

# Topology-Dependent Encapsulation Strategies for Extended Longevity of Wireless Transmission Diodes in Implantable Hydrocephalus Shunt Biotelemetry



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## INTRODUCTION

### Background

- VP shunts fail frequently (40% at 1 year, 80% at 10 years), requiring multiple revision surgeries and burdening patients with cumulative morbidity
- Wireless transmission diodes in implantable biotelemetry systems fail within 4–6 weeks due to tissue interference, corrosion, thermal stress, and chronic inflammation
- Multi-layer encapsulation strategy combines tissue-safe epoxy, parylene C vapor deposition, and silicone elastomer to protect circuitry while minimizing signal attenuation
- Extended diode lifespan from 4–6 weeks to 6–12 months enables continuous wireless monitoring and early detection of shunt malfunction
- Successful development enables proactive shunt management, reduces emergency interventions, improves patient outcomes, and provides a platform for other implanted medical devices

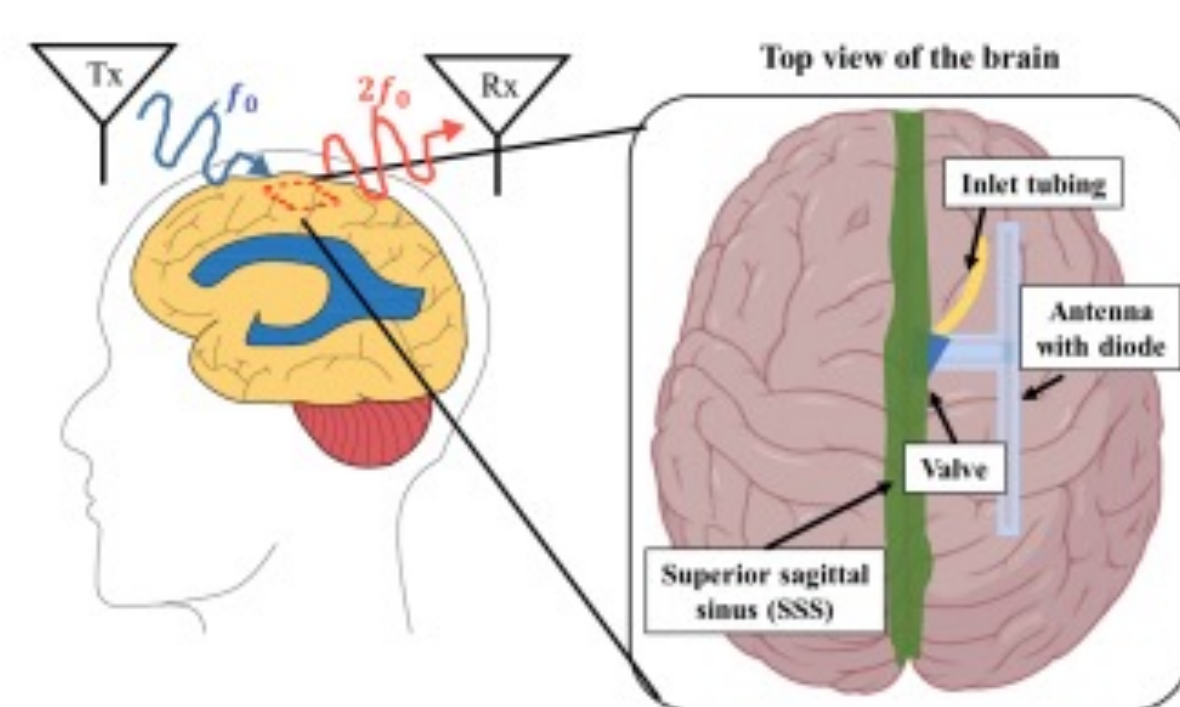


Figure A: The device that is being studied currently



Figure B: The experiment setup

## METHODS

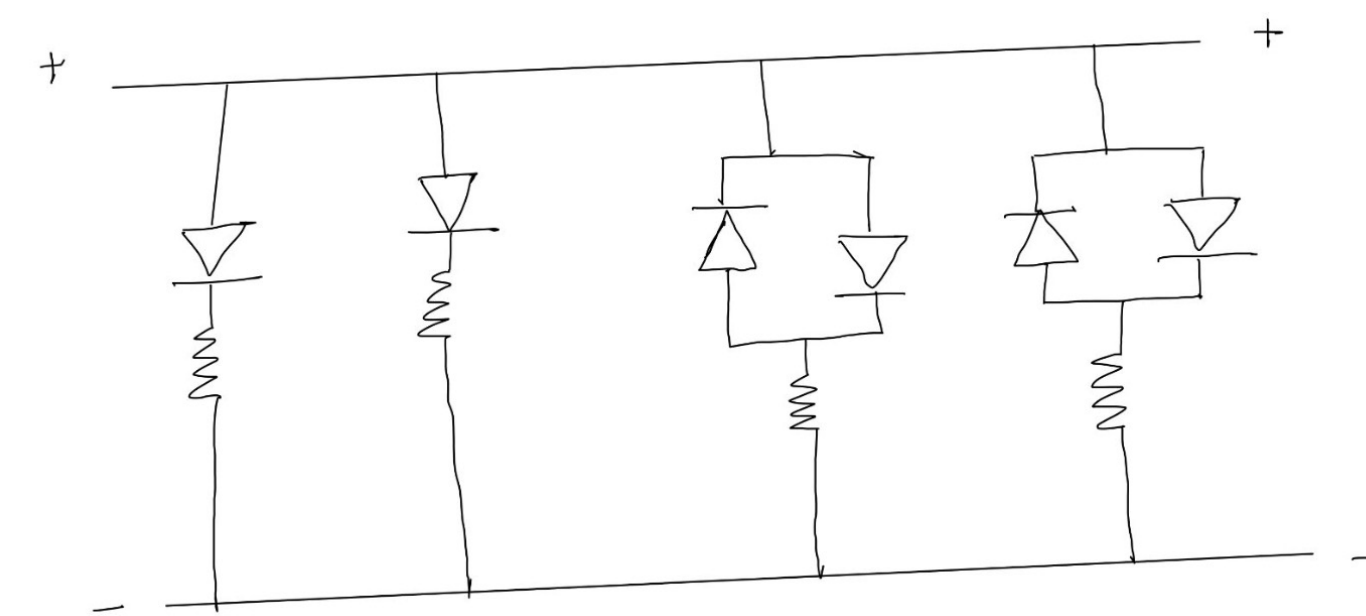


Figure C: Circuitry setup

### How it was conducted

- Multi-stage comparative analysis evaluated four distinct circuit arms under identical conditions: 2.0 V peak-to-peak sinusoidal excitation at 1.0 MHz ( $\pm 0.1\%$  frequency stability)
- Baseline control experiments submerged unencapsulated diode-resistor pairs in deionized water ( $>18 \text{ M}\Omega\cdot\text{cm}$  resistivity) and isotonic saline (280–310 mOsm/kg, pH 7.2–7.4) for seven days under continuous electrical excitation with daily fluid replenishment
- Two encapsulation iterations tested diodes coated in tissue-compatible epoxy resin or medical-grade silicone elastomer (Sylgard 184 PDMS, Shore A 40–60, ISO 10993-5 biocompatibility certified) via standardized dip-coating, followed by identical immersion and excitation protocols

## RESULTS

### The Main Results

- The silicone-encased diodes used Schottky diodes and therefore produced a monophasic sinusoid, the antiparallel diodes produce a biphasic sinusoid.
- The epoxy-encased diodes used LEDs and therefore had normal sinusoids throughout.
- After a few days, the saline-dipped diodes had created alternate current paths around the diodes which increased the current over the resistor.
- Both diodes had an increase in current in saline.

