From the Guest Editor

On behalf of the *Journal of Laboratory Automation* (JALA), I am pleased to present this special issue focused on recent developments in biosensing technologies.

**Biosensor Overview**

Since the idea was originally proposed in the 1960s by Clark and Lyons, biosensors have developed into a thriving field and have been extensively applied in fermentation processes, environmental monitoring, food engineering, clinical medicine, and military medicine. Thereafter, industry became actively involved in the development and commercialization of biosensor production, and the first-generation product for blood glucose testing launched into the market in 1979. The second generation of biosensors was defined by the use of an antibody or receptor protein as recognition components with a more diversified selection of transducers, such as a field effect semiconductor, pressure of the transistor, an optical fiber, or a surface acoustic wave filter. In 1985, the Pharmacia company successfully developed the surface plasma resonance technique, which pushed biosensor detection limits down to as low as $10^{-11}$ g/mL and made real-time detection of biological interactions possible. Recently, the third generation of biosensors has been positioned for more portable, automated, real-time measurement capabilities.

**Application of Biosensors in the Fermentation Industry**

Biosensors are commonly used for detection of amino acid–like substances, sugar, alcohol percentages, and starch content. Biosensors have been widely applied in clinical food analysis, fermentation industrial control, environmental monitoring, defense, and other areas of safety testing. For instance, biosensors are vital elements for the amino acid industry (synthesis of monosodium glutamate, aspartate, alanine, and lysine), antibiotics industry (glucose online monitoring and control systems), alcohol industry, enzymes industry (glucoamylase rapid analysis), starch sugar industry (glucose, starch, and glucoamylase analysis), biological cell cultures (glucose, lactate, and glutamine analysis), microbial desulfurization cell culture monitoring in the petrochemical industry, vitamin production, fermentation of glycerol production, and more. Biosensor detection technology is now an important tool for the enterprise transformation of bioprocessing companies.

**Application of Biosensors in Cell Engineering**

Because of their simple, reliable, accurate properties, especially detection capability in extremely tiny spaces, biosensors have gained great value in cell engineering. Biosensors can not only act as cell counters but also, more importantly, successfully invade cells or even cell organelles to monitor complex cell metabolites. For example, Infineon Technologies and the Max Planck Institute recently developed a new biosensor that connects directly to live nerve cells to collect electrical signals produced by nerve cells. This biosensor chip, named Neuro-Chip, connected snail neurons immobilized on a semiconductor chip. Nerve cells were cultured in nutrient solution on top of the sensor array. The biosensor was able to collect the electrical signals given out by every single cell, whereas the reconstruction of nerve tissue was also sustained. In another example, red blood cell agglutination time and sedimentation rate could be detected accurately through a piezoelectric quartz crystal impedance sensor.

**Application of Biosensors in Environmental Detection**

Microbial sensors for environmental monitoring are among the most traditional and accurate biosensors. They usually are known for good stability, high accuracy of analysis, low cost, and fast analysis speed. There are many types of environmental sensors for the detection of environmental microorganisms, including biochemical oxygen demand (BOD) sensors and poison sensors. Since the first BOD biosensor introduced by Karube in 1977, researchers all over the world have been actively involved in the development of microbial detection technology for environmental monitoring.

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world have put extensive efforts into BOD sensor development. Yet both the research and commercialization process of BOD biosensors are still facing tremendous challenges. First, one kind of biofilm can hardly measure multiple types of sewage simultaneously. Second, because of sensitivity limitations, current biosensors are mainly used in the detection of organic wastewater, whose targets for detection are in relatively high concentrations, rather than quality measurements for pollution of rivers or ocean water. Third, few biosensors are suitable for organic wastewater containing a high concentration of toxic heavy metals, because heavy metals may cause irreversible poisoning to microbes material.

**Application of Biosensors in Medical Field**

Biosensors have gained indispensable positions in medical research and practice. Nowadays, almost all fields of medical and public health research are benefiting from biosensors. Immune biosensors that detect the chemical composition of body fluids provide the basis for a doctor’s clinical diagnosis. In military medicine, rapid detection of biological toxins is an effective way to defend against biological weapons. Biosensors have been used to monitor a variety of bacteria, viruses, and toxins and can also be used to measure a variety of amino acids and various carcinogenic and mutagenic substances.

