Fabrication of platinum electrodes with high roughness factor using a 3D-support

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Implantable glucose fuel cells are promising for the sustainable power supply of medical implants. Theoretically, they can generate sufficient electricity to power medical implants such as cardiac pacemakers [1] from electrochemical oxidation of the body's own glucose. However, endogenous substances such as, for instance amino acids, dramatically diminish the performance of the anodes by blocking the catalytic sites [1]. Hence, to enhance the long-time performance high specific surface areas have to be achieved. Our aim is to show that by increasing the roughness factor of the anode (RF; ratio of surface area to geometrical area) and, thus, obtaining more catalytically active sites, higher current densities can be sustained. The state-of-the-art electrodes are fabricated by electro deposition in a Pt-Cu-electrolyte using a flat layer of evaporated platinum as substrate, resulting in electrode RFs of 6500 ± 700 [2]. By using an electro spun carbon as substrate, that in our case already offers a RF of 173 by itself for the platinum deposition, significantly higher RFs should be achievable. In theory, a 173 times higher RF may be achieved if the platinum deposition process can be transferred to the 3-dimensional substrate.

The new electrodes were deposited onto electro spun carbon fiber mats [3] using the established pulsed electro deposition process [2]. So far, 20, 40, 80, 120 and 240 pulses have been applied with 1000 s of waiting time in open circuit potential (OCP) in between the pulses to ensure that fresh electrolyte is available throughout all parts of the porous substrate. To date, this results in electrodes with RFs of about 3900, 5800, 9400, 12600 and 17300 respectively.

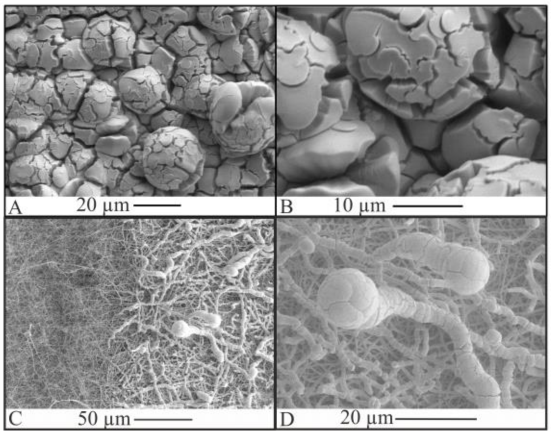

Fig. 1: SEM pictures of a state-of-the-art porous platinum electrode (A,B) [2] and platinum deposited onto electro spun carbon (C,D). Electrodes were fabricated by a pulsed electro deposition process [2] with 1200 (A,B) or 20 (C,D) pulses, respectively.

To compare the structure of the deposited platinum on the electro spun substrate to the state-of-the-art electrodes, pictures have been taken with a scanning electron microscope (Fig.1, C and D). A and B of figure 1 show the cauliflower-like structure of the porous platinum deposited on the flat substrate [2] for comparison. In figure 1C, the transition from platinum-deposited (right) and non-platinum-deposited (left) electro spun substrate is shown. The deposited platinum already exhibits the same cauliflower-like structure (Fig. 1C) as state-of-the-art electrodes, even though only 20 pulses have been applied to the system compared to the 1200 pulses of the state-of-the-art process [2]. The approximate mean distance of the deposited fibers is (610 ± 260) nm, whereas their diameter only reaches (240 ± 74) nm leaving a pore size of about 400 nm. Therefore, the pores of the electro spun substrate are wide enough to make more platinum deposition feasible without clogging becoming a problem.

In conclusion, electrodeposition of platinum on electro spun carbon fiber mats is a promising strategy to increase the roughness factor of the anodes for the implantable glucose fuel cell. In future experiments, we will further increase the RF and test the performance of the electrodes in simulated tissue fluids.

References

[1] Köhler et al., ChemElectroChem, 1 (2014) 1895 – 1900
[2] Köhler et al., J. Power Sources, 242 (2013) 255 – 263
[3] Erben et al., 2nd EU-ISMET (2014), Book of Abstracts, 169