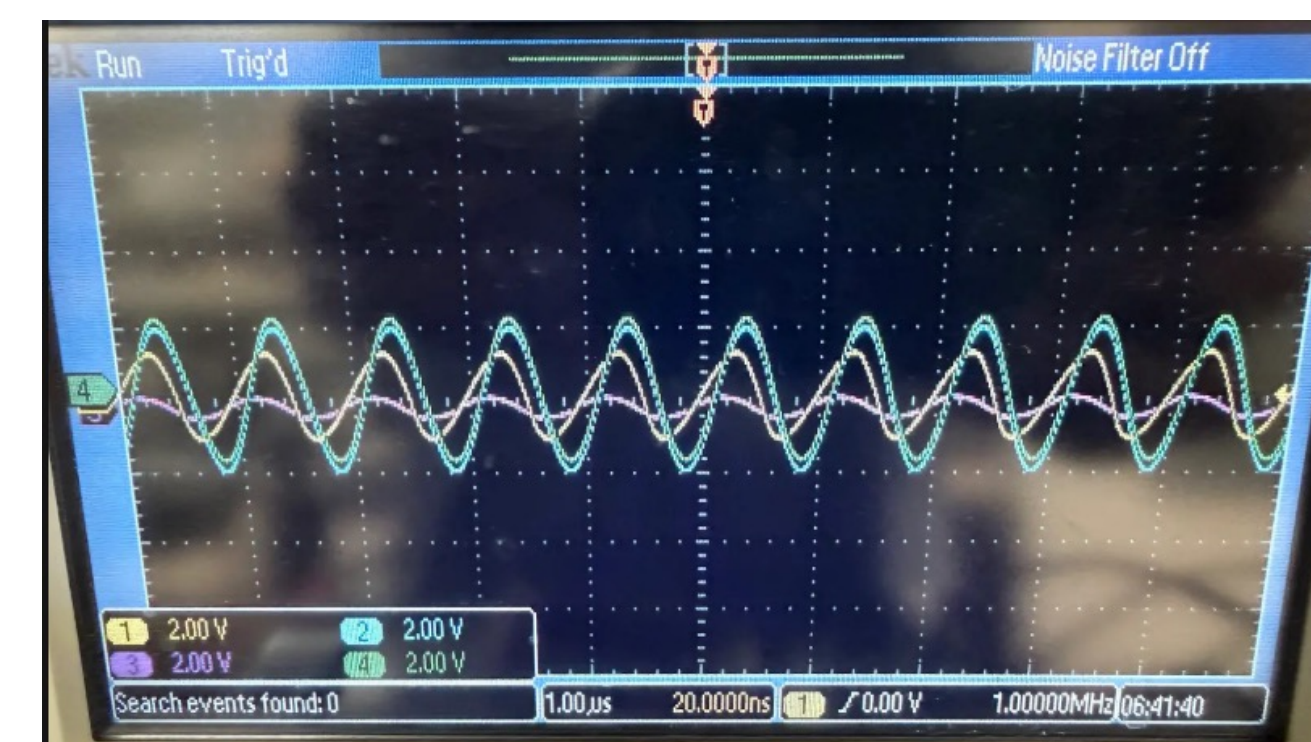


Figure D: Current waveforms for the epoxy diodes

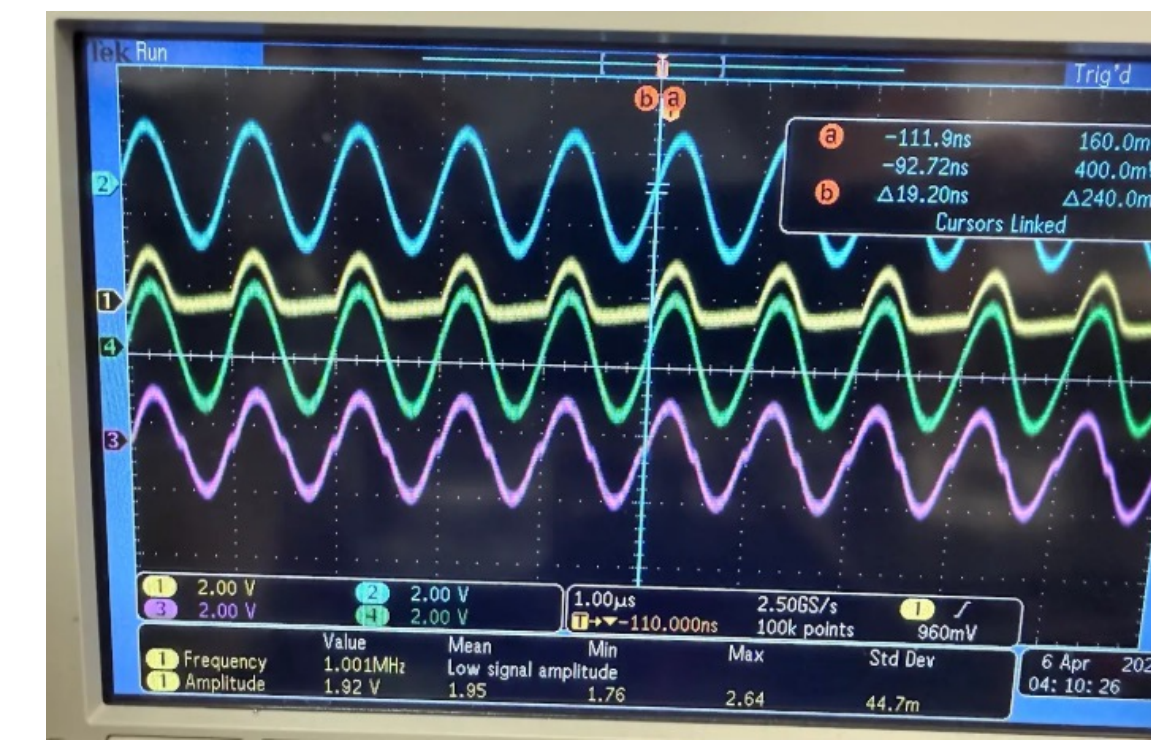


