Development of an electrochemical cantilever platform

Quan, Xueling; Heiskanen, Arto; Grütter, Peter; Tenje, Maria; Boisen, Anja

Published in:
Proceedings of the 11th Nanomechanical Sensing Workshop

Publication date:
2014

Proceedings of the 11th Nanomechanical Sensing Workshop **NMC 2014**
Madrid, Spain

DEVELOPMENT OF AN ELECTROCHEMICAL CANTILEVER PLATFORM

Xueling Quan[1]*, Arto Heiskanena[1], Peter Grütter[2], Maria Tenje[3], Anja Boisen[1]

[1]*Department of Micro- and Nanotechnology, Technical University of Denmark, Lyngby, Denmark*

2Department of Physics, McGill University, Montreal, Canada

[3]*Department of Measurement Technology and Industrial Electrical Engineering, Lund University, Lund, Sweden*

E-mail: Xueling.Quan@nanotech.dtu.dk

Coupled with the ability to fabricate features with micro-nanoscale precision, microfabricated cantilever array can be easily and fully integrated into lab-on-a-chip devices as extremely sensitive, fast and low-cost sensors for real time in situ sensing of many chemical and biological analytes [1-3]. To date, electrochemical sensors have been able to offer sensitivity, selectivity and nanoscale precision for bio/chemical detection [4-6]. Therefore, combining these two powerful sensing tools can dramatically improve the performance of bio/chemical sensing.

In this work we developed a hybrid electrochemical cantilever platform (ECC). It provides an environment in which the surface stress of microcantilever electrode could be monitored simultaneously during electrochemical measurements, with the ability to exchange fluid without disassembling the chamber. This hybrid ECC platform achieved a deflection limit of 0.55 nm, corresponding to a surface stress sensitivity of 0.09 mN/m for a 400 μm-length rectangular ECC sensor.

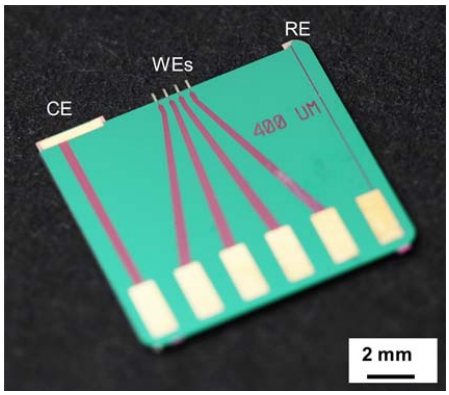
The developed ECC sensor was designed and fabricated based on the experience gained from the electrochemical cantilever sensor designed previously in our group [7]. The sensor has four metal coated silicon nitride cantilevers with a well-defined working electrode area, integrated with metal reference electrode and counter electrode on the same chip. We developed a robust and reliable fluidic cell for assembling ECC chip, as shown in Fig. 1. The system provides electrical, optical and fluidic accesses to facilitate in real-time both electrochemical and deflection measurements. Additionally, for the measurements that require a real reference electrode, the constructed fluidic cell allows utilization of a commercial Ag/AgCl reference electrode without increasing the cell volume.

The hybrid ECC platform was applied to study DNA modification and hybridization process. The detections of different DNA-related processes were performed by monitoring both electrochemical signal and surface stress change [8]. Furthermore, the monitoring of different DNA processes by square wave potential was carried out on ECC hybrid platform. Fig. 2 shows the results of DNA immobilization facilitated by square wave potential. Fig. 3 shows the results of DNA hybridization facilitated by square wave potential.

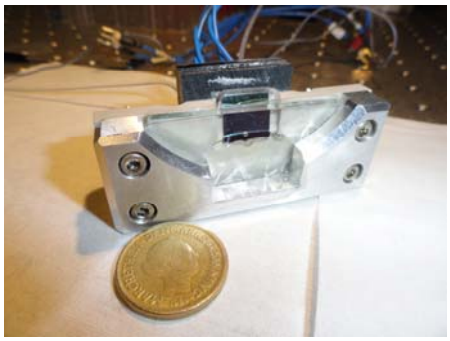
Numerous measurements were successfully performed with the fully-functional electrochemical cantilever platform, which proved to be a powerful tool in bio/chemical sensing.

ACKNOWLEDGMENTS

This work was funded through the Villum Kann Rasmussen center of Excellence ‘NAMEC’.



