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Development of a Glucose-Powered Biobattery for Implantation and Use in Humans

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Table 1 - Evaluation of design vs objectives

Design	Contact Angle (*)	Protein Adsorption (% Reduction)	Degradation (%)	Voltage/Power ($V/\mu W/cm^2$)	Oxidation Rate (μmol/day)	Reduction Rate (μmol/day
Objective	20	>30	<2	2-3/2-5	<37.5	<225
Multi-Cell	18	10*	<1	0.02/0.05	0.18	0.09
Single-Cell	18	10*	<1	0.20/1.18	4.3	2.15

* Difference in measured reduction was not statistically different than uncoated sample

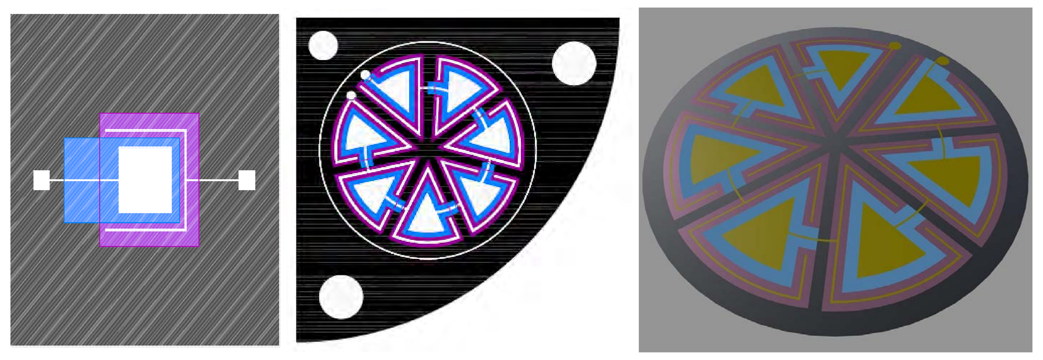


Figure 2: Exposed layer renderings of single and multi-cell biobattery

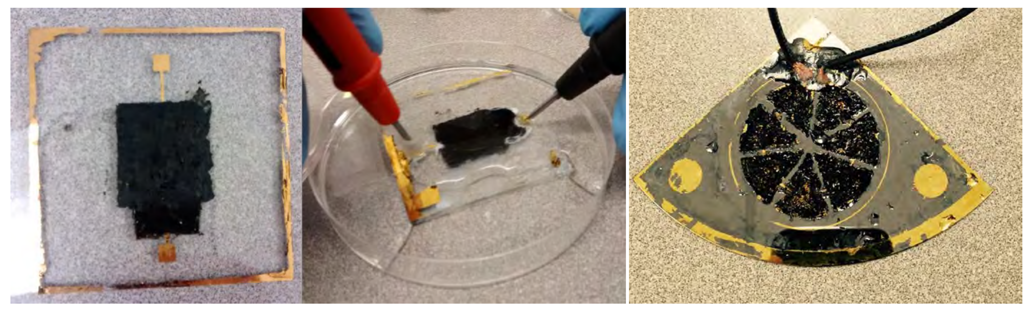


Figure 4: Manufacture biobattery design used in testing

I. Introduction

With current demands for implantable electrical devices increasing, the need for a more stable and biocompatible source of power is becoming increasingly necessary. Several battery types and materials were evaluated. Ultimately, an abiotic biobattery was designed with the goal of implantation in the human body. Nafion, single-walled carbon nanotubes (SWCNTs), and gold were used to create an abiotic biobattery that is powered by glucose.

The SWCNTs were used to create the cathode, the gold was used to fabricate the anode, and the Nafion acted as the separator between the cathode and anode. A thin Nafion membrane was evaluated for overlaying the SWCNT cathode to prevent biofouling. A biofouling resistant membrane should allow the biobattery to continue to operate with greater efficiency without the surface area effectually decreasing over time as a result of biofouling.

