

Introducing Electrical Boundary Potential as a Tool for Manipulating Optical Sensing Properties of Ion-Selective Polymeric Devices

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Abstract

Ion-selective sensors in general, and bulk optical sensors (optodes) in particular are attractive analytical tools for biomedical, environmental, and laboratory applications. They offer a variety of advantages: power-free operation, wireless connection with the reading device, insensitivity to electromagnetic fields, detection of extremely low concentrations [1,2]. All this contributes to reducing the size and cost of optode-based devices. The optical nature of the signal allows remote signal acquisition by digital methods (for example, by a camera) [3], which simplifies the work with such devices and makes it possible to create autonomous integrated monitoring and/or control systems, for example, technical vision systems.

However, nowadays this class of highly selective chemical sensors has significant limitations for use in analytical routine since the potential of their application remains unused due to an insufficient theoretical description of their response [4]. To expand the existing response theory, one shall involve the interfacial electrical potential at the sensor/sample interface in the theoretical description of the optode response mechanism and study the possibilities of controlling the optode characteristics using the interfacial potential.

Herein, we report on the outcomes of such an extended description. The optode response can be formalized via the equality of the electrochemical potentials of the partitioning species at the sensor/solution interface [5]. The involvement of the interfacial potential in the response model allowed us to quantitatively describe the processes occurring simultaneously at the sensor/sample boundary: ion exchange, co-extraction of an aqueous electrolyte into the polymeric phase, and interfacial partition of an organic electrolyte of arbitrary lipophilicity. It is theoretically demonstrated that the addition of a moderately lipophilic organic electrolyte (MLOE) to the sensor phase results in the independence of the pH response of optodes from the metal ion content in a wide range of solution concentrations. In other words, it allows one to obtain an optical sensor of individual ionic activity, which is essentially equivalent to creating an optical analog of a galvanic cell with liquid junction [6]. In addition, the developed model paves the way for addressing several other exciting challenges: optical determination and visualization of electric field distribution in the vicinity of the objects, creating sensors with response characteristics predetermined by the MLOEs addition, as well as polymeric optical systems with complete suppression of interfacial processes [7].

References

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Keywords

Polymeric sensors; Optical sensors; Optodes; Boundary potential.

Biography

Dr. Andrey V. Kalinichev received a Ph.D. degree in physical chemistry from Saint Petersburg State University, Russia, in 2021 under the supervision of Dr. Maria A. Peshkova. His Ph.D. research focused on developing an expended theory of the response of polymeric chromoionophore-based ion-selective optical sensors to predict and modify the analytical characteristics of the sensors. Since 2020, he has been a teaching assistant at Saint Petersburg State University. Dr. Kalinichev's research interests are primarily associated with polymeric ion-selective sensors, namely optodes and ion-selective electrodes. The scope of his interests also includes computer simulation of the sensor response as well as application of digital color analysis for addressing various analytical and practical problems.