Fully graphene-based electrode platforms for biosensing applications

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Electrochemistry as detection strategy

Rapid
- Fast measurements
- “Trial-and-error”

Reliable
- Sensitive
- Accurate

Low cost
- Cheap chemicals
- Low volumes

Easy preparative
- Measures in-site or on-site
Electrochemistry as detection strategy in wearable biosensing

Recognition element:
- Enzyme
- DNA fragment
- Antibody
- Cell

State-of-the-art wearable devices:
- "Tattoo" biosensor
- Flexible wristband

Biomarkers in sweat
- $\text{Na}^+$
- $\text{K}^+$
- Glucose
- Lactate
- Cortisol
- Uric acid

a) J. Kim et al., *Talanta* 177 (2018) 163-170
Electrochemistry as detection strategy in wearable biosensing

Drop-casting
- most common method on lab-scale
- hand-made process
- several layers required

Drawbacks
- low reproducibility
- coating stability
- Not scalable to industrial size

- Five deposition steps, at least!

- Nafion
- (Bio)recognition element
- Linker
- Graphene Oxide
- Redox mediator

Commercial screen-printed electrode

F. Poletti et al., J. Phys. Mater. 3 (2020) 014011
G-Paper Electrodes (GPE)

Printed on PET, a flexible transparent substrate

👍 Advantages

• sensor fabricated with the active element
• no coating required: GPEs can be employed bare
• scalable to industrial size
G-Paper Electrodes (GPE)

Check of the electrode conductivity

Benchmark redox species: 1,1’-ferrocene dimethanol (Fc)

Response for thirty subsequent injections of 0.1 mM Fc on a GPE at +0.35 V obtained using flow injection analysis; pump speed: 1 mL min⁻¹

RSD% = 3.1 %

Good conductivity and repeatability

CV responses on Fc. In the inset is reported the linear correlation \((R^2 = 0.995)\) according to the equation of Randles-Sevcik.
Bare GPEs allow NADH detection at electrocatalytic potential of +0.35 V:

- Higher sensitivity with respect to bare carbon electrodes
- Higher selectivity, as less chemical species can oxidize at low potentials
- No coating is required on the GPE
CVs obtained in absence (dashed line) and in presence (solid lines) of 1, 5 and 10 mM H$_2$O$_2$ in 0.1 M PBS

Bare GPEs allow H$_2$O$_2$ detection at both oxidation and reduction potentials:

- Higher sensitivity at reduction potentials
- No electrocatalysis. Analytical performance similar to commercial SPEs
- No coating is required on the GPE

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<tr>
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<th>GPE</th>
<th>Commercial SPE</th>
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<td>Sensitivity (µA mM$^{-1}$ cm$^{-2}$)</td>
<td>4.45</td>
<td>3.34</td>
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<tr>
<td>Potential (V)</td>
<td>-0.40</td>
<td>-0.40</td>
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Possibility to employ GPEs on dehydrogenase- and oxidase-based enzymes

\[ \text{L-lactate} + \text{NAD}^+ \xrightarrow{\text{LDH}} \text{piruvate} + \text{NADH} \]

\[ \text{L-lactate} + \text{O}_2 \xrightarrow{\text{LOx}} \text{piruvate} + \text{H}_2\text{O}_2 \]
To conclude

• GPEs have a stable, repeatable electrochemical response;
• tests on Fc showed good conductivity;
• great electrocatalysis on NADH oxidation;
• no need for further functionalization.

Perspectives:
• detection of other analytes;
• functionalization with biological elements;
• continuous monitoring in a complex matrix.
Thanks!

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