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FEATURE ARTICLE

Electrochemical sensors for real-world applications

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Electrochemistry plays a key role in many fields of science and technology that are closely related to a sustainable future of humankind. Photovoltaics, batteries, and fuel cells play important roles in the everyday life of many people. Rechargeable batteries are taken for granted in electronic devices such as laptops and mobile phones. Electrochemical sensors are less exposed to the general public, but are still essential for human health and well-being. There is no doubt that electrochemical glucose biosensors have dramatically improved the quality of life for hundreds of millions of diabetics on this planet. In hospitals, electrochemical sensors are part of automated clinical analyzers for determination of electrolytes and blood gases. Potentiometric pH sensors are common tools in chemistry laboratories. Miniaturized electronics and wireless signal transmission enable more distributed and decentralized electrochemical analysis. An exciting example is the on-going development of wearable electrochemical sensors for non-invasive monitoring of biomarkers in sweat or interstitial fluid.

Last year (2019), over 500 review articles were published on electrochemical sensors (Fig. 1). This confirms a high scientific research activity in this field. A plethora of electrochemical sensing concepts are based on nanomaterials and nanostructured sensor surfaces. This is not surprising when considering the unlimited variability offered by multi-component nanomaterials of various shapes, sizes, chemical compositions, and surface functional groups. However, when utilizing multi-component nanostructures of excessive complexity, there is a risk that subtle variations in sensor production will compromise the repeatability and reproducibility of the analytical information provided by the final sensor. Furthermore, specific requirements with regard to the intended application must be considered. Quite often there is a gap between a novel sensing concept and an intended real-world application. For example, a non-enzymatic glucose sensor showing excellent sensitivity to glucose in 0.1 M NaOH may not be ideal for wearable glucose monitoring under physiological conditions.

Despite continuous progress for several decades, current research in the field of electrochemical sensors is facing scientific challenges related to emerging applications, such as wearable sensors for personal health monitoring and autonomous sensors for in situ environmental analysis. Similarly, very few electrochemical sensors are durable enough to be applied for on-line or in-line process analysis. Therefore, future research should focus on a more robust design of electrochemical sensors and biosensors to minimize the need for calibration and to enable long-term continuous monitoring.

Disposable electrochemical sensors represent an alternative approach. Such sensors only have to last for a single measurement, but instead they have to be very cheap and fit for mass production. Paper-based microfluidic analytical devices (μPADs) are excellent examples of disposable chemical sensors where a liquid sample is transported by capillary forces to a detection zone for visual (optical) or electrochemical detection (ePADs). When considering the successful commercialization of disposable glucose sensor strips, the development of ePADs should be a prospective area of electrochemical research, when aiming for single-use sensors.

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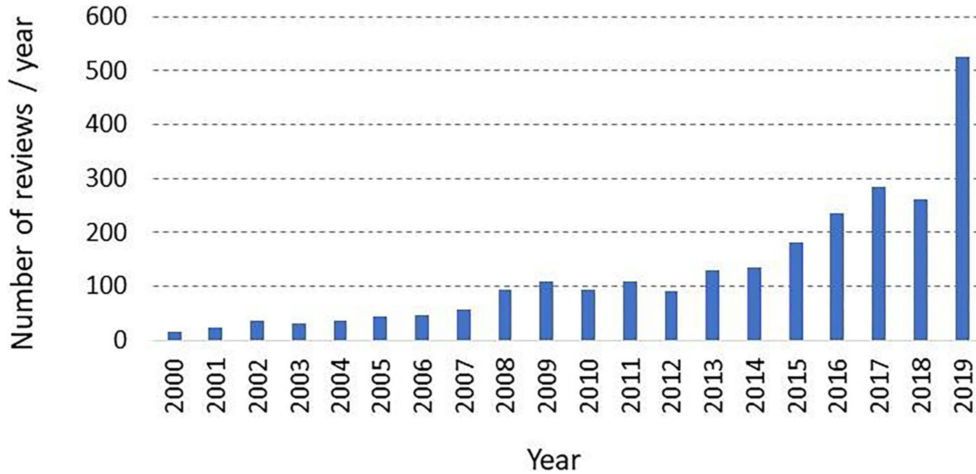

Fig. 1 Number of review articles per year on electrochemical sensors over the years 2000–2019 (Web of Science search on the topic "electrochemical sensors" refined by the document type "review," 31.5.2020)

An important future task of electrochemical research will be to bridge the gap between new electrochemical sensing concepts and real-world analytical applications. Successful completion of this task will enable various analytical measurement scenarios in the future where electrochemical sensors can be used to their full potential.

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