Disposable Polymer Flow Cells with Screen Printed Electrodes for Voltammetric and Electrochemiluminescence (ECL) Applications


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Overview

* Flow Cell Fabrication Process

* Electrochemical Evaluation of the Flow Cell Using Some Common Redox Systems

* Application of the Sensor for Anodic Stripping Voltammetry

* Application of the Sensor for the Electrochemiluminescence (ECL) of Luminol

* Application of the Sensor for the Stripping-ECL Determination of Metal Ions
Fabrication Process of the Electrochemical Flow Cell

- Injection Moulding of the Electrical Connectors
- Screen Printing of the Electrodes
- Base Plate Overmoulding (1)
- Ultrasonic Welding
- Overmoulding (2)
- Injection moulding
- Top plate
Fabrication Process of the Electrochemical Flow Cell

**AutoCAD Design**

* Creating a 3D solid model of the connectors using AutoCAD.

* Then converting it into macro commands using EdgeCAM 10.5 for a CNC milling machine

**CNC Milling**

* Blocks of aluminium (75 mm x 75 mm x 10 mm)
  * Milled using micrograin tungsten-carbide 2 flute routers

Fixed Part

Moving Part

Mould Cavity for the Electrical Connectors
Fabrication Process of the Electrochemical Flow Cell

Injection Moulding Of the Electrical Connectors

Carbon Fibre Loaded (40%) Polystyrene

Contains carbon fibres:
Length 100-150 µm
Diameter 7 µm.

SEM Image of Carbon Fibre Loaded (40%) Polystyrene

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Fabrication Process of the Electrochemical Flow Cell

Base Plate Overmoulding(1)

- Zeonor (1060R)
- Carbon Fibre Electrical Connectors

Overmoulding with Zeonor

- Carbon (C2000802P2)
- Platinised Carbon (C2000511D1)
- (60/40) Silver/Silver Chloride Paste (C61003P7)

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Fabrication Process of the Electrochemical Flow Cell

Screen Printing

SEM Image of (60/40) Silver/Silver Chloride Paste and the Corresponding EDX Spectra
Fabrication Process of the Electrochemical Flow Cell

Screen Printing

SEM Images of A) Carbon, and B) Platinised Carbon Inks

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Fabrication Process of the Electrochemical Flow Cell

Base Plate Overmoulding (2)

Ultrasonic Welding

Overmoulding with Zeonor

Flow Channel

Top Plate Injection Moulding

Top Plate

Fluidic Connectors

Welding Conditions:
Collapse Distance 0.25 mm
Hold Time 3 s

Energy Directing Ridge

Flow Channel

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Fabrication Process of the Electrochemical Flow Cell

The Complete Sensor

Flow Channel Dimensions:
- Width: 5mm
- Length: 30mm
- Depth: 100µm

Electrodes

Overmould 1

Overmould 2

Electrical connectors

Flow Channel

Outlet

Reference Electrode

Interdigitated Working Electrodes

Inlet

Counter Electrode

Electrical Connector

Flow Channel
Electrochemical Evaluation of the Flow Cell Using Some Common Redox Systems
Electrochemical Evaluation of the Flow Cell

Cyclic Voltammetry of Potassium Ferricyanide

Effect of Scan Rate on $3 \times 10^{-3}$ M Potassium Ferricyanide in 0.1 M KCl (vs. Ag/AgCl RE).
Initial & final potential -0.3 V, Vertex 0.7 V.
Electrochemical Evaluation of the Flow Cell

Cyclic Voltammetry of Potassium Ferricyanide

Scan Stability

50 scans saved every 10th

%RSD of Peak Heights:
3.4% forward, and 2.8% reverse

3 \times 10^{-3} \text{ M Potassium Ferricyanide in 0.1 M KCl (vs. Ag/AgCl RE). Initial & final potential -0.3 V, Vertex 0.7 V. Scan rate 0.2 V/s}
Electrochemical Evaluation of the Flow Cell

Cyclic Voltammetry of Ascorbic Acid

Peak potentials 0.303 V and 0.239 V

Cyclic Voltammetry of Hydroquinone

Peak Potentials ~0.069 and 0.401 V
Peak Separation of 0.47 V.