Figure E: Current waveforms for the silicone diodes

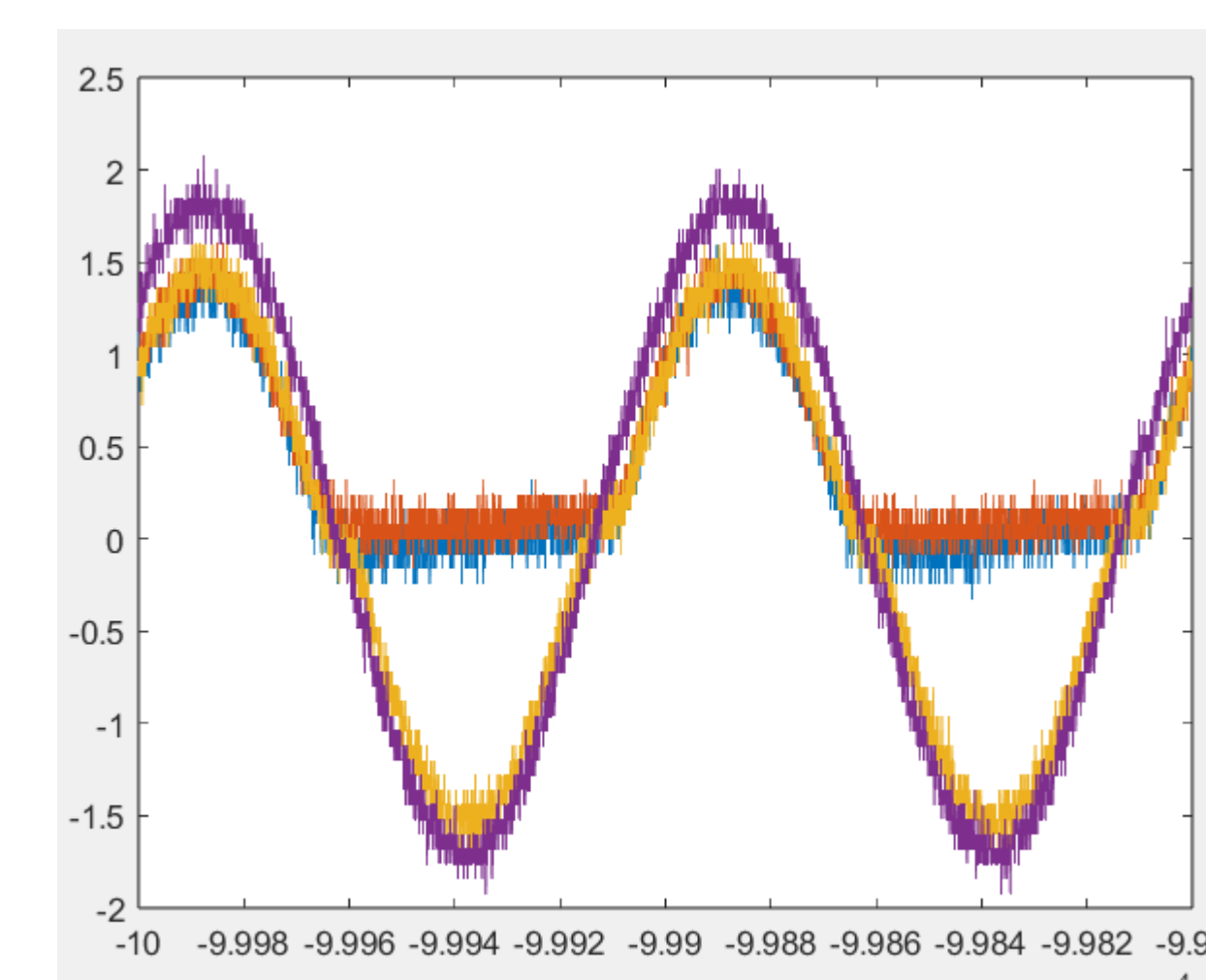


Figure F: Current in silicone-encased diodes on Day 1

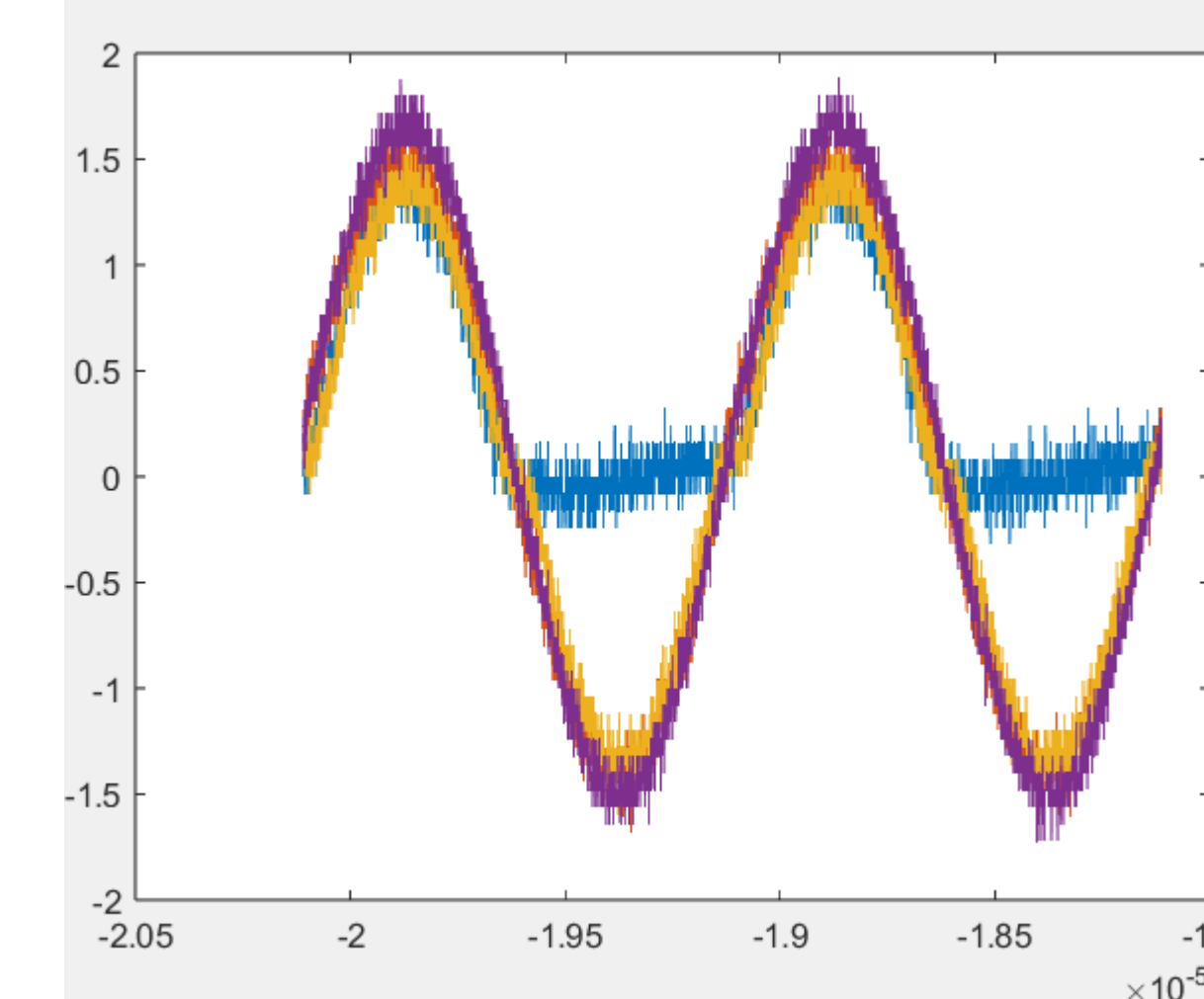


