Biobusters

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Developing battle-ready sensors ? ultra-sensitive and able to ?work in dirt.?  

Folding based sensors that act as signal transducers are the basic thrust of Professor Kevin Plaxco's research.

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Scientists at the Institute for Collaborative Biotechnologies are developing battle-ready sensors that are ultra-sensitive and able to ?work in dirt.?  

It?s not always easy to explain how academic research will affect the wider world. But there?s no such problem with the work of the ICB. The institute, funded largely by the U.S. Army and drawing on the talents of the faculties at UC Santa Barbara, MIT and Caltech, tackles today?s headline issues from terrorism to alternative energy. Its research could well make a life-or-death difference for U.S. troops under threat from roadside bombs or civilians who might be prey to bioweapons.

Nowhere is the ICB?s real-world mission clearer than in its work on biomolecular sensors, one of its four major research areas (the others are bio-inspired materials, bio-network science and biotech tools). Its scientists are developing technology that uses biological compounds to detect minute levels of disease-causing organisms, toxins, explosives or other substances in air, water or soil. The goal is to combine unprecedented sensitivity ? down almost to single molecules ? with reliability, ease of use and ruggedness.
Conjugated polyelectrolytes can also be used to simplify the operation of DNA chips and microarray detection of DNA sequences, as explored in Professor Gui Bazan's laboratory.

The end-product needs to be literally battle-ready. "There are thousands of different types of biosensors in the literature that work wonderfully in the laboratory," says ICB researcher Kevin Plaxco, a UCSB associate professor of chemistry and biochemistry. "Our sensors work in dirt."

They also work in other contaminated environments, such as blood serum. And they can detect staggeringly minute traces — DNA down to parts-per-trillion, for example. They do this by using molecules that are engineered to fold and release an electronic signal when they recognize a particular target. Unlike sensors that rely on adsorption (the binding of molecules to a surface), this technology is "very hard to spoof," Plaxco says.

Plaxco is working on this sensor project with two other UCSB scientists, Alan Heeger, professor of physics and materials, and Pierre Petroff, professor of materials and electrical and computer engineering. Theirs is one of at least 10 projects currently being carried out by ICB's biomolecular sensor team, which includes more than a dozen researchers from the UCSB, Caltech and MIT.

All the projects and participants share the common aim of advancing sensor technology for practical applications. But they come at that target from several different approaches. The folding-biomolecule technology of Plaxco, Heeger and Petroff is just one of these.

Another project group is developing biosensors using surface enhanced Raman spectroscopy (SERS), a method of detecting genes and other objects containing just a handful of molecules. This one includes UCSB physical chemistry Professor and Dean of Sciences Martin Moskovits as well as Plaxco and UCSB chemistry and biochemistry Professor Norbert Reich. Moskovits is also investigating the use of "nanowires" — tiny enough to be packed 50 to 100 per square millimeter -- to detect target molecules.
Reich is studying the potential of metallic and semiconductor nanoparticles for detecting pathogens. UCSB professors Glenn Fredrickson (materials and chemical engineering) and Joan-Emma Shea (chemistry and biochemistry) are developing computer simulation techniques to study the self-assembly principles of biosensor materials.

UCSB chemistry and biochemistry Professor Guillermo Bazan is working with Alexander Mikhailovsky, manager of the university’s Optical Characterization Lab, to amplify biosensor signals. Many biosensing molecules emit light when they recognize a specific target, Bazan says, but the light is too weak to be used in a detection device. Bazan’s project uses light-absorbing polymers to transfer the molecule’s signal and make it about 100 times stronger.

In another UCSB project, Carl Meinhart and Kimberly Turner, both associate professors of mechanical and environmental engineering, are making sensors more efficient by using electric currents to pump fluids and concentrate target molecules. Meinhart says they are able to raise the concentration of DNA molecules 100-fold with just a 50-volt charge. They are also developing sensors to detect airborne chemicals.

Scott R. Manalis, an associate professor in biological and chemical engineering at MIT, has developed a sensor called the suspended microchannel resonator (SMR), which captures molecules or cells flowing through a tiny vibrating channel. Caltech chemistry Professor Nathan Lewis is developing detection technologies that mimic our sense of smell.

All this diversity has a purpose beyond the mere competition of ideas. The ICB operates on the assumption that no single sensor technology will meet all the needs of the Army or the civilian economy. The institute aims to produce multiple options for detecting different types of substances in different environments (such as toxins in liquids or airborne bioweapons). ?There will never be a single platform for bio-sensing,? says Bazan. ?You need a variety of different platforms that are complementary to each other.? Also, as Moskovits notes, ?It?s prudent to assess a variety of different approaches? with nanotechnology still so young. ?The fact that each of us uses a rather different embodiment of the sensor technology is the right thing to do for a university at this stage of development of the field,? he says.

Early-stage it may be, but sensor technology is far enough along to get scientists thinking about potential commercial applications, not to mention the military uses that the Army has in mind. Moskovits, who says his nanowire technology is ?probably 10 years away from commercialization,? nevertheless has an idea or two for putting it to practical use. He suggests that inexpensive diagnostic chips could be made from arrays of nanowires coupled to semiconductors, then deployed ?every few feet in an airport? to detect explosives.

As for biomolecular folding, Plaxco and Heeger see plenty of possibilities. Plaxco says they might be used with ?hand-held electronic devices? that don?t need reagents and are ?reusable in minutes.? They could be used to detect a wide range of particles, from small molecules such as cocaine to pathogen-related DNA sequences and platelet-derived growth factor, a protein ?believed to be diagnostic for several types of cancer.? Heeger says ?the basic work? on this technology has been done, with researchers now
learning how to improve the sensitivity and selectivity. The next step, he says, is either to spin off a company or get someone interested in developing it as a commercial venture. That stage won’t happen at the university, he adds, but the science-to-technology part is being done here and done well.

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