Supporting Electrolyte 0.1 M HCl.
0.15 V/s Scan Rate.
Accessible Potential Window of the Screen Printed Carbon WE

Linear Sweep Voltammetry scanned at 0.3 V/s.
0.1 M Electrolyte Concentration
Glycine and Ammonium Chloride pH9
Sodium Hydroxide pH 12
Acetate Buffer pH 4.6
Citrate Buffer pH 2.5
Application of the Sensor for Anodic Stripping Voltammetry
Application of the Sensor for Anodic Stripping Voltammetry

**Pb (II)**
- SWASV of Pb (II) in pH 9 glycine buffer. Deposition at -0.8 V for 300 s

**Cu (II)**
- DPASV of Cu (II) in 0.1 M nitric acid. Deposition at -0.6 V for 500 s

**Cd (II)**
- DPASV of Cd (II) in pH 9 ammonium citrate buffer. Deposition at -1.2 V for 120 s
Application of the Sensor for Anodic Stripping Voltammetry

SWASV of:

a) Pb (II) in pH 4.6 acetate buffer.

Preconcentration at:

a) -1 V for 90 s

SWASV of:

b) Cu (II), Pb (II) and Cd (II) in pH 4.6 acetate buffer.

Preconcentration at:

b) -1.2 V for 120 s
Application of the Sensor for Anodic Stripping Voltammetry

Copper (II) in Industrial Waste Sample

DPASV in Glycine Buffer.
Deposition at -1 V for 60 s.
Calculated concentration 2.33±18.8%

Cadmium (II) Spiked in Lake Water Sample

DPASV in Ammonium Citrate Buffer.
Deposition at -1.2 V for 60 s
Average Recovery 113%
Application of the Sensor for the Electrochemiluminescence of Luminol
Application of the Sensor for the ECL of Luminol

Carbon WE

Platinised Carbon

Luminol Oxidation 0.36 V
Luminol Reduction 0.31 V

1x10^-3 M Luminol
2x10^-4 M Luminol

in Borate buffer pH 9 scanned at 0.15 V/s
Application of the Sensor for the ECL of Luminol

Time-Dependence of the Potential Under DPV Conditions and the Corresponding ECL Response.

2x10^-4 M luminol with or without 0.05 M H_2O_2 solution in borate buffer pH 9 containing 0.1 M NaCl
Application of the Sensor for the ECL of Luminol

Platinised Carbon WE

Time-Dependence of the Potential Under DPV Conditions and the Corresponding ECL Response.

2x10^{-4} M luminol with or without 0.05 M H_{2}O_{2} solution in borate buffer pH 9 containing 0.1 M NaCl
Application of the Sensor for the ECL of Luminol

Time Course Step Potentials and the Corresponding ECL Response of the Luminol-\(\text{H}_2\text{O}_2\) System.
Application of the Sensor for the ECL of Luminol

The Stability of the ECL Emission With Time for The Luminol-H$_2$O$_2$ System
Application of the Sensor for the Stripping ECL Determination of Metal Ions
Application of the Sensor for the Stripping ECL Determination of Metal Ions

1. Deposition
2. Reagent Flow
3. Stripping-ECL
Application of the Sensor for the Stripping ECL Determination of Metal Ions

Copper (II) Luminol- H₂O₂ System

Deposition in Glycine Buffer at -0.7 V for 60 s
ECL in Glycine Buffer at 0.6 V for 2 s
Application of the Sensor for the Stripping ECL Determination of Metal Ions

Cu (II) Stripping-ECL
- Deposition in Glycine Buffer at -0.7 V for 60 s
- ECL in Glycine Buffer at 0.6 V for 2 s

Cd (II) Stripping-ECL
- Deposition in Ammonium Citrate at -1 V for 60 s
- ECL in Borate Buffer at 0.5 V for 2 s

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