Layered carbon-stabilised porous silicon nanostructures to build electrochemical sensors

Beatriz Prieto Simón

[1]Universitat Rovira i Virgili, Av. Països Catalans 26, 43007 Tarragona, Spain
[2]ICREA, Pg. Lluís Companys 23, 08010, Barcelona, Spain

beatriz.prieto-simon@urv.cat

Advances in the design of electrochemical biosensors based on nanostructured materials have paved the way towards the next generation of diagnostic tools. Building biosensors from nanostructured transducers which morphological and electrochemical properties can be easily tuned is key to maximise their analytical performance.

While the incorporation of carbon-based nanomaterials within the design of electrochemical sensors has opened new avenues, in some cases the advantages are overshadowed by large background currents, poor stability, or long and costly fabrication processes. To overcome those limitations, our research has focused over the last few years on exploring carbon-stabilised porous silicon (pSi), a new class of nanostructured material which can be straightforward fabricated, shows great versatility in terms of both structural features and surface chemistry, and is highly effective as electrochemical transducer (Figure 1). We previously reported electrode architectures based on pSi carbon-stabilised via *in situ* thermal decomposition of acetylene gas [1-3]. Such carbonisation method forms a conformal conductive ultrathin carbon layer on pSi, delivering two types of electrochemical transducers depending on the temperature selected for carbonisation: thermally hydrocarbonised pSi (THCpSi) and thermally carbonised pSi (TCpSi). Recently, we envisaged a new approach to generate a carbon layer on pSi, and thus produce another type of high-performing pSi-based electrochemical transducers. We followed a previously reported method of thermally carbonising furfuryl alcohol (FA)-coated pSi. FA is first infiltrated within a pSi template, then polymerised, and finally subjected to extensive pyrolysis. Polyfurfuryl alcohol-modified pSi (PFApSi) adds to the already reported THCpSi and TCpSi, complementing their physicochemical properties, and thus broadening the suite of available carbon-stabilised pSi electrochemical transducers.

The potential of these novel materials to design new electrochemical sensing strategies is herein exemplified by a double-layer pSi nanostructure fabricated via a two-step electrochemical anodisation process [4]. The pore morphological features (e.g. pore size, depth) at each pSi layer are precisely defined by simply varying the anodisation parameters. Next, different types of carbon with tailored wettability and surface chemistry are formed *in situ* on the pore walls of each layer via stepwise temperature-controlled acetylene decomposition. Double-layer structures with distinct functionalities on each layer are harnessed for site-specific modification of bioreceptors. These platforms not only feature remarkable geometrical properties, but also excellent electrochemical performance, underpinned by their fast electron-transfer kinetics, low double-layer capacitance and high sensitivity. The potential of carbon-stabilised pSi double-layer structures as novel highly performing biosensors is here demonstrated through a voltammetric sensor for the detection of key nucleic acid biomarkers.

References

[1] K. Guo, A. Sharma, R. Toh, E. Alvárez de Eulate, T.R. Gengenbach, X. Cetó, N.H. Voelcker, B. Prieto-Simón. Adv. Funct. Mater., 29 (2019) 1809206

[2] K.-S. Tücking, R.B. Vasani, A.A. Cavallaro, N.H. Voelcker, H. Schönherr, B. Prieto-Simón. Macromol. Rapid Commun., (2018) 1800178

[3] M. Alba, M. Robin, D. Menzies, T.R. Gengenbach, B. Prieto-Simón, N.H. Voelcker. Chem. Comm., 55 (2019) 8001–8004

[4] K. Guo, M. Alba, G.P. Chin, Z. Tong, B. Guan, M. J. Sailor, N.H. Voelcker, B. Prieto-Simón. ACS Appl. Mater. Interfaces, 14 (2022) 15565–15575

Figures

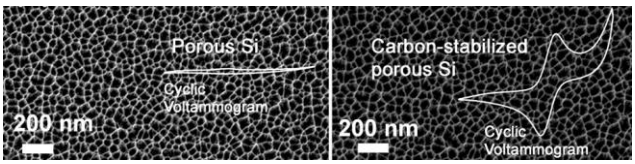

Figure 1. Scanning electron microscopy images and cyclic voltammograms of a pSi substrate prior and after carbon stabilisation