Using Contact Lenses to Monitor Diabetes

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Situation

- Millions of diabetic patients have to frequently prick their fingers to track their glucose level. Using this common method, diabetic patients are more susceptible to infections and pain.
- Studies have shown that blood glucose levels are directly correlated to glucose levels found in tear fluid [1].
- Using this analogy that correlates tear and blood glucose levels, a contact lens that could continuously and wirelessly monitor glucose levels in the tear fluid can be implemented to provide an alternative non-invasive method to monitor diabetes.

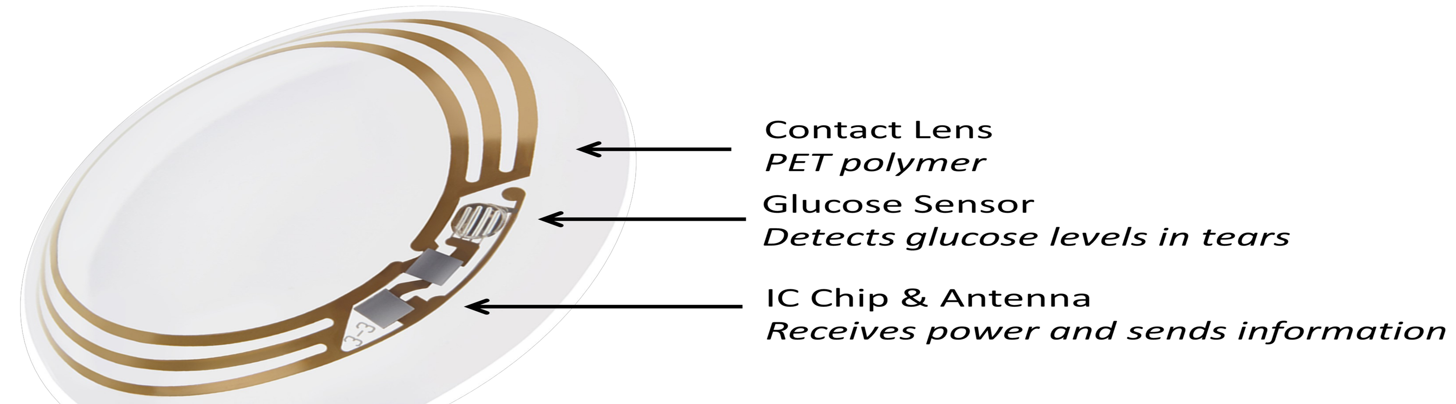
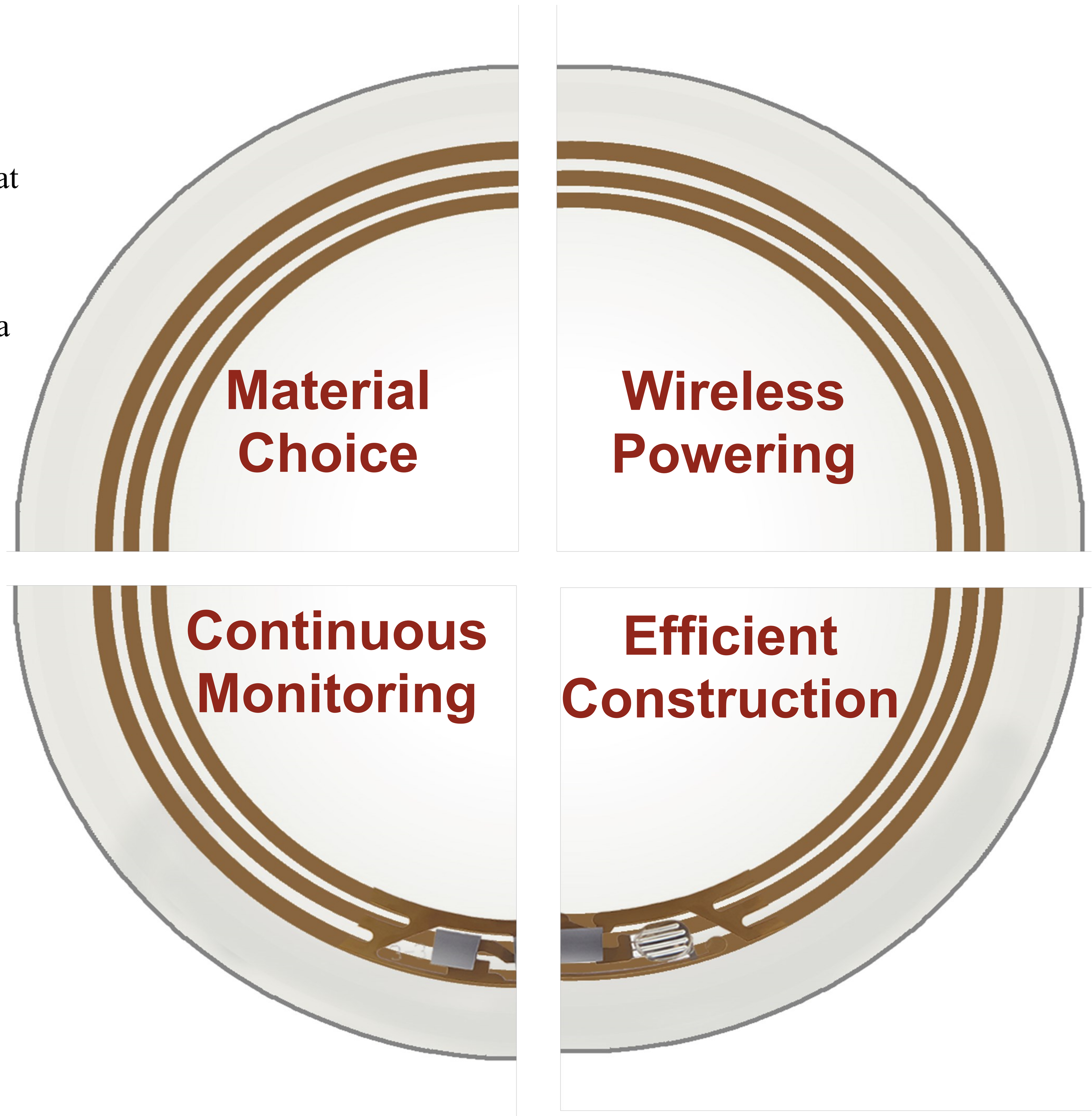


