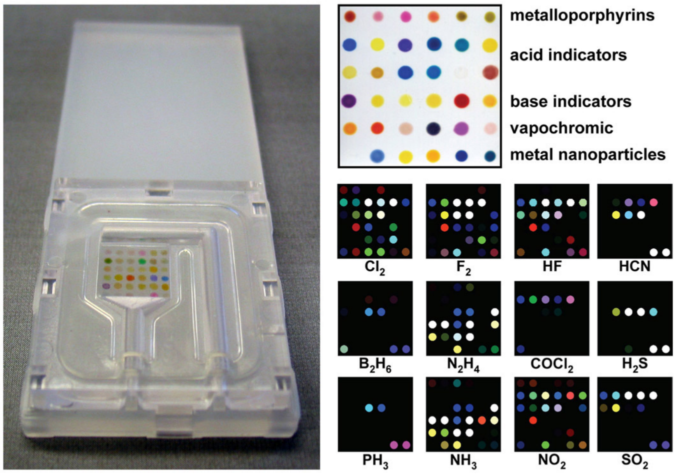

Figure 1. *Our colorimetric sensor array. The device uses a printed array smaller than a postage stamp composed of nanoporous pigments that change color in response to their chemical environment. The color differences are shown for a few representative poison gases.* Cl_2*: Chlorine.* F_2*: Fluorine. HF: Hydrogen fluoride. HCN: Hydrogen cyanide.* B_2H_6*: Diborane (also known as boroethane, boron hydride, and diboron hexahydride).* N_2H_4*: Hydrazine (diazane).* $COCl_2$*: Phosgene (dichloromethanal or carbonyl chloride).* H_2S*: Hydrogen sulfide.* PH_3*: Phosphine (phosphane).* NH_3*: Ammonia.* NO_2*: Nitrogen dioxide.* SO_2*: Sulfur dioxide.*

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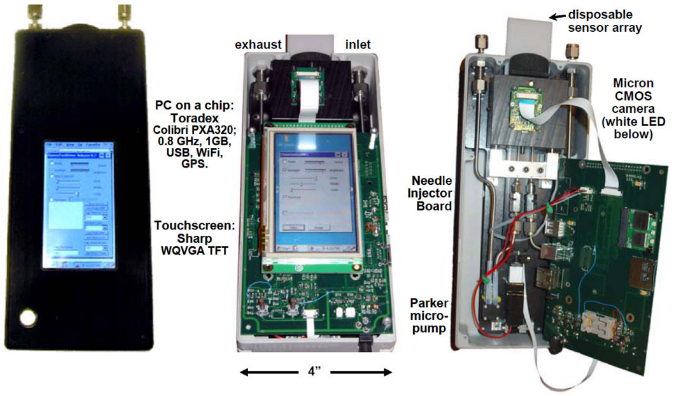

Figure 2. *Handheld array reader. The device analyzes the color changes in the sensor array to quickly monitor the environment for toxic chemicals. USB: Universal serial bus. GPS: Global positioning system. WQVGA TFT: Wide quarter-video-graphics-array thin-film transistor.*

Older electronic-nose methods relied on sensors whose response originated from weak and highly nonspecific chemical interactions, while our new technology is based on stronger dye-analyte interactions that are responsive to a diverse set of chemicals. The ability of our sensor to identify so many volatile toxins stems from the increased range of interactions that are used to discriminate the array’s response. In previous studies, we showed the ability to discriminate among different chemicals and complex mixtures, including 100 volatile organic compounds,[3] sweeteners,[4] soft drinks,[5] and even beers.[6]

One of the advantages of this technology is that it uses components that are readily available and relatively inexpensive. Given the broad range of chemicals that can be detected and the high sensitivity of the array to those compounds, we expect that this device will be particularly useful in occupational settings. Our recent developments bring us one step closer to having a small wearable sensor that can detect multiple airborne toxins, and this is what we expect to have by 2011.

This project is funded by the National Institute of Environmental Health Sciences. The device is currently being commercialized by iSense (Palo Alto, California, and Champaign, Illinois).

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