GUEST EDITORIAL

Chemical Sensors

Interdisciplinary science is not just another buzzword. Slowly but surely, our single-discipline academic departments, effective though they are at teaching one field of science or technology in a focused and coherent manner, are being augmented by coordinated interdepartmental, interdisciplinary programs that more nearly reflect the diverse but integrated set of skills needed to contribute to rapid progress in endeavors both fundamental and applied. Personal and professional relationships fostered by such interdisciplinary environments lead to productive life-long collaborations between individuals with similar global objectives, but different areas of technical expertise. This academic trend is synergistic with gradual shifts in funding emphasis: the most attractive research retains a fundamental flavor while being sufficiently "relevant" that at least one technological, societal, or environmental problem of global importance will be positively impacted by progress.

Chemical sensors and microanalytical systems constitute a paradigm for relevant, interdisciplinary endeavor in which the key limiting problems are remarkably fundamental in nature. A successful sensor-based system must respond with application-dependent sensitivity, selectivity, reversibility, speed, and longevity to a desired analyte, while consuming minimal power and volume, not to mention being manufacturable from inexpensive materials using economical batch methods. This overconstrained problem can be solved only by an ingenious combination of the most fundamental interfacial chemistry, the basic physics of device platforms, clever engineering of the package and overall system, and optimal use of mathematical techniques to produce from raw data a meaningful response.

Of the many requirements for success, the simultaneous need for high selectivity and complete reversibility is most often elusive, and this problem in particular requires a thorough understanding of fundamental interfacial chemistry. The crux of this issue is that perfect selectivity and perfect reversibility are to a significant degree contradictory. Selectivity is enhanced when the interaction between the chemically sensitive interface and an analyte is more chemically specific, implying a stronger and less reversible binding process. Notably, size and shape selection provide partial respite from these contradictory requirements, by using the physical rather than chemical details of a molecule to distinguish it. Small wonder, then, that biological recognition systems use shape and size so extensively, and that considerable effort is being expended to develop highly specific chemical sensors that are nonetheless fully reversible.

While the chemistry of molecular recognition continues to make great strides, with powerful implications for specific chemical sensors—some of them documented in this issue—nature also provides an alternative model approach for chemical identification: the pattern recognition associated with olfaction and gustation. Though physical adsorption lacks the inherent specificity of chemisorption, "like dissolves like" is relevant nonetheless. Thus, an array of chemically sensitive but chemically diverse interface materials, their interactions with analytes characterized by energies closer to physical adsorption than chemical, can yield unambiguous response patterns for dozens of individual species and mixtures—a sort of chemical fingerprinting system. (A fanciful representation of this concept adorns the cover of this issue.) To label these straightforward sorption-based systems, backed by computational capabilities immeasurably less effective than the brain of a dog, "artificial noses" is at once an exaggeration and a disservice to the complexity, versatility, and efficacy of mammalian olfaction. The source of the inspiration, however, cannot be denied.

Any discussion of methods for obtaining chemical speciation using small devices cannot ignore the promising, captivating results being reported at a rapid pace in microanalytical instrumentation, commonly called μ-TAS (micro-total analytical systems) or "lab-on-a-chip". These systems seek to bring the powerful methods of the analytical laboratory, notably sample preparation and separations methods, to bear on the issue of chemical identification, thereby adding a third speciation alternative to molecular recognition and arrays. The goal is to implement analytical methods on a scale small enough to be included in hand-held instrumentation, and the preliminary results are exciting. With a focus much less centered upon the chemically sensitive interface, however, μ-TAS are not a focal point of this issue.

While uncertainty remains regarding which overall recognition strategy will prove most effective, there is little doubt about the myriad applications that are, or may soon be, addressed by chemical sensors. Automotive oxygen sensors, home carbon monoxide sensors, and new clinical diagnostic systems utilizing sensor technology are some of the most familiar examples. The surface has only been scratched, however, in attempts to solve problems in environmental monitoring and remediation, closed-loop industrial process control, space systems and planetary exploration, detection of illicit substances, national security, public health and safety, and drug discovery. Such important and direct applications of advances in interfacial chemistry motivated the development of this special issue of *Accounts of Chemical Research*.[1]

Antonio J. Ricco
Sandia National Laboratories

Richard M. Crooks
Texas A&M University

Guest Editors

(1) The views expressed in this short editorial are largely derived from discussions held at the first NSF Workshop on Chemical Sensors held May 8−10, 1997, at Blue Mountain Lake, NY. The complete Workshop report is available on the World Wide Web at http://www.chem.tamu.edu/walker/chemsens.html.

AR980479O

S0001-4842(98)00479-8 CCC: $15.00 © 1998 American Chemical Society
Published on Web 05/01/1998