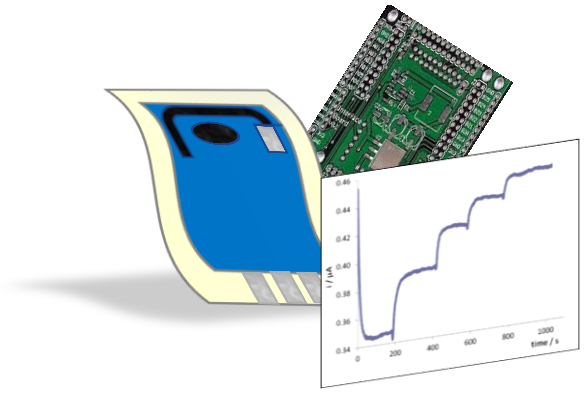
XXXVI Reunión del grupo de electroquímica de la Real Sociedad Española de Química
XVII Encontro Ibérico de Electroquímica

Research Project – Electrochemical science and technology



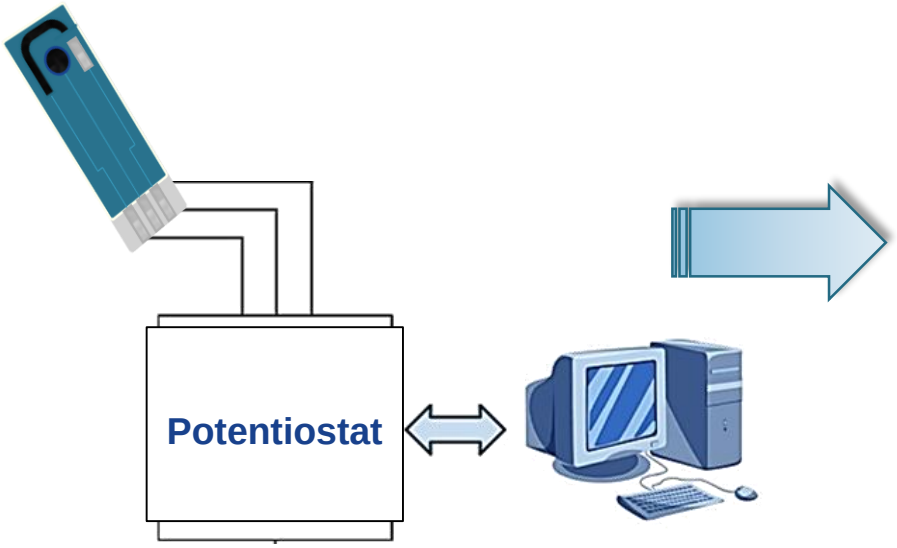
Screen printing of electrochemical biosensors on flexible substrates. Development of electronic prototype devices

