Editorial

Introduction: Modern Topics in Chemical Sensing

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Introduction: Modern Topics in Chemical Sensing

Chemical Sensors is a large branch of analytical chemistry that has unique characteristics. It is very broad, ranging from solid-state physics to molecular biology. Because of this breadth, choice has to be made between the all-encompassing, but rather shallow treatment of the subject on one hand or selection of a few topics covered in depth by experts in the field. The latter approach has been chosen for this issue. It does not pretend to cover all new aspects of this active and growing field. Several rather important modern topics of chemical sensing that could have been included have not been, mainly because of the lack of available and willing authors.

There is some confusion in the terminology. The label "chemical sensor" is often used to describe an analytical procedure that should be more appropriately called an "analytical assay" or "sensing system". The main difference between the two lies in the mode of information acquisition. While a chemical sensor acquires information *continuously*, a sensing system obtains information in *discrete steps*. It does not matter that most modern analytical, specifically bioanalytical, assays are automated and can run unattended for long periods of time. The discontinuous nature of their operation still distinguishes them from true chemical sensors. The two groups of procedures are fully complementary and valuable tools of analytical chemistry. This thematic issue is limited to true chemical sensors only.

A typical modern chemical sensor consists of a physical, "*transducer*" and a chemically selective *material*. Different *strategies* can be employed to extract maximum information about the sample. Among these are multivariate analysis of data obtained from sensing arrays, use of spatially and temporally distributed sensors, and integration of sensors with solid-state processing technology. Two examples of important sensor applications have been also included in this issue.

Ion selective electrodes are one of the oldest chemical sensors. In the past decade, some significant—although not always positive—developments have taken place, such as the lowering of detection limits by nonequilibrium operation. The important issue of internal contact in solid-state potentiometric sensors has been one of the most significant contributions of Johan Bobacka, Ari Ivaska, and Andrzej Lewenstam. Joseph R. Stetter and Jing Li focused their review of amperometric sensors on the sensing of gases. After a rather brief overview of the general amperometric sensing principles, the authors concentrate on new nanomaterials that have been recently utilized in these devices.

Somewhat neglected but very interesting semiconductor junction gas sensors are thoroughly reviewed by Karin Potje-Kamloth. With the advent of organic semiconductors, the importance of this type of chemical sensor is expected to grow, as is indicated by the very large number of references included in her review. This review should also be of interest to researchers dealing with organic electronics, such as organic field-effect transistors.

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Four reviews are devoted to advances in optical sensing. Colette McDonagh, Conor S. Burke, and Brian D. MacCraith emphasize new hardware that has become available thanks to rapid advances in communication and signal processing technologies. Utilization of optical sensing principles in combination with biologically derived selectivity is covered in the review by Sergey M. Borisov and Otto S. Wolfbeis. It includes selectivity derived from enzymatic, immunochemical, oligonucleotide, and organismal principles. Sensors based on plasmon resonance are discussed in the review by Jiří Homola and in the closely related review by Matthew E. Stewart, Christopher R. Anderton, Lucas B. Thompson, Joana Maria, Stephen K. Gray, John A. Rogers, and Ralph G. Nuzzo. The latter introduces the new subject of nanostructuring.

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Cantilevers are a rapidly growing subgroup of mass sensors. That growth is fueled by the wide use of microfabricated tips for various types of scanning microscopy. The subject is reviewed by Karen M. Goeders, Jonathan S. Colton, and Lawrence A. Bottomley. A review of sensors for radionuclides has been prepared by Jay W. Grate, Oleg B. Egorov, Matthew J. O'Hara, and Timothy A. DeVol and is believed to be the first of its kind. For that reason, the criterion of "continuous data acquisition", used to define true chemical sensors, has been somewhat relaxed, allowing some crossover to sensing systems.

There is much to be gained by increasing the "order" of chemical sensors, in direct analogy with hyphenated analytical techniques such as GC-MS, MS-MS, etc. Many deficiencies in the performance of single sensors can be avoided by grouping diverse sensors into higher order arrays, as shown by Andreas Hierlemann and Ricardo Gutierrez-Osuna. The benefits of increasing the sheer number of sensors to "very large sensing arrays" are demonstrated in the review by Christopher N. LaFratta and David R. Walt. This article also highlights an elegant approach to the tricky problem of addressing individual elements in such an array. Very large scale integration of electronics is an inevitable requirement in the realization of sensing arrays. That aspect is addressed in the review by Hierlemann and is also exhaustively treated by Segyeong Joo and Richard B. Brown Rather interesting coupling of the Internet with chemical sensing is discussed in a review by Dermot Diamond, Shirley Coyle, Silvia Scarmagnani, and Jer Hayes. It clearly shows that sensors are taking over the world as "wireless sensing networks".

The extraction of distributed spatial and temporal information through multiple sensing channels and the acquisition of information from the dynamic behavior of sensing arrays are demonstrated in a review by Takamichi Nakamoto and Hiroshi Ishida. Electronic noses have been in existence for at least two decades. The current state of this mode of multivariate sensing is discussed by Frank Röck, Nicolae Barsan, and Udo Weimar.

Development of new sensing materials is essential for the advancement of modern chemical sensors. It has been discussed to some extent in all of the above reviews. However, several contributions have been devoted exclusively to this important aspect of research. A review by Jay W. Grate focuses on the development of materials for gas and vapor sensing that are based on acidic hydrogen-bonding polymers. David W. Hatchett and Mira Josowicz treat composites of intrinsically conducting polymers with various nanomaterials. These heterogeneous sensing materials include metals, carbon-based nanomaterials, and semiconductors. A broad overview of combinatorial strategies for the development of new sensing materials is presented by Radislav A. Potyrailo and Vladimir M. Mirsky. The issue concludes with two topics of perennial interest: glucose biosensors, by Joseph Wang, and application of modern sensors to critical care medicine, by Bruce A. McKinley.

Chemical sensors have achieved a rather dubious distinction. They often serve as the default mode for a material or procedure that "did not quite work out" for its original purpose or to justify results for which there is no obvious "other use". The phrase "...and it can be also used for chemical sensing" is typical and unfortunately much too common in the chemical literature. Hopefully, the reviews compiled in this issue will change this paradigm at least to some extent.

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