Figure G: Current in silicone-encased diodes on Day 20

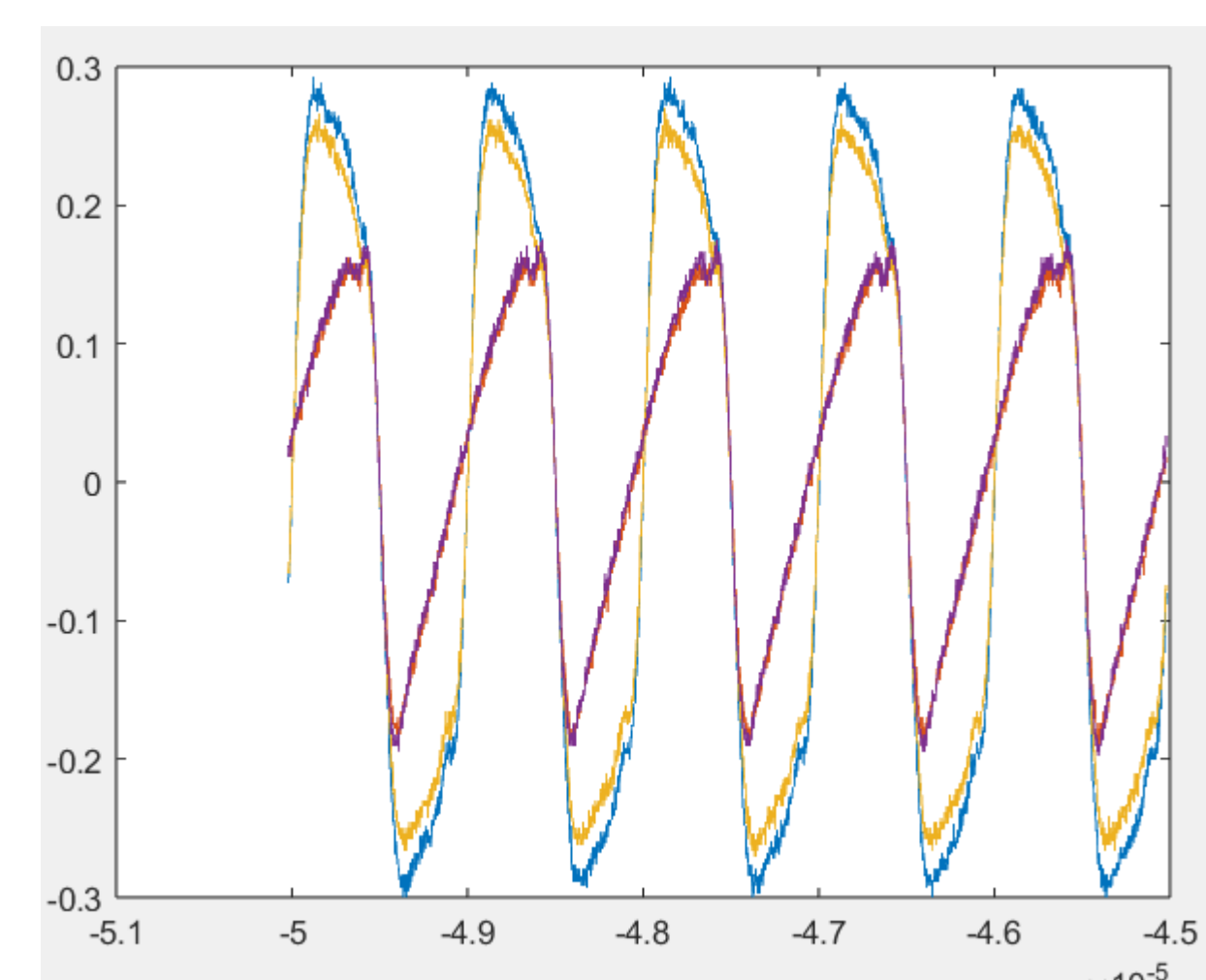


Figure H: Current in epoxy-encased diodes on Day 1