Hugo Flávio Cunha da Silva

Supervisor : María Julia Arcos Martínez

Main Goal

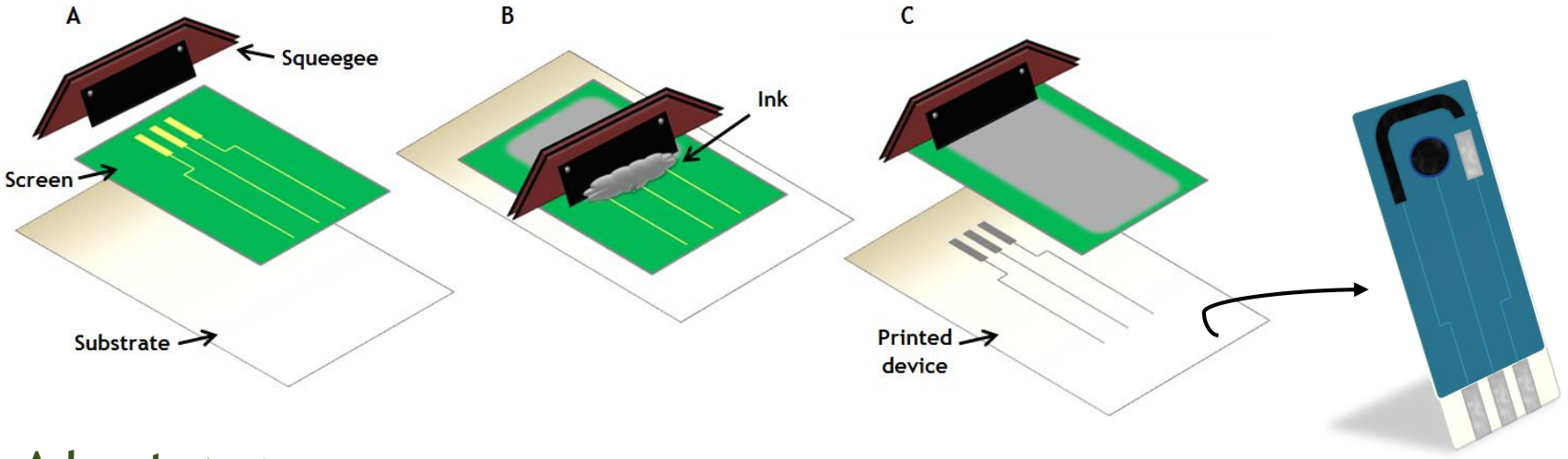
- Development of screen-printed systems, using conductive textiles modified with enzymes and/or with nanomaterials, to be used as an autonomous biosensor without the need of a connected conventional potentiostat.



Wearable autonomous biosensor

Adapted from Malzahn K., *et al*. Analyst, 2011, 136, 2912

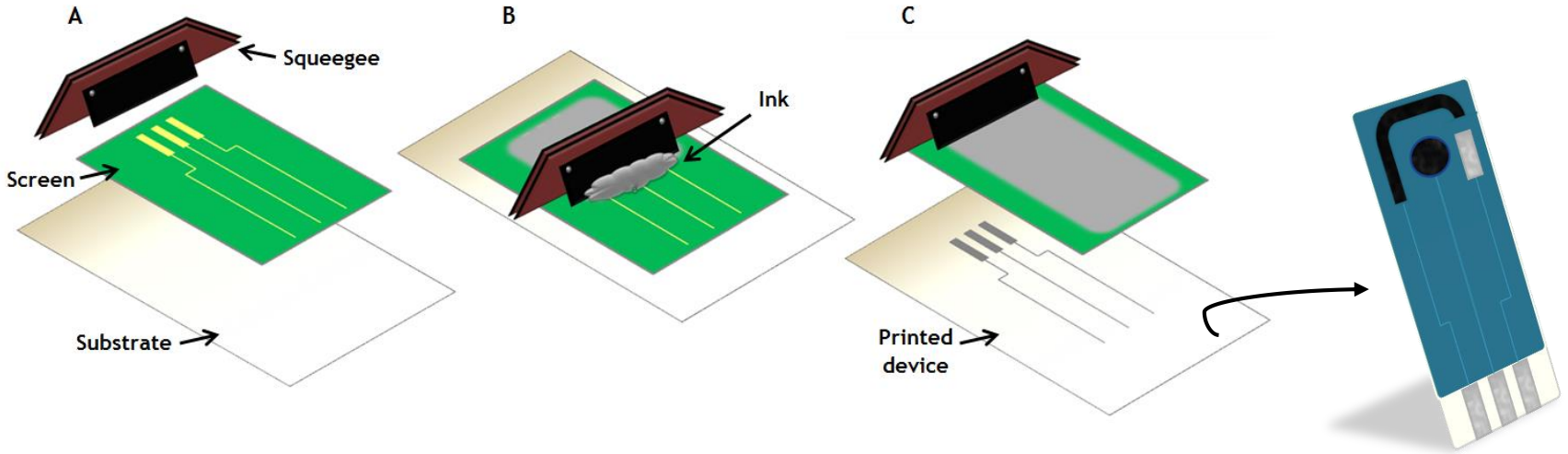
Screen-Printed Electrodes

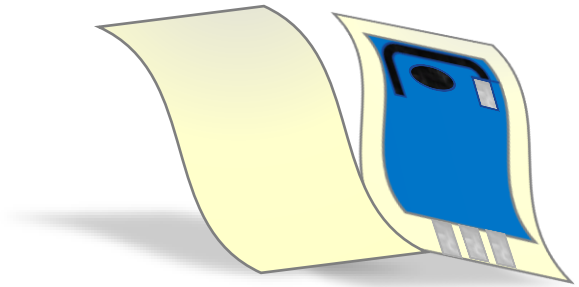


Advantages:

