Optical Sensors and Sensor Arrays

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We have used coherent imaging fibers to make fiber-optic chemical sensors. Sensors can be made with spatially-discrete sensing sites for multianalyte determinations. Sensor arrays have been fabricated for simultaneous multianalyte detection. For example, sensors for pH, CO_2 and O_2 have been prepared and used to monitor the dynamic fluctuations of these three analytes during the fermentation of beer. Integrated biosensors that measure both the dependent and independent analytes for penicillin and glucose have also been prepared. Oligonucleotide arrays also can be prepared allowing for the detection of single base-pair mutations.

We have also created optical sensors based on principles derived from the olfactory system. A cross-reactive array of sensors is created such that specificity is distributed across the array's entire reactivity pattern rather than contained in a single recognition element. This approach has been demonstrated with a new vapor sensing device that is designed as an array of optically-based chemosensors providing input to a pattern recognition system incorporating artificial neural networks. In the present device, primary chemosensing input is provided by an array of fiber-optic sensors. The individual fiber sensors, which are broadly yet differentially responsive, were constructed by immobilizing a fluorescent indicator dye in polymer matrices of varying polarity, hydrophobicity, pore size, elasticity, and swelling tendency, creating unique sensing regions that interact differently with vapor molecules. Using signals from the fiber array as inputs, artificial neural networks were trained to identify both single analytes and binary mixtures, as well as relative concentrations. The system is able to recognize a wide variety of volatile organic compounds and mixtures of compounds. This "artificial nose" maintains all the advantages of fiber optics (e.g. remote sensing, small). The ability to use such information-rich assemblies for broad-based sensing will be discussed.

Finally, we are investigating the limits of our ability to create high-density sensing arrays containing thousands of microsensors and nanosensors. Micrometer- and nanometer-sized wells have been fabricated by etching the cores of the optical imaging fiber. Well arrays can be prepared with individual wells ranging in size from 7 microns to 200

nanometers. Different sensing chemistries have been immobilized on the surfaces of microspheres and nanospheres. A mixture of the microsphere sensors is then randomly dispersed in the wells creating a high-density sensor array with each well/sensor connected to its own optical channel. Detection of the sensor signals was achieved by interfacing this fiber optic array with an epifluorescence microscope, a CCD camera, and a computer using commercial microscopy analysis software. This technique could facilitate miniaturization, automation, and increased sample throughput of measurements conventionally performed on microtiter plates or microscope slides. Sensing arrays have been prepared for genosensing, immunosensing and small biomolecule detection.