Biophotonics - Exploring photonic devices for use in optogenetic stimulation of neural tissue

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Aims

- To test how the driving configuration affects device lifetime, using a degradation rig.
- To design a model that can simulate the properties of an optogenetic device.

Introduction

Optogenetics offers the possibility to use light to stimulate or inhibit specific subsets of neurons. One possible application of optogenetics is to modulate abnormal activity to prevent seizures.[1]

Optogenetic devices are coated with a thin passivation layer to protect it from short-circuiting. This passivation degrades over time due to charge escaping from the circuit, eventually reaching a point where it fails and the device short circuits.

This study aimed to assess how driving configuration affects device lifetime, with a view to prolonging it. The driving configuration controls the voltage input into the circuit.

The three driving configurations were: monophasic with shared ground, monophasic and biphasic. Figure 1 shows the basic schematic that was used for all 3 configurations.

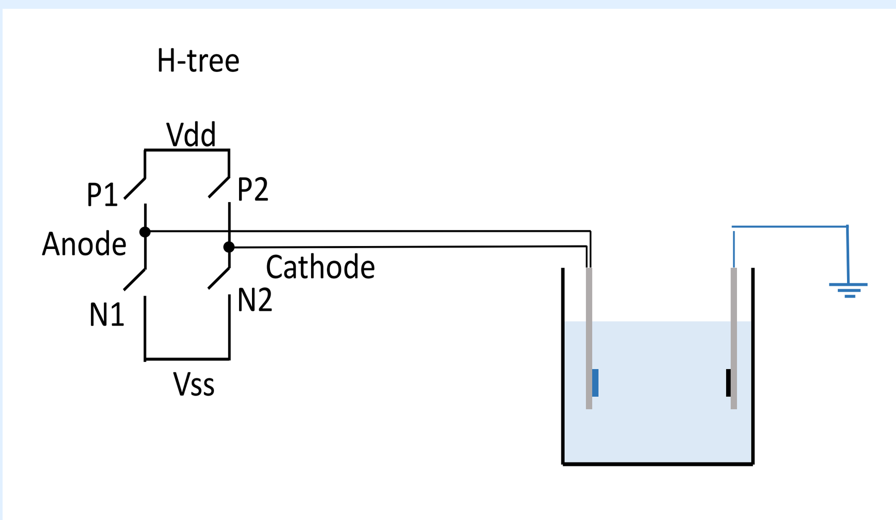

Figure 1: LED (left) is submerged in a saline solution and connected to the device via H-tree. An electrode (right) is also submerged in the solution, grounding it

To test how each of the configuration affected the passivation, the impedance between the anode, cathode and the solution were periodically recorded using an impedance analyser. Impedance is the measure of the circuits opposition to the flow of current.[2]

The model was designed to simulate the current and voltage output of the submerged LED measured by an electrode that was also submerged in the saline.

Figure 2 is a voltage–time graph showing how the driving configuration affects the voltage input for each LED.