- ✓ Automated, easy and low cost fabrication
- ✓ Reusable or disposable devices
- ✓ Possibility of electrode modification with bio and nanomaterials
- ✓ Miniaturized for fast analysis of small volume samples
- ✓ Portability for use in situ
- ✓ Reproducibility

Screen-Printed Electrodes



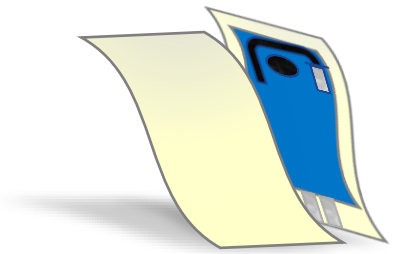


Flexible Substrates

- Incorporation into clothes,
- Incorporation into food packages,
- Noninvasive devices for "*in situ*"
- Incorporation of potentiostat

Screen-Printed Electrodes

Flexible Substrates



Inert and resistant properties

Mechanical resiliency, plasticity, thermal stability

Hydrophobicity, suitable dielectric and insulating properties

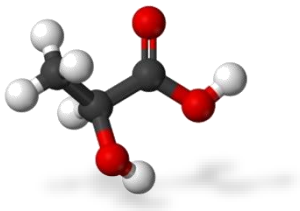
- Polyimide (Kapton),
- Polyethylene naphthalate (PEN),
- Polyethylene terephthalate(PET),
- Polytetrafluoroethylene (Teflon),
- Tattoo paper

- Gore-Tex
- Neoprene
- Polyester
- Nylon

Textiles

Interest Analyte

❖ L-lactic Acid



- Sports medicine — Training status and physical condition of the individual
- Clinical diagnosis — Respiratory insufficiency, shocks, heart failure and metabolic disorder
- Food industry — Indicator of fermentative process, storage quality and products freshness.

Analytical methods

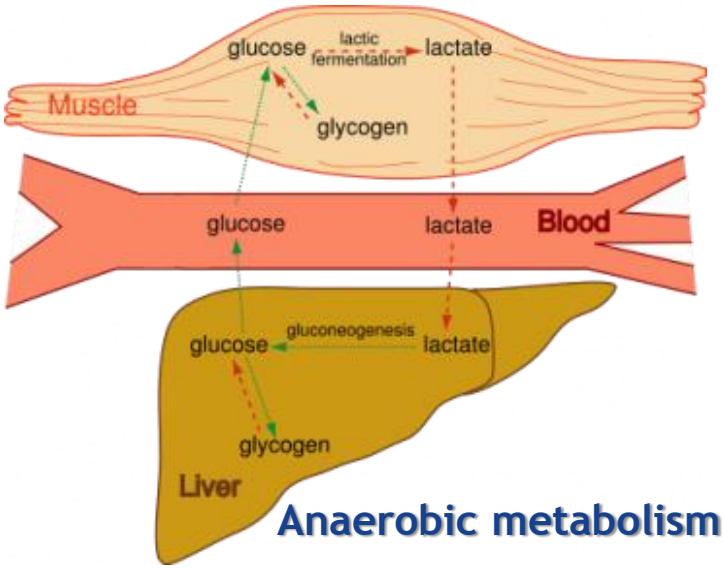
- ✓ High-performance liquid chromatography
- ✓ Fluorometry
- ✓ Magnetic resonance spectroscopy
- ✓ Enzymatic Kits