(a)



(b)

Fig. 1. (a) A photograph of the finished 2G ECC chip with working cantilever (WEs) , reference electrode (RE), and counter electrode (CE); (b) A photograph of the finished and assembled fluidic cell.

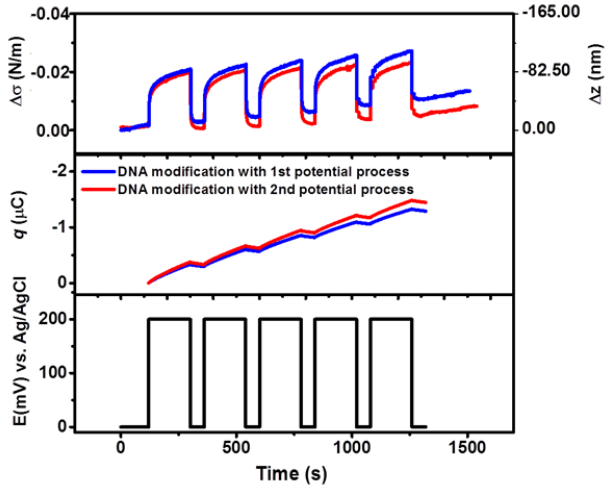


Fig. 2. The change in surface stress and deflection as function of time on the Au (111)-textured microcantilever electrode in 50 mM TEAA buffer solution (top panel, blue curve) with 2 μM HS-ssDNA probe (top panel, red curve) under the applied potential steps (+300 mV for 120 s and 0 mV for 60 s, the bottom panel); the change in charge based on integration of the current measured during the applied potential steps (middle panel).

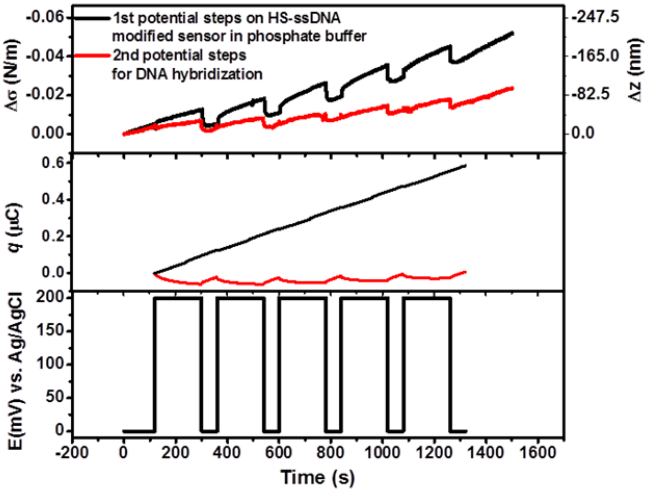


Fig. 3. The change in surface stress and deflection as function of time on the Au (111)-textured microcantilever electrode with immobilized DNA probes in 100 mM phosphate buffer (top panel, blue curve) with 500 nM target DNA (second panel, red curve) under the applied potential steps (+200 mV for 180 s and 0 mV for 60 s, the bottom panel); the change in charge based on integration of the current measured during the applied potential steps (middle panel).

REFERENCES

[1] A. Boisen, S. Dohn, S.S. Keller, S. Schmid, M. Tenje, "Cantilever-like micromechanical sensors," Rep. Pro. Phy, 74 (2011).

[2] J. Fritz, "Cantilever biosensors," Analyst, 133 (2008) 855-863.

[3] J. Tamayo, P.M. Kosaka, J.J. Ruz, A. San Paulo, M. Calleja, "Biosensors based on nanomechanical systems," Chem. Soc. Rev., 42 (2013) 1287-1311.

[4] J. Wang, "Electrochemical glucose biosensors," Chem. Rev., 108 (2008) 814-825.

[5] T.G. Drummond, M.G. Hill, J.K. Barton, "Electrochemical DNA sensors," Nat Biotech, 21 (2003) 1192-1199.

[6] E. Bakker, Y. Qin, "Electrochemical Sensors," Anal. Chem., 78 (2006) 3965-3984.

[7] L.M. Fischer, et. al., "Development of a microfabricated electrochemical-cantilever hybrid platform, " Sensor. Actuat. B-Chem., 157 (2011) 321-327.

[8] X. Quan, et. al., "Development of electrochemical cantilever sensors for DNA applications," ECS Transaction., 50 (2012) 77-81.