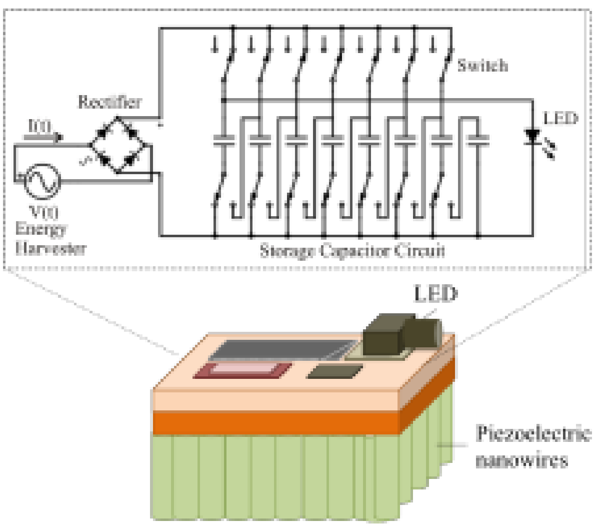
BB610 Team 1 - Fabrication Flowchart

We have decided to try and fabricate the device described in [this paper](), along with some modifications. Little to no details are given in the paper as to how to fabricate the device itself.

The Device



This is a picture of the device, as presented in the Paper. We will be focusing on individual parts of the design, and how to fabricate them.

The device operates on the principle of neural dust, and is completely wireless - enabling deep implantation. The piezoelectric nanowires help the device to receive power via ultrasound waves, generated by external controllers as described in the brainstorming evidence.

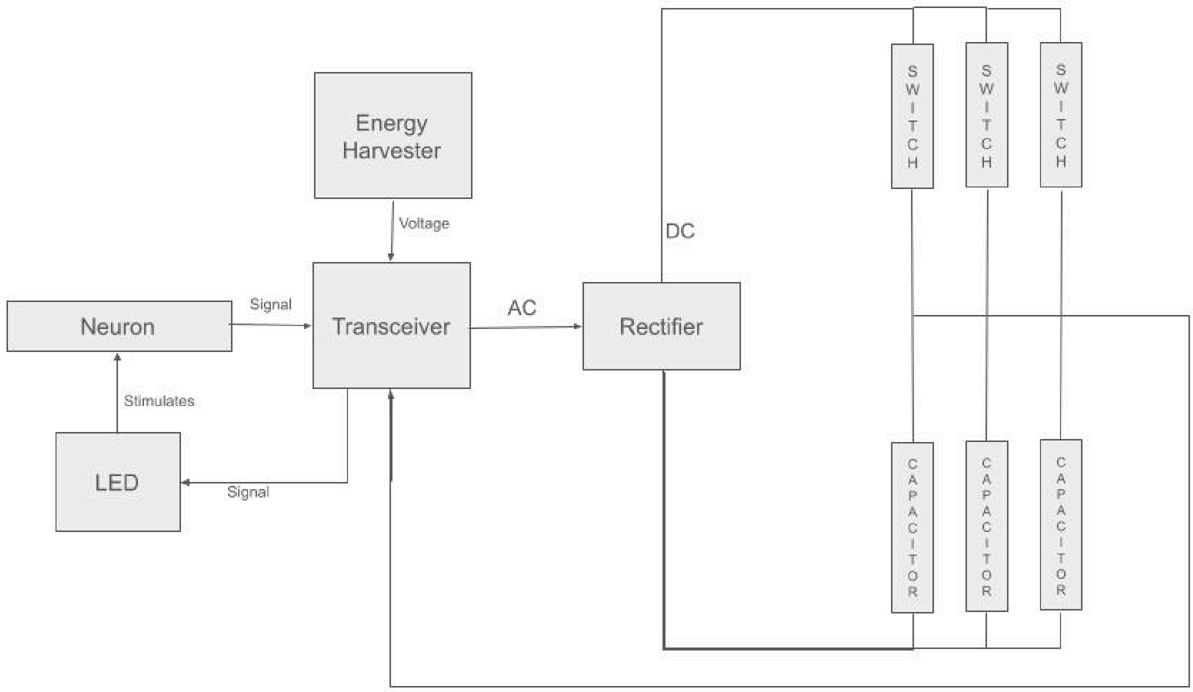
This allows stimulation of required areas using the LED, and we can extend this to even send data back to the external controller.

Our calculations put the size within the range of (0.8mm*0.7mm*0.5mm). This figure was arrived at by looking at the dimensions of the LED that the paper suggested to use.

