Numerical Simulations For Designing Wireless Electrochemiluminescence Imaging Microdevices

Pascale PHAM[1], Abdulghani Ismail[2], Silvia Voci[3], Loïc Leroy[2], Ali Maziz[4], Lucie Descamps[2], Alexander Kuhn[3], Pascal Mailley[1], Thierry Livache[2], Arnaud Buhot[2]

[1]CEA-LETI, Minatec Campus, Grenoble, France
[2]Univ. Grenoble Alpes, CEA, CNRS, INAC-SyMMES, 38000 Grenoble, France
[3]Univ. Bordeaux, CNRS, Bordeaux INP, ISM, UMR 5255, F-33400, Talence, France
[4]LAAS-CNRS, Université de Toulouse, 31400 Toulouse, France

Abstract

ElectroChemiLuminescence (ECL) is a phenomenon of light emission resulting from an initial electrochemical reaction [1]. Today, ECL is used for detecting biomolecules (DNA, RNA, biomarkers). Unlike other optical detection methods used in biosensors (e.g. fluorescence), ECL is a highly sensitive and selective method because it does not require an exciting light source. BiPolar Electrochemistry (BPE) is an elegant electrochemical wireless technique based on the use of a conducting object (i.e. a mono-electrode) which, immersed in a sufficiently high electric field, is polarized into two poles, one of which acts as the anode and the other as the cathode simultaneously [2].
The usual pre-dimensioning techniques for the BPE show that its implementation in microsystems was not feasible due to the high values of the required applied voltage [2]-[3]. However, we could perform ECL in a 2D micropore (20 x 10 µm) for applied voltages of a few volts [3]. A gold deposit (6 x 3 µm) at the bottom of the same 2D micropore was also the site of ECL reactions (results in publication).
The dimensioning of the microdevice was carried out by numerical simulation (Comsol Multiphysics™, complex electrokinetic equation). Here we present our numerical results and show the interest of using numerical simulation for designing Wireless Electrochemiluminescence Imaging microdevices.

Reference

[1] L. Bouffier, S. Arbault, A. Kuhn, et N. Sojic, « L'électrochimiluminescence : une méthode de choix pour la bioanalyse », p. 11, 2018.
[2] G. Loget et A. Kuhn, « L'électrochimie bipolaire, un nouvel outil pour la chimie analytique et les nanosciences », p. 16, 2011.
[3] A. Ismail et al., « Enhanced Bipolar Electrochemistry at Solid-State Micropores: Demonstration by Wireless Electrochemiluminescence Imaging », Anal. Chem., vol. 91, no 14, p. 8900-8907, 2019, doi: 10.1021/acs.analchem.9b00559.

Figures used in the abstract

Figure 1 : Figure 1: a) Scanning Electron Microscopy image of the microchip with the micropore (10 x 10 x 20 µm) and the integrated feeder Au electrodes. b) zoom to the micropore where the

ECL-emitting bipolar rhombus-shaped Au surface (6 x 3 μm) is visible in the m

Figure 2 : Figure 2: Top: b) Numerical 3D geometry of the ECL microchip with the micropore (10 x 10 x 20 μm), a) the integrated feeder Au electrodes and the ECL-emitting bipolar rhombus-shaped Au surface (6 x 3 μm). Bottom: numerical results (0 Hz): electric potenti