Figure 1. Contact Lens Components [1].



Material Choice

Problem

- The material chosen for the contact lens should not interfere with the patient's health or cause any kind of irritation to the patient's eye.

Solution

- Using a polyethylene terephthalate (PET) polymer, a biocompatible lens can be fabricated.
- Embedding the electric components between two layers of PET polymer ensures that they are not in contact with the eye cornea.

Evaluation

- Comparing the contact lens to the classical method, infections can be eliminated in a safe and convenient way.
- Testing the PET polymer on both in vivo and clinical levels assures the biocompatibility and the safety of the polymer.

Continuous Monitoring

Problem

- The Glucose Oxidase (GOD) enzyme essential to activate the electrochemical reaction (figure 2) is hard to maintain at the electrodes of the glucose sensor, thus no current will be generated.

$$D - \text{Glucose} + O_2 \overset{GOD}{\rightarrow} H_2O_2 + D - \text{Gluconolactone}$$
$$H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$$

Figure 2. Electrochemical Reaction to convert glucose concentration to an electric signal [2].

Solution

- Entrapping the GOD enzyme with Sol gel capsules (shown in figure 3) helps in maintaining the enzyme at the electrodes.
- Generating a continuous current proportional to the glucose concentrations can thus be achieved in the presence of GOD enzyme [5].

Evaluation

- Presents diabetic patients with a reliable and continuous monitoring method.

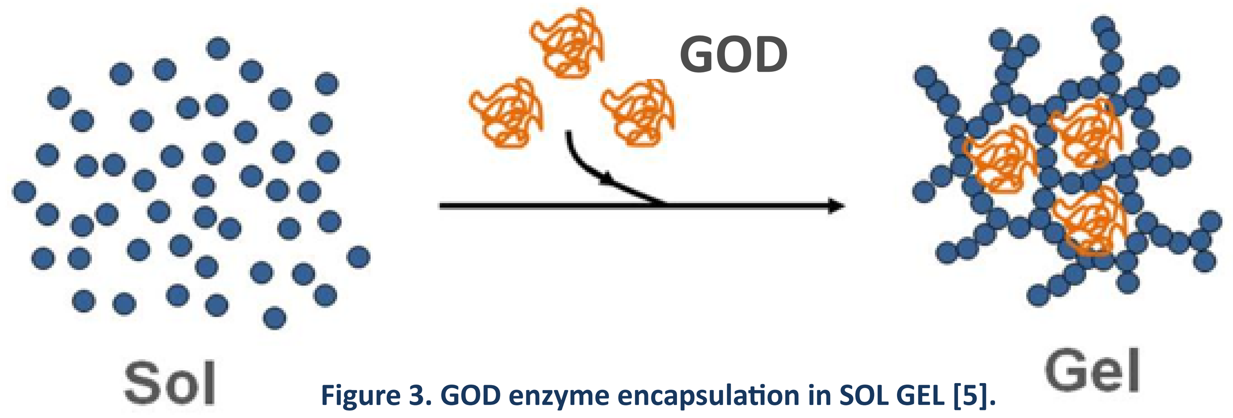


Figure 3. GOD enzyme encapsulation in SOL GEL [5].

