Development of Automated System Concept Intended for the Electrochemical Evaluation of Micro-Objects

I. Morkvėnaitė-Vilkončienė, A. Dzedzickis, J. Subačiūtė-Žemaitienė, M. Greitans, Po Ting Lin, and V. Bučinskas

Abstract—**This paper presents the automated system for the electrochemical evaluation of micro-objects. Electrochemistry at microelectrodes, positioned close to the object of interest, can provide the information about the electric properties and chemical reactivity of non-biological objects, for biological objects – the viability and electrochemical activity. Successful positioning of the microelectrode at desirable distance from the micro-object leads to reliable experiments and ensures the repeatability of results. Automated positioning and scanning of the micro-object should ensure that the quality requirements for the measured data will be fulfilled.**

I. Introduction

The scanning probe microscopes are partly automated devices, used for the evaluation of micro-objects properties [1, 2]. Scanning electrochemical microscope (SECM) is one kind of them, it allows the determination of sample electrochemical properties by scanning its surface at close (1-10 µm) distance between the probe and the surface of interest. Commercially available SECMs have cameras for visual object detection and probe positioning in the manual mode. Such an approach allows the operator positioning the probe in respect of object only approximately. This complicates measurement procedure, reduces the repeatability of results. The most essential drawback of existing technology is that the quality of the results depends on the operator's skills since the start point for scanning is still selected by user.

II. Formulation of The Concept

The ‘dream machine’ could be a e microscope, which using computer vision and machine learning algorithms automatically recognizes all micro-objects in the working area, choose automatically or allows for operator to select the ‘right’ object to scan, defines object center coordinates, generates movement trajectories for probe approach and scanning, scans the object at suitable speed and distance, and provides results in required form.

I. M.-V. is with the Vilnius Gediminas Technical University, Vilnius, 10223 Lithuania (e-mail: inga.morkvenaite-vilkonciene@vilniustech.lt).

A. D. is with the Vilnius Gediminas Technical University, Vilnius, 10223 Lithuania (e-mail: andrius.dzedzickis@vilniustech.lt).

J. S.-Ž. is with the Vilnius Gediminas Technical University, Vilnius, 10223 Lithuania (e-mail: jurga.subaciute-zemaitiene@vilniustech.lt).

M. G. is with the Institute of Electronics and Computer Science, Riga, LV1006, Latvia. He is also full member of Latvian Academy of Sciences (e-mail: modris_greitans@edi.lv).

P. T. L. is with Department of Mechanical Engineering at National Taiwan University of Science and Technology (NTUST), Taipei 10607, Taiwan (e-mail: potinglin@mail.ntust.edu.tw).

V. B. is with the Vilnius Gediminas Technical University, Vilnius, 10223 Lithuania (Corresponding author. phone: 370-523-70668; e-mail: vytautas.bucinskas@vilniustech.lt).

The creation of such a machine covers several scientific and technological issues: visual detection and recognition of object of interest, determination of object canter coordinates, generation of probe movement trajectories, and control of the entire system. Each of these issues has its own uncertainties, for example: visual detection requires implement close to real-time image processing algorithms to ensure adequate image quality; object recognition and canter coordinate determination requires to implement machine learning based sorting algorithms; trajectory generation must take into account all imperfections off mechanical microscope systems and compensate positioning errors, the control system of whole machines must relate electrochemical measurements results with actual probe position.

III. Conclusion

Since the SECM is a universal machine and can work with various objects, the first step should be to create the database with images of an object which we need to recognize. Specialized research laboratories usually focus on several different objects. For example, our laboratory uses round-shaped yeast cells, which are easily recognizable due to their shape and clear contours. Electrochemical evaluation in our lab is done with many yeast cells, immobilized in 1mm spot [3]; or individual stem cells [4, 5]. We evaluated the electrochemical activity of living cells by measuring electrical current, which is proportional to the concentration of electro-active materials. In such experiments, the distance from the probe to the surface of interest plays a crucial role since measurements are performed in the aquatic environment, where convection and diffusion phenomena occur.

Acknowledgment

This project has received financial support from the Research Council of Lithuania (LMTLT), Nr. P-LLT-21-6, State Education Development Agency of Latvia, Nr. LV-LT-TW/2021/8, and Ministry of Science and Technology (MOST) of Taiwan, Nr. MOST 110-2923-E-011-006-MY3.

References

[1] I. Morkvenaite-Vilkonciene, D. Virzonis, A. Dzedzickis, V. Bucinskas, J. Rozene, R. Vilkoncius, D. Vaiciulis, A. Ramanaviciene, and A. Ramanavicius, "The improvement of the accuracy of electromagnetic actuator based atomic force microscope operating in contact mode and the development of a new methodology for the estimation of control parameters and the achievement of superior image quality," *Sensors and Actuators A: Physical*, vol. 287, pp. 168-176, 2019.

[2] A. Dzedzickis, V. Bucinskas, D. Viržonis, N. Sesok, A. Ulcinas, I. Iljin, E. Sutinys, S. Petkevicius, J. Gargasas, and I. Morkvenaite-Vilkonciene, "Modification of the AFM sensor by a

precisely regulated air stream to increase imaging speed and accuracy in the contact mode," *Sensors*, vol. 18, no. 8, p. 2694, 2018.

[3] A. Ramanavicius, I. Morkvenaite-Vilkonciene, A. Kisieliute, J. Petroniene, and A. Ramanaviciene, "Scanning electrochemical microscopy based evaluation of influence of pH on bioelectrochemical activity of yeast cells− Saccharomyces cerevisiae," *Colloids and Surfaces B: Biointerfaces*, vol. 149, pp. 1-6, 2017.

[4] J. Petroniene, I. Morkvenaite-Vilkonciene, R. Miksiunas, D. Bironaite, A. Ramanaviciene, K. Rucinskas, V. Janusauskas, and A. Ramanavicius, "Scanning electrochemical microscopy for the investigation of redox potential of human myocardium-derived mesenchymal stem cells grown at 2D and 3D conditions," *Electrochimica Acta*, vol. 360, p. 136956, 2020.

[5] J. Petroniene, I. Morkvenaite-Vilkonciene, R. Miksiunas, D. Bironaite, A. Ramanaviciene, L. Mikoliunaite, A. Kisieliute, K. Rucinskas, V. Janusauskas, and I. Plikusiene, "Evaluation of redox activity of human myocardium-derived mesenchymal stem cells by scanning electrochemical microscopy," *Electroanalysis*, vol. 32, no. 6, pp. 1337-1345, 2020.