DESIGN AND MANUFACTURING OF A CAPACITIVE STRAIN SENSOR TO MONITOR BLADDER ACTIVITY

Supervising staff

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Context

"Neurogenic bladder" usually defines bladder and sphincter dysfunctions related to a neurological disease or a condition such as a spinal cord injury (SCI). Clinical manifestations include detrusor overactivity leading to incontinence and detrusor sphincter dyssynergia which can result in irreversible kidney damage. A neurogenic bladder has tremendous repercussions on patients' physical and psychological well-being, constituting a financsial burden on healthcare systems.

To prevent most of these issues, patients rely on uncomfortable bladder management techniques such as clean intermittent catheterization, which often lead to urinary tract infections and subsequent renal failure if managed incorrectly or in poor conditions.
Being able to monitor and predict bladder contractions, as well as rising intravesical pressure, would allow patients to adapt their management techniques and increase their quality of life. Moreover, it would be possible to stimulate the afferent nerves in a closed feedback loop to refrain from their urge to urinate. Therefore, monitoring bladder activity in SCI patients is a top research priority.

One of the possibilities for monitoring bladder activity is its deformation. A resistive strain gauge is its simplest implementation but presents two major flaws:

- The elasticity of a standard strain gauge is low. It is, therefore, not correctly following the bladder deformation. The flexibility, stretchability, and durability are also limited, and the measurement presents some hysteresis.
- Measuring the gauge strain requires a relatively high current flow which is to be avoided in an implant design because of limited battery capacity and risk of overheating.

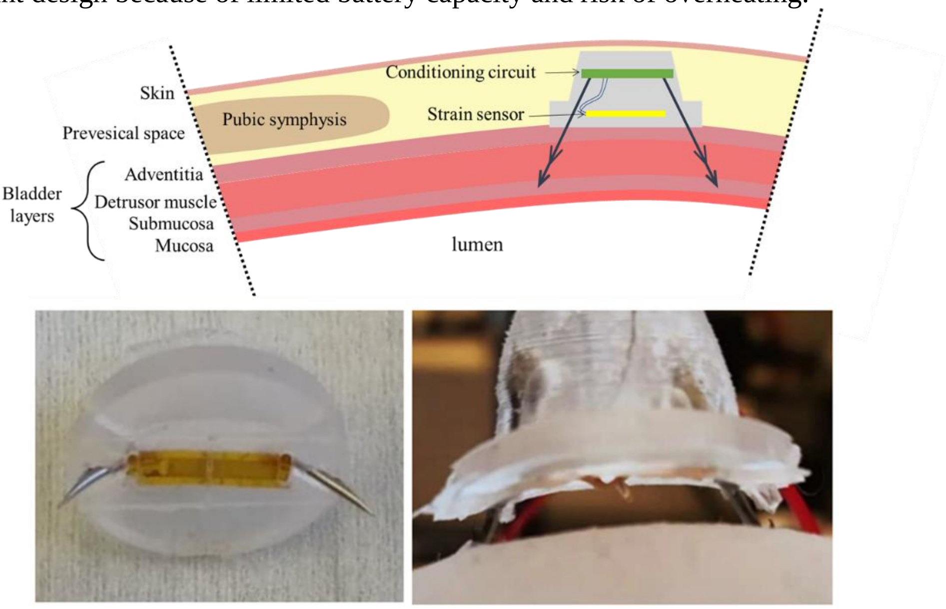

Figure 1: Encapsulated strain gauge to be anchored on the bladder wall

A capacitive strain sensor (i.e., a sensor whose capacitance changes depending on its strain) has been designed to overcome these limitations. It comprises a stretchable silver-coated fabric, acting as electrodes, and silicone, acting as the dielectric. The change in the sensor capacitance largely depends on the variation in the geometric structure of the electrodes and the dielectric layer. This increases the linearity of the measurements and removes any hysteresis behavior. Multiple designs exist and should allow a greater elasticity of the measuring device, which the anchoring on the bladder wall will benefit from. Two different designs have been investigated.