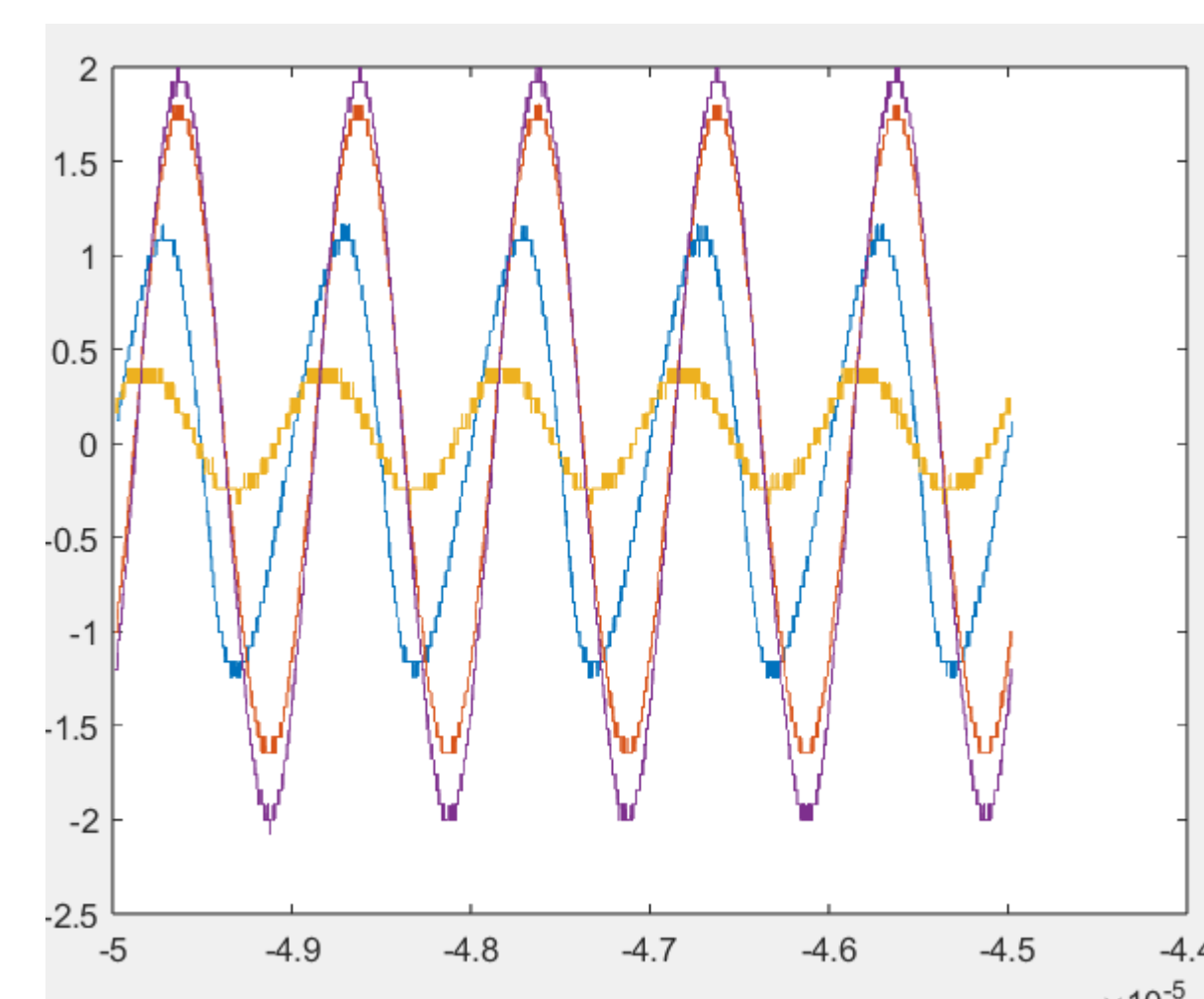


Figure I: Current in epoxy-encased diodes on Day 40

## RESULTS

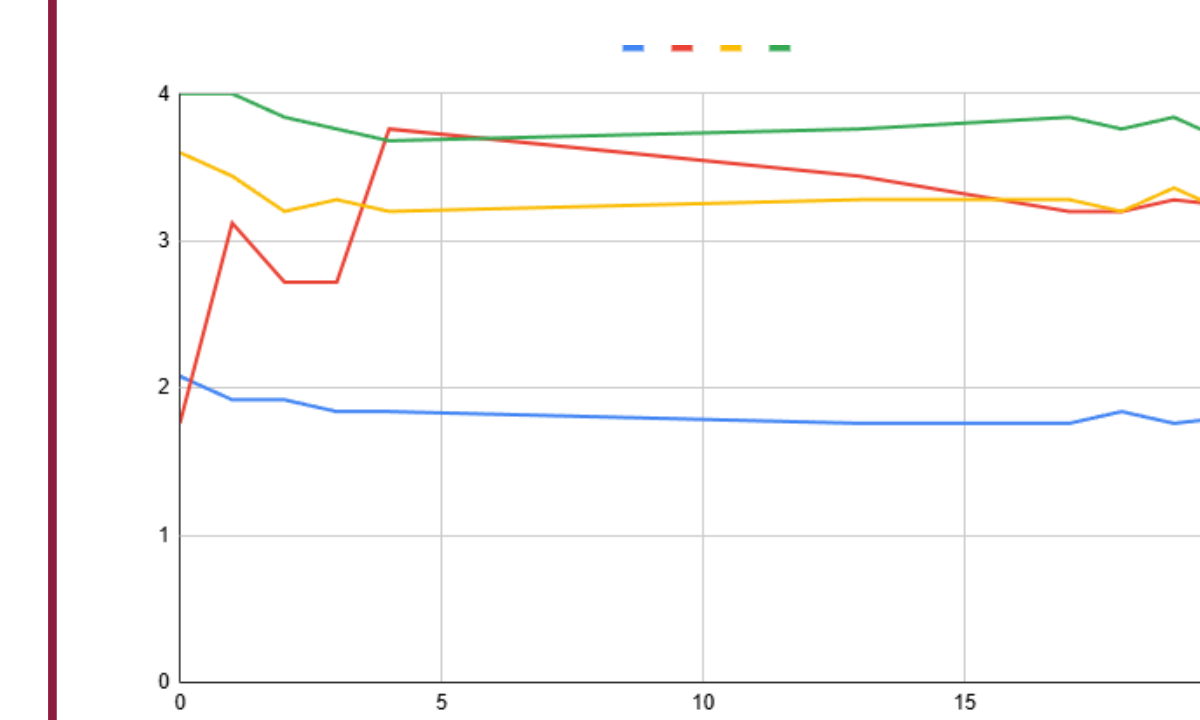


Figure J: Current in silicone-encased diodes over 20 days. The red and green lines represent single and double diodes in saline respectively.

