Computer Simulation of Electrochemical Impedance Spectroscopy for Detection of Single-bacterial Cell using Microelectrodes on CMOS LSI Chips

○Shigeyasu Uno[1] and Kazuo Nakazato[2] (1.Ritsumeikan Univ., 2.Nagoya Univ.)
E-mail: suno@fc.ritsumei.ac.jp

1 Introduction

Living cell monitoring has widely been used in medical and pharmaceutical research, and one of the promissing methods is based on electrochemical impedance spectroscopy (EIS) [1]. Single cell monitoring using EIS has also been demonstrated [2], and a large-scale integrated (LSI) circuit chip is an ideal platform because of its massive integration of microscale sensor electrodes and low-noise measurement using complementary metal-oxide-semiconductor (CMOS) circuits. The reported size of microelectrodes on LSI can be as small as 1.2μm×2.05μm, which is comparable to single-bacterial cell [3].

In this study, feasibility of single-bacterial cell detection by EIS using microelectrodes on CMOS LSI chip is explored by means of computer simulation.

2 Simulation Method

Fig. 1 illustrates the simulated model structure involving a set of elliptical microelectrodes of width W and length L at the bottom of wells with depth D in the separation S, where the values and shapes were estimated from a previous report [3]. Maxwell's equation is then solved by a finit-element method simulator COMSOL Multiphysics® to calculate the electrochemical impedance between two electrodes from the alternating current under sinusoidal voltage stimulation. A bacterial cell was modeled as a sphere with 1.0μm diameter.

3 Results and Discussion

Fig. 2 shows simulated EIS with/without a sphere representing a single bacterial cell. The EIS without cell distinctly shows electric double layer capacitance ($f < 10^5$Hz), solution resistance (10^5Hz$< f < 10^8$Hz), and solution capacitance between two microelectrodes ($f > 10^8$Hz). The existance of a cell increases the solution resistance from 1.64MΩ to 1.87MΩ at 1.0MHz. Such increase may be read-out by on-chip CMOS circuit.

4 Conclusion

EIS with/without single bacterial cell as small as 1.0μm has been numerically simulated to show feasibility of single bacterial cell detection using CMOS LSI chip.

This work was supported by JSPS KAKENHI Grant Number 25220906.

References

[1] J. Mamouni et al., Biomed. Microdevices. vol. **13**, pp. 1075-1088 (2011).

[2] Z. Zhu et al., Sci. Rep. vol. **5**, p. 17180 (2015).

[3] K. Niitsu et al., IEEE Trans. Biomed. Circuits Syst. vol. **9**, pp. 607-619 (2015).

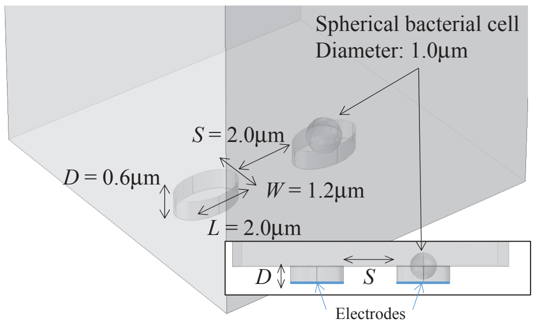

Fig. 1: Model of microelectrodes and bacterial cell.

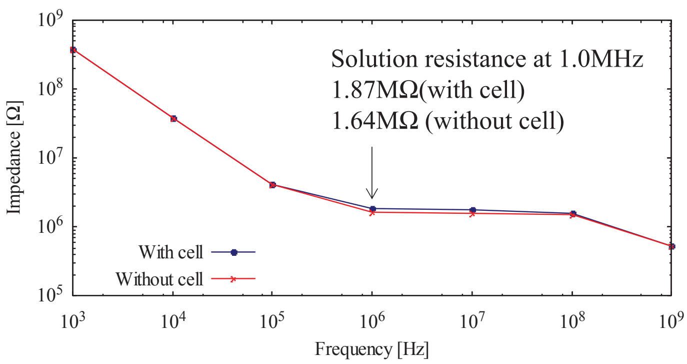

Fig. 2: Simulated electrochemical impedance spectroscopy.