Disadvantages

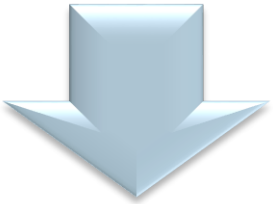
- × Time-consuming,
- × Require the sample pre-treatment
- × Expensive
- × Require educated personnel
- × Need of sample collection

Interest Analyte

- L-lactic Acid in sport medicine

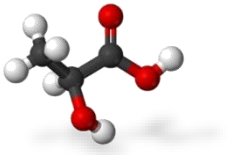


Anaerobic metabolism



Muscles Performance

Lactic Acid Concentration



Blood Levels

Rest - 0.5–1.5 mM

During Exercise - as high as 12 mM

Extreme conditions and extensive physical exercise - 25 mM

Interest Analyte

- L-lactic Acid in sport medicine

Samples	Blood	Interstitial fluid	Tears	Exhaled breath	Saliva	Sweat*
[LA]	0.5-20.0 mM	1.9-2.2 mM	1.0-5.0 mM	13.5-22.0 µM	0.1-2.5 mM	Max. 25.0 mM

L.Rassei *et al. Anal Bioanal Chem, 2013, 406: 123-137;* * *J. Green et al.* Eur J Appl Physiol (2004) 91: 1-6.

Sweat lactate

Sweat Eccrine gland energy metabolism

↑ Exercise intensity ↑ [Lactate]

Interest Analyte

XXXVI

- L-lactic Acid in sport medicine

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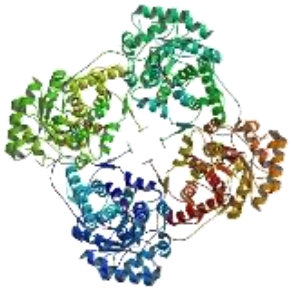
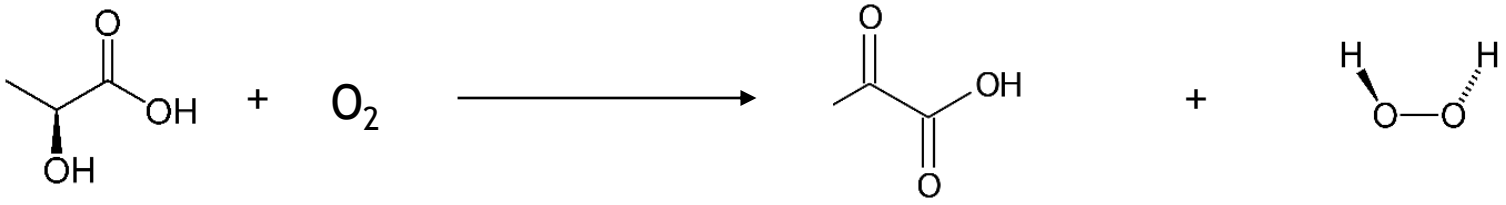
Wearable Lactate Biosensor

Interest Analyte

Lo_x - Lactate Oxidase



Electrode modification with LO_x provides selectivity in body fluids analysis.

