Grand Challenge Area

Chemical-Biological-Radiological-Explosive (CBRE) Detection and Protection: The Application of Nanotechnology to Homeland Defense

Challenge

Conventional explosives have been the weapon of choice for terrorists, and their use remains a serious threat to the Nation's security. At the same time, the recognition that small amounts of chemical, biological, or radiological agents can exact a much greater human toll than an equivalent amount of explosives has prompted the need for additional precautions and mitigation methods. New technologies that reliably and rapidly detect trace amounts of chemical, biological, radiological, or explosive materials are critical to the national defense, as are new technologies to protect people from the devastating effects of these substances.

Vision

Nanotechnology offers the potential for unprecedented improvements in the sensitivity, selectivity, response time, and affordability of detection technologies. Nanoscience and nanostructures also offer the opportunity for revolutionary advances in adsorbent materials (personal and collective protection), separation technologies (protective clothing and filters), decontamination and neutralization of agents, and prophylactic measures.

One key objective for this grand challenge area is the development of miniaturized intelligent sensors. Such devices would have the potential to sense the presence of specific molecules with accuracy and sensitivity well beyond what is commercially available today. Building such devices will require a much better understanding of nanoscale forces and interactions.

Another key objective is to develop novel protection, neutralization, and prevention technologies. Protective masks and clothing depend on high surface area materials. Nanostructures inherently have large surface-to-volume ratios and also tend to have highly reactive surfaces that may neutralize the toxic material rather than simply hold it. Nanostructures also can be tailored to selectively disrupt the biological activity of pathogens.

Agency Participation

(lead in bold)

DOD	Detection of and protection against CBRE agents
DOE	System integration, lab-on-a-chip, CBRE detection
DHS	Detection of and protection against CBRE agents
DOT	Advanced transportation security systems
EPA	Reduction and remediation of hazardous material
FDA	Processes to ensure safety and security of the food chain
IA	Detection of CBRE agents
NASA	System integration, miniaturization, robotic systems
NIH	Detection of and treatment for chemical, biological, and radiological exposure
NIST	Chemical microsensors, single-molecule measurement
NSF	Sensors and basic principles for detection of and protection against CBRE agents
USDA	Processes and detection techniques to secure agricultural production and food resources

Note: The NNI works closely in this area with the interagency Technical Support Working Group (TSWG), which coordinates efforts in CBRE detection as part of its mission to facilitate development of technologies to combat terrorism.

Research Example: Cantilever Array for Chemical and Biological Threat Analysis (supported by DOE)

Experience with the micro-cantilevered probes used in atomic force microscopes has stimulated the development by various researchers of nanoscale cantilever-based physical, chemical, and biological sensors. Extending the fabrication techniques for microelectromechanical systems (MEMS) to produce devices with nanoscale components not only allows for even smaller and lighter detectors, but also enhances sensitivity. Demonstrated applications include detection of chemical warfare agents, alpha particles, biomolecules, TNT, and plastic explosives. It is possible to arrange arrays of micro- and nano-cantilevers on a single chip to allow detection of multiple targets or to extend the dynamic range (i.e., range of concentrations that can be detected).

One cantilever-based approach detects adsorbed molecules by measuring the change in resonance frequency of individual cantilevers. In general, the smaller the cantilever, the higher its resonance frequency will be and the greater its sensitivity. To date, frequencies from one megahertz to over one gigahertz have been achieved by pushing the cantilever dimensions into the nanometer scale. Whereas cantilever geometry determines sensitivity, selectivity is controlled by coating the cantilever surface with compounds that bind only to the molecule of interest. Researchers at Oak Ridge National Laboratory have developed a cantilever sensor (Figure 9) that uses this approach to detect the presence of nanoscale quantities of material. By having a range of cantilever shapes, and hence frequencies, the sensor array is able to detect a wide range of molecular concentrations. In addition, individual cantilevers may be treated with different coatings to allow detection of multiple target compounds. The Oak Ridge team has demonstrated the ability to detect certain agents down to the single molecule level.

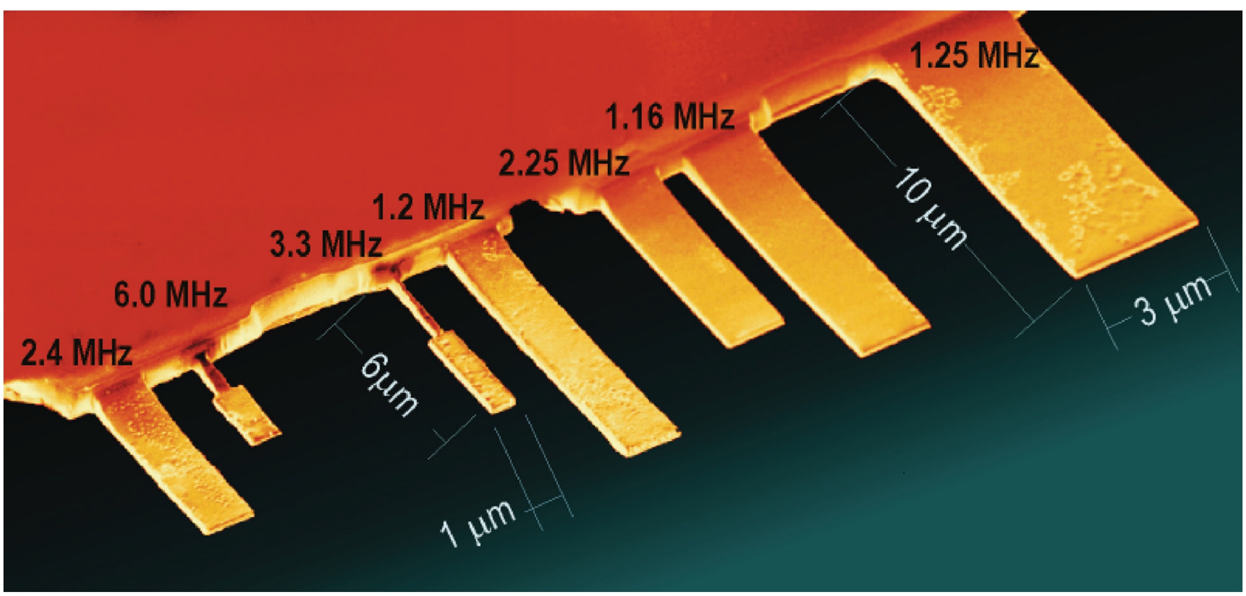

Figure 9. Scanning electron micrograph of an array of silicon cantilevers, milled to various dimensions with a range of resonance frequencies. Detection of adsorbed molecules is achieved by measuring frequency shifts. The cantilevers shown here are coated with gold, which allows detection of as little as a few femtograms (10^{-15} g) of an acidic test compound (courtesy P. Datskos, Oak Ridge National Laboratory).