PLD Electrodes in a coupled microfluidic fuel cell to a lab on a chip system for energy generation.

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Abstract. An inorganic microfluidic fuel cell (i-μFFC) was integrated in a glucose sensor LOC device. This device was constructed by using a mini CNC and evaluated for energy harvesting from glucose. The i-μFFC with PLD electrodes exhibits the highest performance compared to the i-μFFC with spray electrodes microfluidic fuel cell for the three conditions, obtained the best performance in alkaline conditions (3.53 μW), which is enough energy to power low-consumption microelectronic chips or microsensors.

1. Introduction
Lab-on-a-chip devices (LOC) are systems in which components of conventional laboratories are integrated into a monolithic device generally size of a postage stamp or a credit card. This reduction in size transforms them into portable laboratories that, for examples in the case of diagnostics, enable point-of-care analysis of blood samples [1]. These microfluidic devices are still as prototypes in the laboratory because they need a miniaturized power source to be completely portable. Microfluidic fuel cells can provide the energy for powering these systems. These devices could be coupled to a lab on a chip [2] or integrated in the lab on a chip structure as a proof-of-concept in this work.

In this work, an inorganic microfluidic fuel cell (i-μFFC) was integrated in a glucose sensor Lab on a chip device, to find an energy source for the sensor. This device was constructed by micro-machining techniques and evaluated for energy harvesting from glucose on synthetic solutions with Au/C and Pt/C electrodes and compared with Au-Toray and Pt-Toray synthetized by Pulsed Laser Deposition (PLD) technique.

2. Experimental
2.1. Au/C and Pt/C nanoparticle electrodes preparation
The Au/C preparation was reported previously by our group [3] and Pt/C 20% w/w was purchased from E-TEK. The anodic and cathodic catalysts, Au/C and Pt/C, respectively, were deposited on Toray carbon paper (EC-TP1-060T) electrode collectors that were of 0.0084 cm² in area via the spraying method (2 mg x cm² of catalyst load).
2.2. Au-Toray and Pt-Toray electrodes preparation
The Au-Toray (anode) preparation was reported previously by Gougis et al. [4] and Pt-Toray (cathode) synthesis was reported by Abrego-Martínez et al. [5].

2.3. LOC device construction
The LOC device was constructed utilizing micromachining techniques using a mini CNC (Deacitec, XR-1000 model). We used a copper wire to serve as the current collector. The electrodes were incorporated into the microfluidic fuel cell channel. This was then assembled using clamping pieces made in a 3D printer (Fig. 1).

2.4. Microfluidic fuel cell compartment evaluation
The i-FFC performance was evaluated using polarization curves obtained at 20 mVs⁻¹ with 0.3 mLh⁻¹ of volumetric flow. In this evaluation, ideal medium solutions (Fuel: Glucose 5 mM in 0.3 M KOH and Oxidant: 0.3 M KOH) were used. Neutral medium solutions (at blood pH): (Fuel: Glucose 5 mM in Phosphate Buffer Solution pH 7 (PBS 7) and Oxidant: PBS 7) were evaluated. Also, we studied the behavior of these electrodes in anolyte neutral medium (Glucose 5 mM/PBS7) and catholyte ideal medium (KOH 0.3M).

3. Results and discussion
Figure 2 shows the polarization and power density curve for the microfluidic fuel cell in ideal medium solutions (Fuel: Glucose 5 mM in 0.3 M KOH and Oxidant: 0.3 M KOH). The open circuit potential (OCP) for the i-μFFC with PLD electrodes was around 0.34 V vs 0.15 V for the i-μFFC with Au/C and Pt/C electrodes and the maximum power density for the i-μFFC with PLD electrodes was 0.42 mWcm⁻² vs 0.09 mWcm⁻² for the Au/C and Pt/C electrodes. These results could be attributed to a better distribution of the catalyst particles on the surface of the electrode, which is obtained by PLD technique.

Figure 1. Design of the device with the glucose sensor.
Figure 3 shows the polarization and power density curve for the microfluidic fuel cell in neutral medium solutions (at blood pH): (Fuel: Glucose 5 mM in Phosphate Buffer Solution pH 7 (PBS 7) and Oxidant: PBS 7). The OCP for the i-\(\mu\)FFC with PLD electrodes was around 0.15 V vs 0.17 V for the i-\(\mu\)FFC with Au/C and Pt/C electrodes and the maximum power density for the i-\(\mu\)FFC with PLD electrodes was 0.12 mWcm\(^{-2}\) vs 0.07 mWcm\(^{-2}\) for the Au/C and Pt/C electrodes. This reduction in performance could be attributed to changes in pH (from 13.5 to 7.4), which seriously affected both reactions: glucose oxidation and oxygen reduction.

Figure 4 shows the polarization and power density curve for the microfluidic fuel cell in anolyte neutral medium (Glucose 5 mM/PBS7) and catholyte ideal medium (KOH 0.3 M). The OCP for the i-\(\mu\)FFC with PLD electrodes was around 0.16 V vs 0.21V for the i-\(\mu\)FFC with Au/C and Pt/C electrodes and the maximum power density for the i-\(\mu\)FFC with PLD electrodes was 0.11 mWcm\(^{-2}\) vs 0.03 mWcm\(^{-2}\) for the Au/C and Pt/C electrodes. This reduction in performance could be attributed to the change in pH affected the oxidation reaction carried out in the anode electrode.
4. Conclusions
The i-μFFC with PLD electrodes exhibits the highest performance compared to the i-μFFC with spray electrodes microfluidic fuel cell for the three conditions, in ideal conditions 3.53 μW was obtained which is enough energy to power low-consumption microelectronic chips or microsensors [6].

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