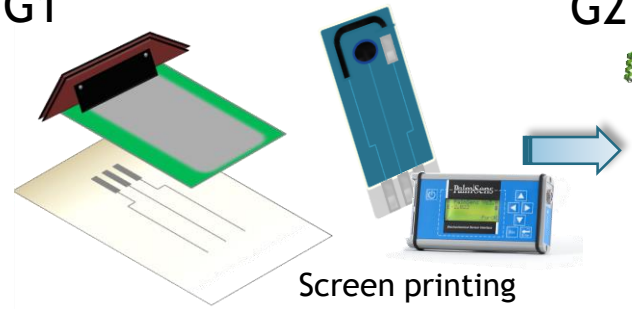


Lactic Acid Pyruvate Hydrogen Peroxide

Summary Research Schedule

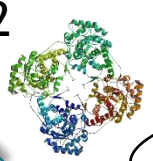
XXXVI

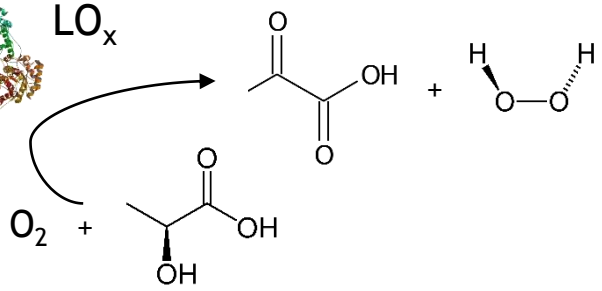
G1



Screen printing

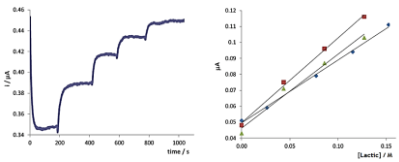
G2





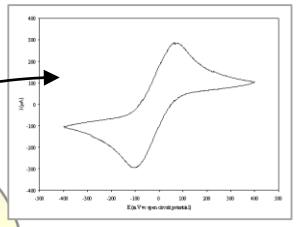
L-Lactic acid determination

- Nanomaterials
- Mediators

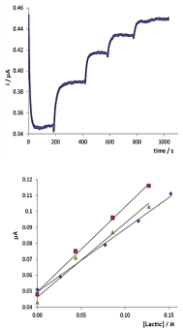


Conventional Substrates

G3

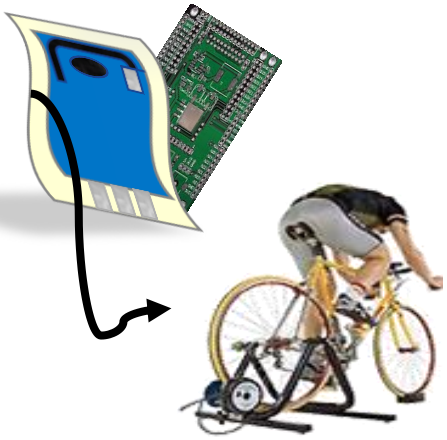


$$Fe^{III}(CN)_6^{3-} + e^- \leftrightarrow Fe^{II}(CN)_6^{4-}.$$



Flexible Substrates

G4



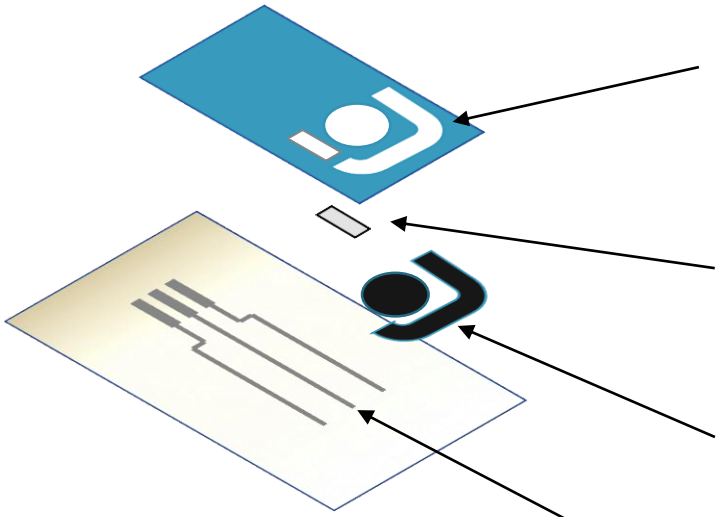
Potentiostat

- HPLC

Validation

Screen-Printing Electrodes

Screen-printing inks



Insulating Layer

Dielectric material 242-SB (Electro-Science Laboratories Inc., USA)

Reference electrode

Ag/AgCl Electrodag SS 6037 (Acheson Colloiden, Netherlands)

Working and counter electrodes

Carbon C10903P14 (Gwent Group, Great Britain)