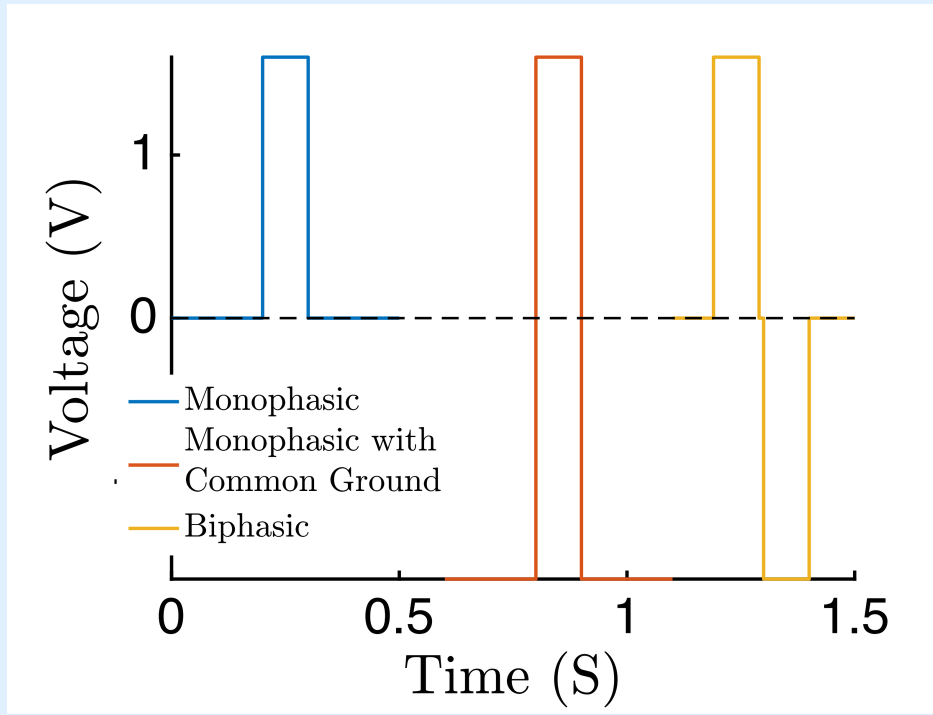

Figure 2: Voltage–time graph for each driving configuration

Results and Discussion

From the data shown in Figure 3, it can be seen that only the device driven by the monophasic configuration didn't fail, as it was the only one for which the resistive element of the impedance recorded did not substantially drop.

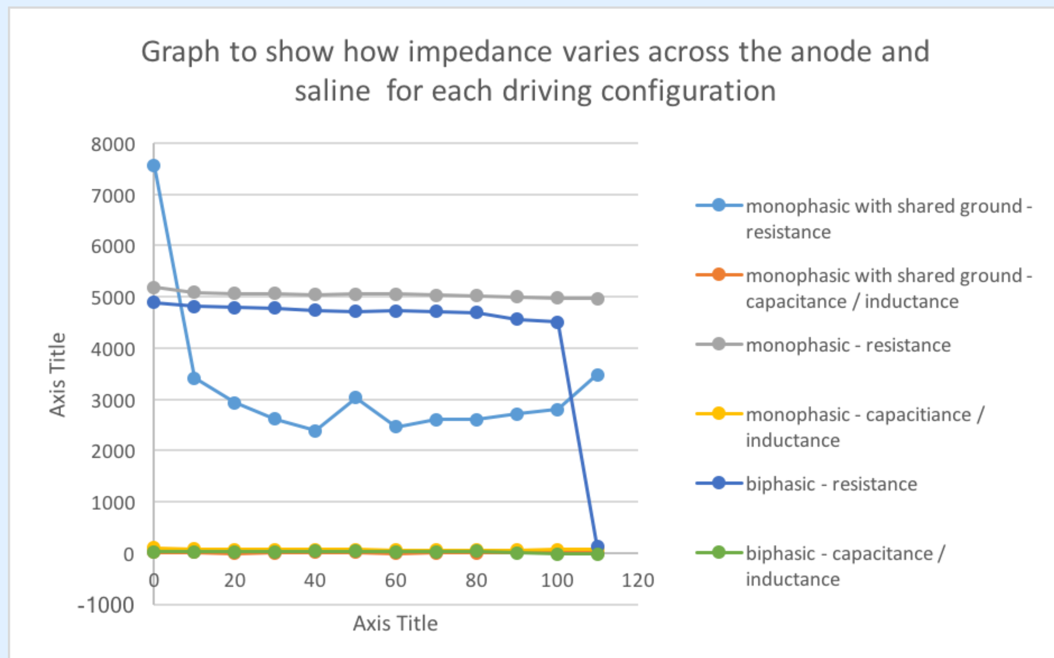

Figure 3: Shows how the impedance across the LEDs anode and the saline varied with time for each driving configuration.

The impedance recorded for all 3 configurations was much lower than anticipated. To test possible causes of this a simple resistor-capacitor was connected to a Keighley sourcemeter, the impedance analyzer and the impedance analyzer when submerged in saline.

When connected to the sourcemeter the magnitude of the resistor-capacitor was much higher and more accurate than when it was connected to the impedance analyser.

Figure 4 is the model designed to simulate the properties of the optogenetic device and Figure 5 shows the simulated current and voltage output.