**Point-of-Care-Technology**

Point-of-care-technology (POCT) is a newly developed segment of the in vitro diagnostic industry that allows patients to receive timely diagnosis and treatment. Currently, POCT products are widely used in hospitals, clinics, and patient homes to detect the vast majority of routine clinical indicators. Recent reports indicate that the current global POCT market is more than US$40 billion, with an average annual growth rate of more than 7%—faster than the growth rate of drugs. Compared to traditional biosensors, POCT has a series of unique advantages, such as portability, ease of operation, timeliness, and accuracy. The most common areas of POCT applications include detection of blood glucose, blood gas and electrolytes, cardiac markers, drugs and alcohol, pregnancy and ovulation, tumor markers, infectious diseases, blood and urine biochemistry, coagulation, and fibrinolytic therapy. From a global POCT scale, glucose monitoring accounts for more than half of the share, but with the saturation of its market, its growth rate has slowed down. There have been calls for growing investigations of blood electrolytes, cardiac markers, infectious diseases, tumor markers, and blood lipids.

Early POCT development began in the mid-1900s and mainly focused on blood and urine dry chemistry test strips. Thereafter, the development of immunochromatography and dot immunogold filtration assay began promoting POCT applications in infectious diseases and cardiac diseases. For the latter, microfluidic techniques have led to a major turning point for POCT, opening a new era for POCT miniaturization and intelligent development. Nowadays, POCT has gradually realized high-throughput and multiget detection because of the development of gene chips, protein chips, and chip-based rapid development laboratories (lab-on-a-chip) and other biochip technologies. As the communication technology further improves, POCT is moving toward remote data centers. Future POCT products are expected to integrate fast and convenient analysis with remote data terminals to identify optimal treatments and enable a smarter and more efficient health system.

**Biosensor Future**

With advancements in nanotechnology, new types of biosensors such as quantum dots, DNA, and oligonucleotide ligands sensors have emerged. Future biosensors are likely to be versatile, portable, disposable, rapid detection analysis machines. They can be widely used for rapid detection in food, environment, war, disease, and other related biological areas. Yet challenges also widely exist among all nanobiosensors, such as sensitivity, specificity, biocompatibility, simplification, integration of multiple technologies, cost-effectiveness, and mass production.

**The JALA Special Issue on New Developments in Biosensing Technologies**

In this special issue, the JALA editorial team and I have assembled 17 reports from innovators in China (including Hong Kong and Taiwan), Germany, Singapore, and the United States. We begin this issue with five notable reviews. These review articles cover a wide spectrum of research interests that have been extensively examined in recent years. They range from paper-based systems for point-of-care biosensing, label-free biosensing based on microarray platforms, methods for endotoxin detection, developments of portable biosensors, and biosensors for monitoring airborne pathogens. Each review provides a summary of recent efforts in the development of biosensing research from a unique viewpoint.

Subsequent original research reports share recent achievements in the biosensing domain for various applications, including biosensing for accurate identification of nucleic acids in low abundance, gold nanorods for intracellular delivery and cell apoptosis, identification and optimization of combinatorial glucose metabolism inhibitors in hepatocellular carcinomas, oxygen sensor for monitoring microbial cultures, an automated platform for
culture dish handling and monitoring, biosensing for life cell with scanning ion conductance microscopy, a heat-driven nanobiosensing system, discussion of a spherical cell weighing method, single-cell manipulation in microfluidic chips, and mesangial cell hypertrophy biomarker identification. Finally, two technology briefs present interesting and innovative ideas for biosensing with lateral flow in leaf and biosensing in stacked paper networks.

As you read through this special issue, we hope you find that biosensing is a very broad research field that calls for continued development within both scientific and industrial arenas. Advancement in technologies will enrich the application of biosensing devices and platforms in disease diagnosis, biological investigation, environmental monitoring, food engineering, and drug discovery. We believe that continued innovation will eventually lead to inexpensive, environmental-friendly, rapid biosensing systems that are readily available in developed nations as well as developing and underdeveloped countries.

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