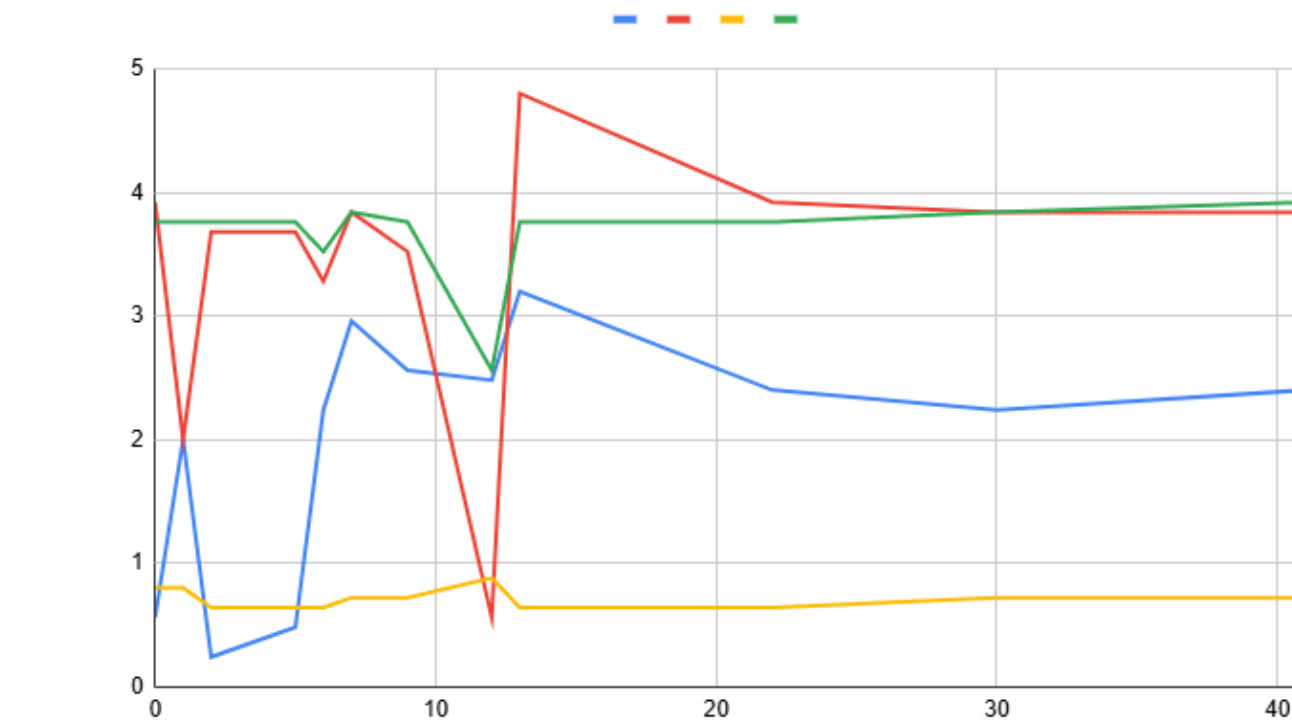


Figure K: Current in epoxy-encased diodes over 40 days. The red and green lines represent single and double diodes in saline respectively.

- These linear graphs show that current is better maintained in a silicone encapsulation with an antiparallel diode setup.

## SUMMARY, CONCLUSIONS AND FUTURE DIRECTIONS

- Single-diode silicone configurations failed within 2–4 days due to ionic bypass pathways through material defects, while double-diode designs maintained stable voltage (3.80 V vs. 3.04 V,  $p = 0.0005$ ) with 74% reduced variance.
- Current room-temperature testing ( $22^\circ \text{C}$ ) underestimates degradation by 2–4 fold compared to physiological conditions ( $35\text{--}37^\circ \text{C}$ ); extended testing at body temperature for 8–12 weeks minimum is essential to reliably predict 6–12 month clinical longevity
- Future work must employ uniform Schottky diodes across all conditions, replace simple I-V characterization with multiparameter monitoring (impedance, harmonic content, waveform analysis), and integrate superior epoxy ionic-blocking properties with double-diode topology

## REFERENCES

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