Component	PET Polymer	Glucose Sensor	Loop Antenna	IC Chip	Total
Average Cost ($)	0.0033	34.82	12.53	4.57	51.92

Table 1. Cost Analysis of the contact lens.

Wireless Powering

Problem

- Standard surface mount components such as energy storage devices cannot be used in powering the lens due to size constraints.

Solution

- Powering the lens must be done wirelessly. This can be achieved through using Radio Frequency Identification (RFID) technology which employs a 5 mm-radius loop antenna and an IC chip [3].
- The antenna extracts power from an external device and then sends out glucose information to it. The IC chip (shown in figure 4) converts the (alternating) AC voltage produced from the antenna into a workable (constant) DC voltage.

Evaluation

- Power efficiency is achieved since the lens only requires 5 μW of power [2].

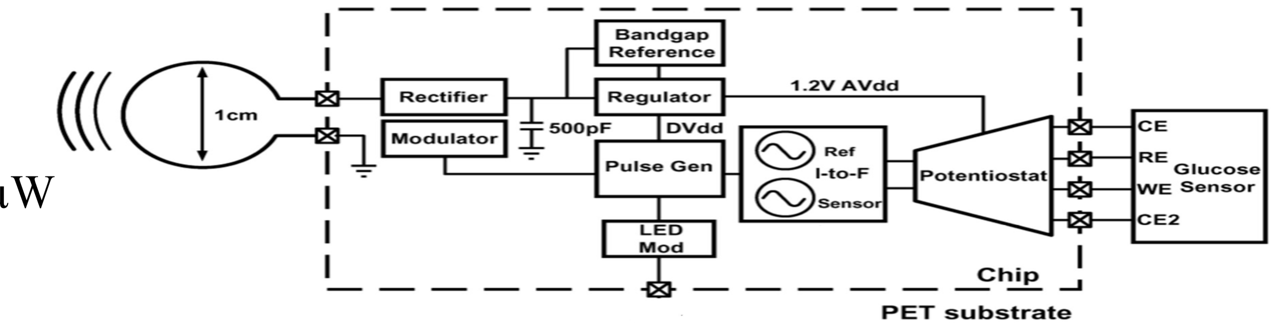


Figure 4. Integrated Circuit chip [2].

Efficient Construction

Problem

- The allowable area on which components can be placed is 0.36 mm^2 to allow clear vision [2].

Solution

- Heat molding the micro fabricated PET film in a way that the components are on the edge of the lens leaving a clear central area.
- Placing the devices on the outer surface of the lens to prevent friction that could occur between the devices.

Evaluation

- Prevents vision blurring.
- Ensures durability of the lens by protecting devices from intrusions.

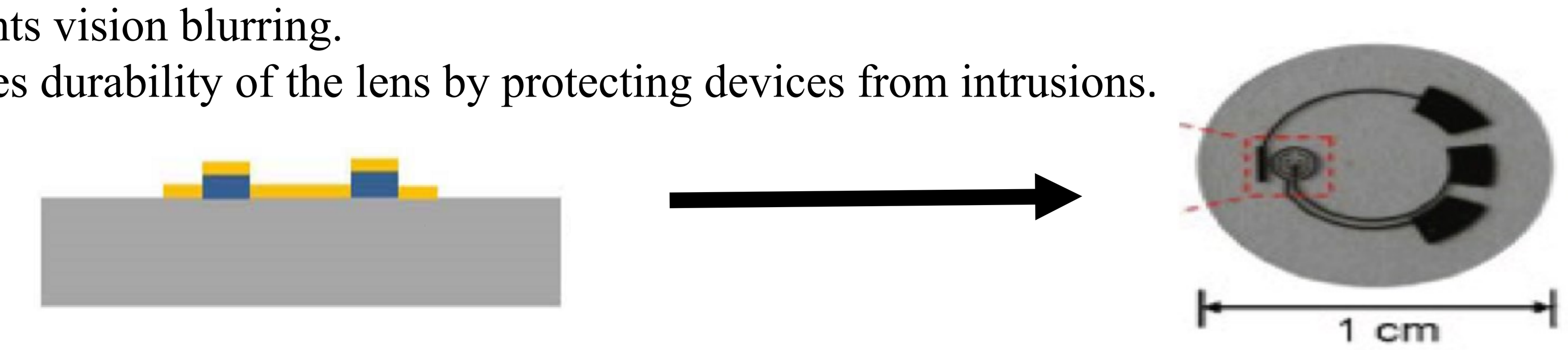


Figure 5. Heat Molding Shape [4].

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