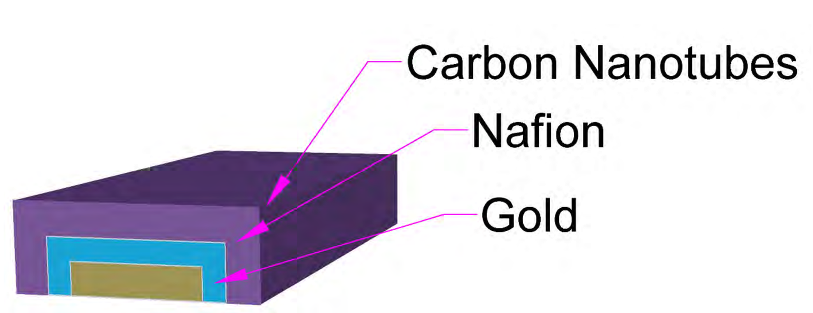


Figure 1: Layered biobattery design

II. Design Criteria

The final design selection is intended to meet the following objectives:

- Low water contact angle (< 20°)
- Reduces 1 week BSA protein adsorption by 30% over control
- Able to last 10-15 years without noticeable degradation or harm to the human body
- Produces 2-3 V and 2-5 μW/cm2 of power
- Oxidizes glucose at a rate of 37.5 μmol per day or less
- Reduces oxygen at a rate of 225 μmol per day or less

III. Final Design

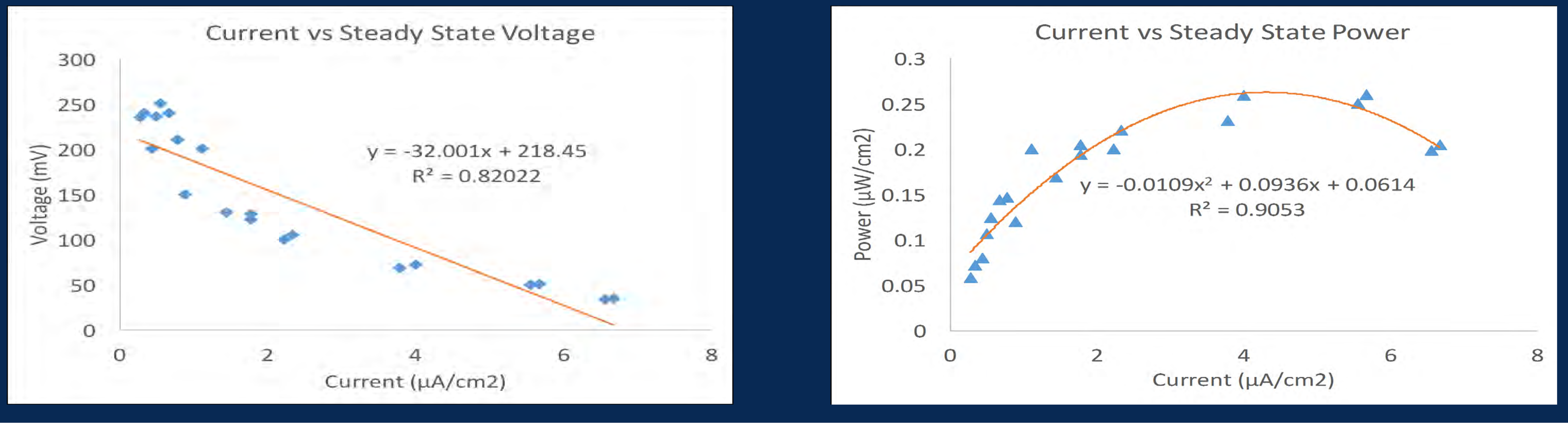
The final battery design that was chosen was an abiotic biobattery with a gold anode, a layer of Nafion on top of the gold anode served as the proton exchange membrane, and a SWCNT mesh suspended in Nafion as the cathode (Figure 2). This design was built on a glass substrate for testing purposes. The final design also investigated the use of a layer of Nafion, which is overlaid on the SWCNT layer as a anti-biofouling layer. Both a multi-cell and a simplified single-cell design were manufactured and tested.

Table 1 shows an evaluation of the biobattery designs against project design criteria. Evaluation of the biobattery costs about $45-$50 and manufacturing time of 2-3 days. Figure 4 shows the final designs of the biobattery.

IV. Results

The single cell batteries had an average steady state voltage of 198 mV with a standard deviation of 36.8 mV after exposure to glucose. Comparing these results to batteries to deionized water, which yielded an average voltage of 6 mV with a standard deviation of 6 mV, produced a p-value of $7*10^{-6}$, indicating that these results were statistically significant. The voltage drop and power output were tested for several resistive loads producing a maximum power of about 0.28 $\mu W/cm^2$ at a current drawn of 4.4 $\mu A/cm^2$ (Figure 3).

Figure 3: Voltage and power generation from simple design



V. References

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