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Investigation of Electrochemical and Mechanical Behaviour of Electrochemical Cantilever Sensor by Electrochemical methods

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1 INTRODUCTION

Microcantilevers show great potential for use as chemical sensors. Specifically, combining electrochemical techniques together with cantilever devices is a highly efficient way to improve the performance of cantilever sensing. Several groups have made efforts towards the development of electrochemical-cantilever (ECC) based sensors (Chapman et. al., 2007; Lavrik et. al., 2004). However, one main limitation of cantilever based sensing is the unclear origins of surface stress (Godin et. al., 2010), which lead to poor reproducibility and unreliable results.

In order to further the understanding of surface stress and behaviour of the electrochemical cantilever system, we investigate the surface stress response induced by electrochemical processes happening on the cantilever surface. In this work we fabricated the silicon nitride cantilever chips with integrated nanoporous gold working, reference and counter electrodes, as shown in figure 1 and created an electrochemical-cantilever platform combined with microfluidic cell (Fischer et. al. 2011). Solutions containing 5 mM, 1mM, 500μM of $[Fe\ (CN)_6]^{3-/4-}$ couple (with 200 mM, 40 mM, 20 mM KNO_3 supporting electrolyte, respectively) were measured on this platform by amperometry at a potential of + 0.45 V vs nanoporous gold applied. Direct and complementary information related to nanomechanical changes on the surface were obtained by optically measuring cantilever deflection.

2 RESULTS AND DISCUSSION

As shown in figure 2, the results reveal that the concentration of $[Fe(CN)_6]^{3-/4-}$ couple had an effect on the surface stress generated on the cantilever, i.e. a higher concentration resulted in a larger change in surface stress, in accordance with amperometric results that the larger limiting current. The main contribution to this change in surface stress is the charge accumulated on the surface of the cantilever after the current reaches a limiting value during the period of the applied potential. The complex physical/chemical event occurs on the cantilever in very short period (less than 2 secs) from applying a certain potential to reaching the limiting current, but the mechanical signal data collection is relatively slow (e.g. one data point per second). Therefore, the electrochemical and mechanical behaviour of cantilever during this period is difficult to interpret. The change of surface stress in a solution of 500 μM $[Fe(CN)_6]^{3-/4-}$ with 20 mM KNO_3 does not follow the trend of the 5 mM and 1 mM $[Fe(CN)_6]^{3-/4-}$ solutions, , indicating the concentration of electrolytes also might strongly impact the electromechanical behaviour, in particular, when it is below a critical value. Hence, dependency of electrolyte concentration on the surface stress was studied by the amperometric method (data are not shown here). We observe that the lowest concentration electrolyte has the strongest influence on the surface stress change of cantilever, in which case influence of uncompensated resistance, as well as migration effect should be taken into consideration. These results suggest that an optimal combination of mechanical and amperometric methods is a powerful strategy to acquire more details during electrochemical processes, demonstrating the electrochemical cantilever platform as a competitive chemical sensing tool.

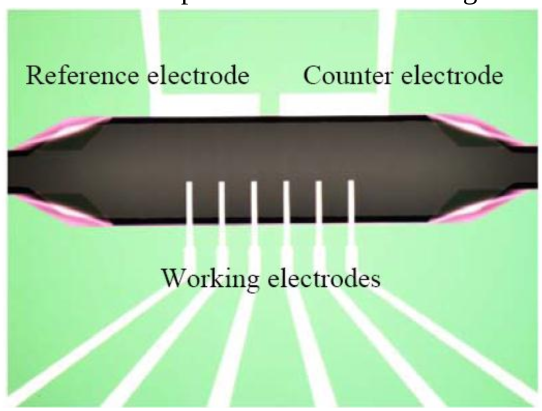
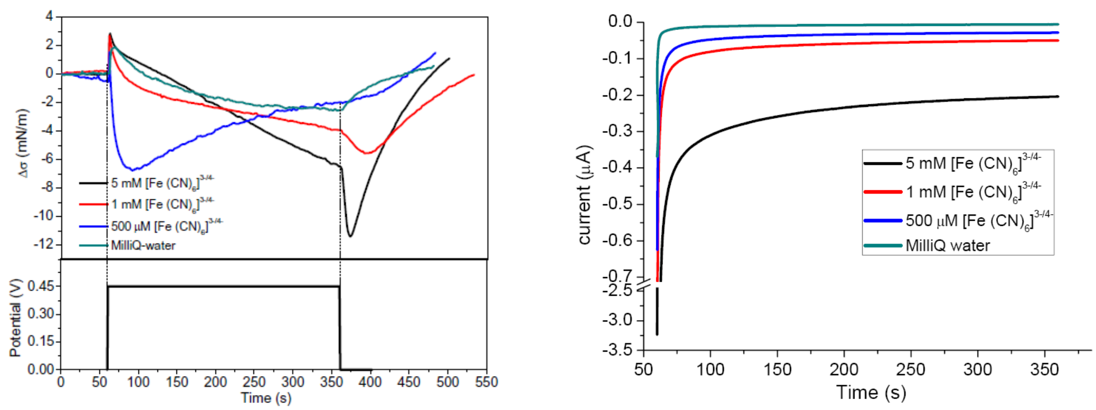


Figure 1 An image of the ECC chip, with the cantilever working electrodes (WE) in the channel, as well as the counter (CE) and reference (RE) electrodes.



(a) (b)

Figure 2 (a) Surface stress (top signal) and applied potential (bottom signal) are plotted versus time for a cantilever in the $[Fe\ (CN)_6]^{3-/4-}$ couple solution with various concentrations. (b) Amperometric current–time responses in the $[Fe\ (CN)_6]^{3-/4-}$ couple in KNO_3 electrolytes with various concentrations and milliQ water.

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REFERENCES

Chapman P. J., Long Z., Datskos P., Archibald G., R. and Sepaniak M. J. (2007). Differentially ligand-functionalized microcantilever arrays for metal ion identification and sensing. Analytical Chemistry, vol. 79, no. 18, pp. 7062–7068, 2007.

Fischer L.M., Dohn S., Boisen A., Tenje M. (2011). An electrochemical-cantilever platform for hybrid sensing applications. In Proceedings of the IEEE: The 24th International Conference on Micro Electro Mechanical Systems (IEEE MEMS 2011), Canc´un, Mexico, 24-27 January 2011, Paper No. 0338.

Godin M., Tabard-Cossa V., Miyahara Y., Monga T., Williams P. J., Beaulieu L. Y., Lennox R. B. and Grutter P. (2010). Cantilever-based sensing: the origin of surface stress and optimization strategies. Nanotechnology, vol. 21, no. 7, 075501.

Lavrik N. V., Sepaniak M. J., and Datskos P. G. (2004). Cantilever transducers as a platform for chemical and biological sensors. Review of Scientific Instruments, vol. 75, no. 7, 2229–2253.