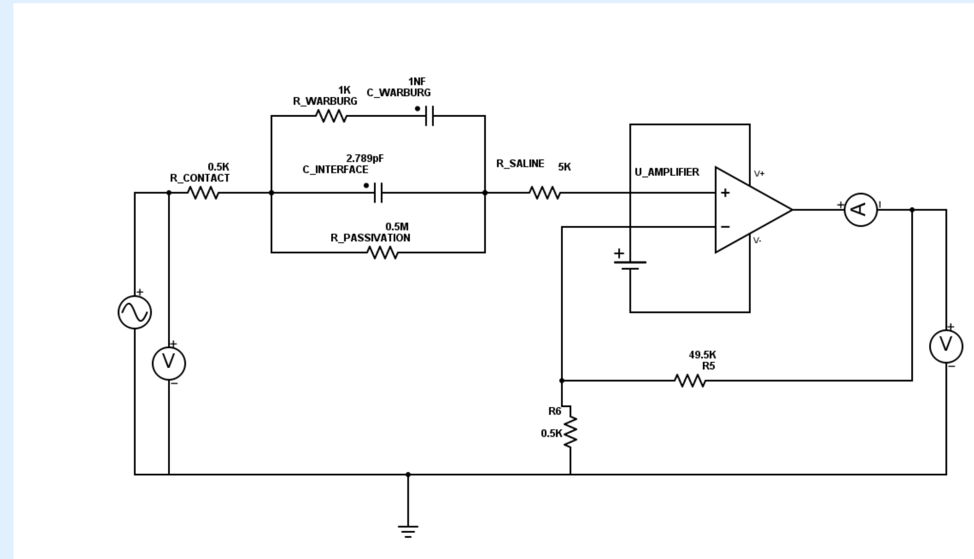

Figure 4: Equivalent circuit used to model the optogenetic device

The model has two components that have unknown values: the Warburg resistance and capacitance. These Warburg elements are used to model the diffusion of charge at the surface between the passivation layer and the saline. The value for these were incalculable as the diffusion coefficients of the material were unknown. Without having all the correct values of the variables, the model was unable to simulate the properties of the device successfully.

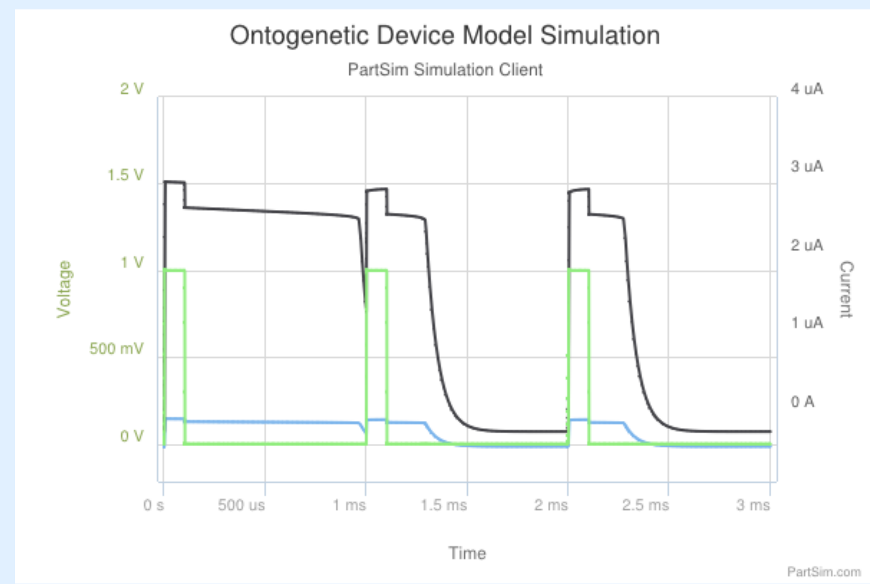

Figure 5: Shows the current (black), voltage input (green) and voltage output (blue) for the model

Conclusion

- Currently the computer model is unable to simulate the properties of the devices, as not all the values of the components are known.
- The monophasic driving configuration was the driving configuration that led to the longest operating LED.

References

[1] *About CANDO; CANDO; Newcastle University* (2017) [Online]. 2017. Available at: http://www.cando.ac.uk/aboutcando/. (Accessed: 3 October 2017).
[2] *electrical impedance | physics* (2017) [Online]. 2017. Available at: https://www.britannica.com/science/electrical-impedance. (Accessed: 4 October 2017).