The Circuit

The following is the ASIC diagram we have to fabricate. We have also added a transmitter, so that the device is able to communicate both ways:

The switches are required to change the configuration of the capacitors between parallel and serial - we will charge the device in parallel and use the charge in series configuration.



- The Energy Harvester is basically a set of connections from the Piezoelectric wires.
- The LED will be a pre-manufactured device designed for MEMS applications - like the InGaN Cree's Direct Attach DA2432 LED.
- The rest of the design can be made using standard ASIC design techniques discussed in class for e.g. surface micromachining, etch-back, lift-off etc.

For example, for the capacitors, we could do the following:
- On the silicon substrate, first deposit an insulating layer(SiO_2) using CVD technique.
- Then for the electrodes, deposit Aluminium/Copper layer using sputtering.
- We use photoresist and dry etching to create shapes which result in capacitive behaviour.
- We deposit a dielectric layer, and then the top electrode to finally form our capacitor.

An alternative method would be to go the VLSI route: Dope the silicon wafer using masks in such a way that a capacitor is formed on the surface of the wafer itself.

Completely making this circuit in a MEMS process could prove to be tedious, which is why our current proposal is to make it as an ASIC chip and implant it onto our device.

Piezoelectric wires

Piezoelectric materials exhibit the piezoelectric effect - the ability to generate an electric charge when mechanically deformed (direct effect), or mechanically deform when an electric field is applied (converse effect). This can thus power our circuit

Common piezoelectric materials used in MEMS:

- Lead zirconate titanate (PZT) - Very high piezo response, but contains lead.
- Aluminum nitride (AlN) - Moderate piezo response, but lead-free and CMOS compatible.
- Zinc oxide (ZnO) - High piezo response, biocompatible, used for energy harvesting.

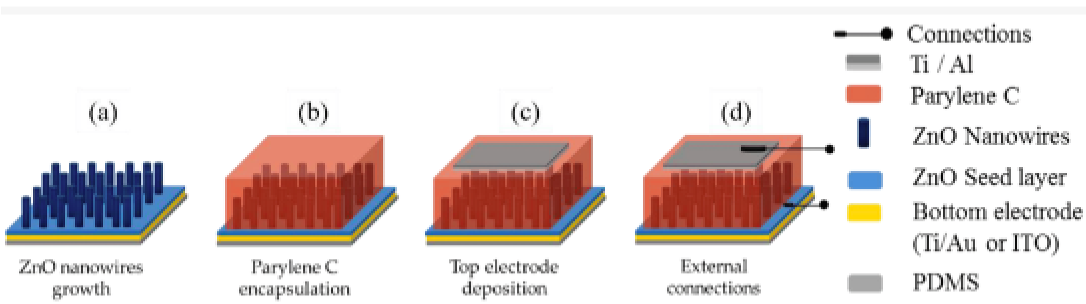
We found two methods to build the nanowires:
a) Top-Down Bulk Micromachining:
Used to fabricate suspended piezo structures like membranes and cantilevers from deposited piezo films.
Involves patterning, etching and releasing steps.

b) Bottom-Up Nanowire Growth:
Piezoelectric nanowires of materials like ZnO can be grown using vapor techniques.
Offers high aspect ratios, enhanced piezo properties.

We will be choosing the second method.

The following is an overview of the process used to build these nanowires:
- First, we take a PDMS substrate, which offers a flexible membrane-like structure which allows movement in the wires.
- We then deposit a layer of ITO (Indinium Tin Oxide) via low-power sputtering to avoid damage to the PDMS substrate. This layer is 400nm thick.
- Then a thin ZnO seed layer is deposited using RF sputtering.
- Then, the hydrothermal method is used to actually grow the ZnO NWs.
- A paylene-C layer is added to insulate the NWs from each other.
- Connections are made using layers of Ti/Al, which is why a final layer is deposited at the top by evaporation technique.

Below is a diagram demonstrating the different steps involved in this process.



Coating

As these devices will be inserted in the brain, we need to properly cover it with biocompatible materials so that the device and its surroundings are not damaged.

A thin layer (thickness<100um) of Methyl Methacrylaye(MMA) can be used for coating. It offers excellent adhesion properties, has low permeability to moisture. It also provides good stability in energy harvesting processes.

Coating solution components-
MMA polymer as a base, commercially available in markets with high purity(>99%),
Initiator such as benzoyl peroxide for polymerization, Solvent like acetone or toluene for having customizable viscosity.

How to apply this coating-

1. To ensure uniform coating thickness, submersion tank with controlled temperature and agitation can be used having desired viscosity.
2. Spray coating- Spray gun with adjustable nozzle for coating thickness control, and compressor with pressure regulator for consistent airflow can be used together.