Connectors and paths

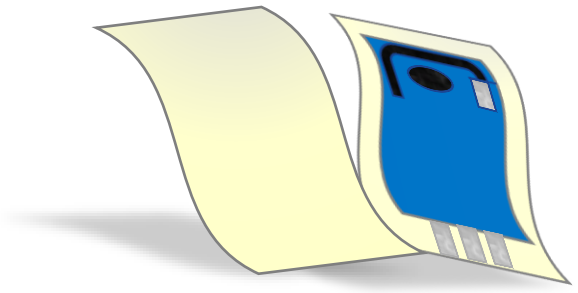
Silver Electrodag SS 418 (Acheson Colloiden, Netherlands)

Conventional Substrate

PET 500 µm (HiFi industrial film, ltd.)

Screen-Printing Electrodes

Flexible Substrates

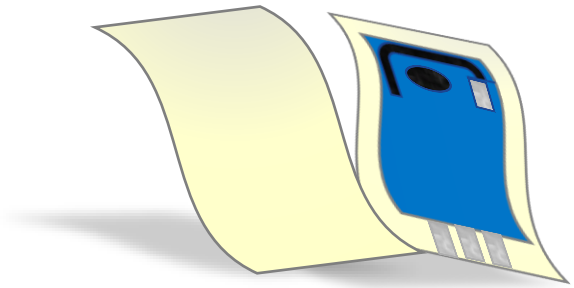


Substrates	
cellulose acetate	
~~PET (18µm)~~	Adhesion
Gore-Tex	
~~Nylon~~	Hydrophobicity
~~Poliéster~~	

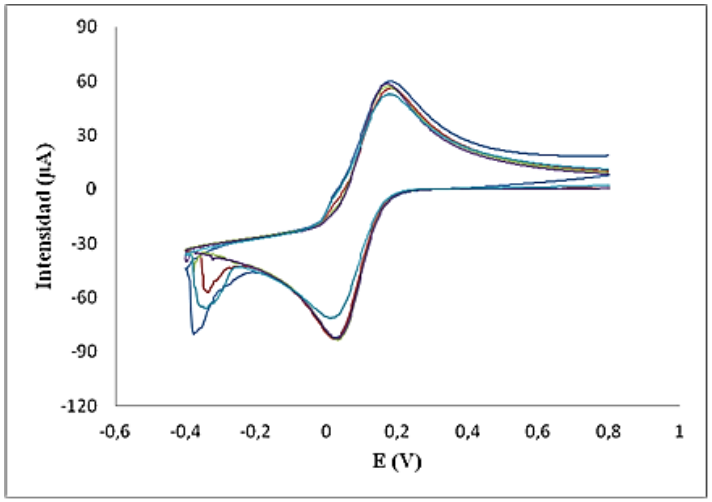
- ✓ Excellent inks adhesion,
- ✓ Hydrophobicity
- ✓ Endurance with screen-printing process,
- ✓ Suitable conductivity

Screen-Printing Electrodes

Flexible Substrates



Substrates
cellulose acetate
Gore-Tex



Cyclic Voltamperogram for **Ferrocyanide** *5 mM in KCl (100 mM). Scan Rate of 50 mV* s^{-1}.

- ✓ Redox behavior similar to the one observed in conventional substrates (PET 500 µm).

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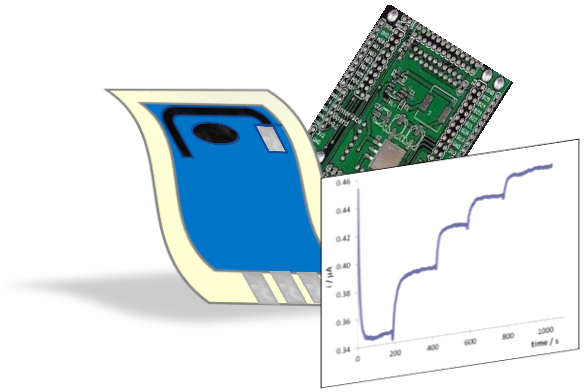

Thank You

Acknowledgements:

MINISTERIO
DE CIENCIA
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Desarrollo Regional