IPRO 331

Non-invasive Blood Glucose Monitoring
What is Diabetes?

- Diabetes is a disease in which the body ineffectively uses blood glucose for energy.

- **Type I**
  - Endocrine
  - Previously known as juvenile onset

- **Type II**
  - Metabolic
  - Previously known as adult onset
Complications of Diabetes…

- Heart Disease
- Kidney Disease
- Eye Complications
- Neuropathy and Nerve Damage
- Podiatric Complications
- Dermal Complications
Complications of Insulin Treatment…

- Hyperglycemia
- Hypoglycemia
Current Methods

- Lancet/Syringe
- Glucose pump
- Glucowatch
## Pros/Cons

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lancet/Syringe</td>
<td>Accurate/Quick</td>
<td>Invasive</td>
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<tr>
<td></td>
<td></td>
<td>Painful</td>
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<tr>
<td>Glucose Pump</td>
<td>Accurate/Self-monitoring</td>
<td>Invasive, can malfunction</td>
</tr>
<tr>
<td>Glucowatch</td>
<td>Non-invasive convenient</td>
<td>Inaccurate Unreliable</td>
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Objectives for the Semester

Create a design for a non-invasive blood-glucose monitoring system:

- Simple in concept
- User-friendly (especially for children)
- Does not hamper a person’s daily lifestyle
- Cost-effective
- Portable
Overview of Design

- Ultrasound
- Vacuum Suction
- Reaction Method
- Transfer of Data
Ultrasound
Ultrasound Design

- Components
  - Transducer
  - Amplifier

- Frequency of 20 kHz

- Requires 20 W power (battery-operated)
Ultrasound Example

Ultrasound Transducer/Amplifier

SonoPrep Skin Permeation Device

Handpiece

Return Electrode
Vacuum Suction
To use vacuum pressure to draw interstitial fluid (ISF) continuously into the patch and over the glucose sensor inside it
Diagram

Activation of Piston

Upward movement of ISF
Reaction Method
Glucose Oxidase Reaction

\[
\beta-D\text{-glucose} + O_2 \xrightarrow{\text{glucose oxidase}} \text{D-glucono-1,5-lactone} + H_2O_2
\]
Methods of Measurement

• pO2 Electrode
• H₂O₂ Electrode
• Mediator Electrode

Diagram of pO2 Electrode

- Glucose
- Gluconic acid
- Glucose oxidase

- (a) Oxygen
- (b) Oxidised mediator

- (a) Hydrogen peroxide
- (b) Reduced mediator

- Oxygen permeable membrane
- Ag
- Pt
- GOD
- Glucose

Electrons

Diagram of pO2 Electrode
Comparison of Reactions

**pO₂ Electrode**: Set $E = -0.6\,\text{V}$, $O₂$ is reduced to $H₂O$

**H₂O₂ Electrode**: Set $E = +0.68\,\text{V}$, $H₂O₂$ is reduced to $O₂ + 2H^+$

**Mediator Electrode**: Set $E = +0.19\,\text{V}$, Ferricinium$^+$ reduced to Ferrocene

*All electrode potentials (E) are relative to the Cl-/AgCl,Ag0 electrode.*
The current is then measured and using the following equation the rate of reaction can be determined:

\[ i = nF A v A \]

- \( i \) = current
- \( n \) = number of electrons transferred
- \( F \) = Faraday
- \( A \) = electrode area
- \( vA \) = rate of reaction
Control the rate of reaction by diffusion using a membrane

Electric current produced is proportional to the analyte concentration (independent of enzyme & electrochemical kinetics)
Data Transfer
Data Transfer

Two types:

- Direct – Automated measurement and periodic downloading
- Indirect – Manual measurement and the data communicated via telephone or online services to the central receiver
Data Transfer (contd.)

- Method of blood glucose measurement involves:
  - Transcutaneous biosensors (blood glucose conc. is an extrapolation)
  - Data Port
  - Computer
  - Diabetes Management Software
Data Transfer (Contd.)

- Advantage: Less prone to human error

- Disadvantage: Transcutaneous measurement of glucose is less precise
Aesthetics

Angled View

Side View
Aesthetics

CPU:
- Suction Automation
- Processing Electrode Signal
- Display/Memory Functions

Thermocouple

Electrode

Reaction Chamber

Membrane

Interface with the skin

*Not Drawn to Scale*
Other Details
Total Estimated Cost

- Ultrasound- $25-$100
- Suction-$25
- Electrode-$50-$75
- Data Transfer-$25-$50
- Aesthetics-$10-20
- Total- $150-$270
Accomplishments

- Unique design and concept
- Integrated multiple aspects of the design
- Identified proper reactions
- Created visual prototype
Considerations

- Temperature affects the reaction
- Skin irritation
- Membrane clogging
- Make the device look like a common device
- Convince users that the device is accurate
Future Goals

- Company sponsorship
- Make a prototype
- Test the prototype
- Make improvements upon design
- Clinical testing
- Obtain a patent
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Acknowledgements

- Dr. Matt Corcoran, University of Chicago
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