DESIGN OF AN IMPLANTABLE CUFF ELECTRODE USING LASER-INDUCED GRAPHENE

1 Supervising staff

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2 Context

Neurostimulation is the artificial stimulation of brain tissue, peripheral nerves, or muscles to treat neurological disorders or restore impaired or lost body functions. The field of applications is quite large. Here are a couple of examples: deep brain stimulation for Parkinson's disease, cochlear implants providing a sense of sound to people who are deaf, vagus nerve stimulation for the treatment of epilepsy, muscular and sensory nerve stimulation for sensory-motor feedback and restoration for people with paralyzed or lost limbs, to name a few. Neurostimulation is either performed with an external or an implantable neurostimulator. When implanted, it usually consists of an electrical pulse generator, holding the electronics, connected to a lead towards an electrode at the stimulation site, as shown in the following figure:

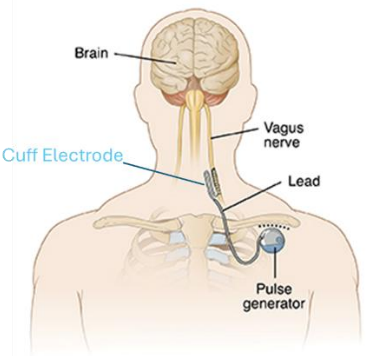

Figure 1: Typical implantable neurostimulator; an example of vagus nerve stimulation [1]

This master thesis will focus on the electrode part, specifically the design of a cuff electrode, meant to be wrapped around a peripheral nerve. A cuff electrode (example shown in Figure 2) is composed of the cuff (the flexible material that curls on the nerve), electrically conductive contacts where stimulation occurs, and conductive tracks connecting the contacts to the lead and further to the pulse generator. The main advantage of such an electrode is its self-sizing ability to adapt to the diameter of the nerve [[2], [3]].

Figure 2: Example of a cuff electrode [4]

3 Work

Manufacturing a cuff electrode is a long and tedious process, requiring accurate and intensive craftsmanship. The cuff itself consists of two or more layers of silicone glued together, one of them being pre-stretched before gluing to provide a natural curling ability. Contacts and tracks are embedded on and into the support, requiring welding and/or crimping. The overall process is complex [5], meaning that the price for such an electrode remains expensive and that they are prone to reliability issues and failures.

This master thesis aims to design and manufacture a cuff electrode using a different approach, with the potential advantages of manufacturing simplification and improved electrode characteristics (impedance, reliability, softness, less corrosion). The capabilities of the manufactured electrode will be assessed on a test bench and potentially on small animals.

The proposed manufacturing process is shown in Figure 3. and consists of:

- A. Realizing a cuff support made of two silicone sheets, one being pre-stretched;
- B. Using a sheet of polyimide material (such as Kapton ©) where the electrode contacts and tracks will be structured through a method called laser-induced graphene (LIG) [6]: using a 2D motorized benchtop laser, the polyimide treated by the laser will turn into graphene, an allotrope of carbon with exceptional conductivity and impedance properties;
- C. Gluing the resulting sheet of polyimide on the cuff support and isolating tracks.

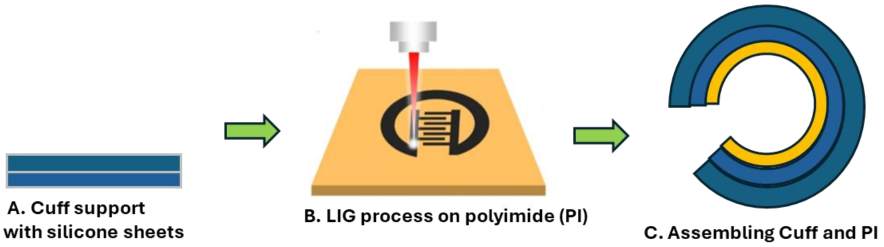

Figure 3: Proposed manufacturing flowchart

The main focus of the work evolves around the development of the LIG process, with careful state-of-the-art review, laser and material selection, implementation, and assessment.

4 References

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