The 3-layer design is a simple sandwich of fabric electrodes around a single dielectric layer. When stretched, the silicone layer gets thinner, and the capacitance increases as the electrodes get closer.

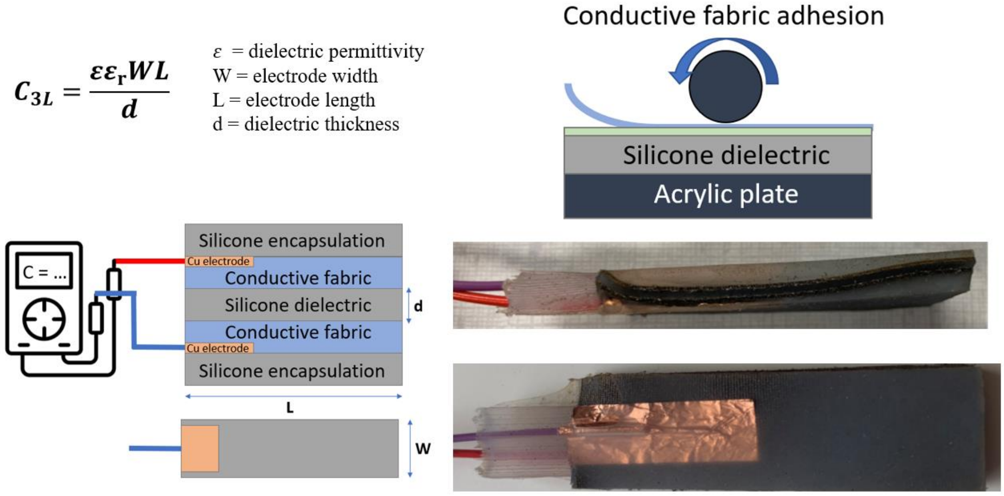

Figure 2: 3-layer design

The interdigital design is a succession of fabric electrodes in the same 2D plane, separated by silicone. Similarly, the electrodes get closer as the sensor is stretched, and the capacitance increases.

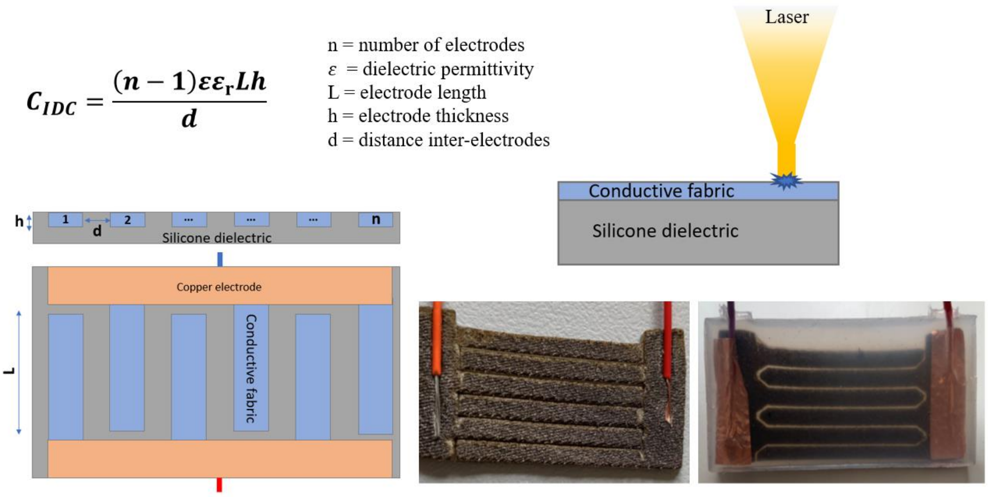

Figure 3: Interdigital design

Although the sensors are promising, the manufacturing technique may still benefit from improvements, and the fabrication parameters could be tuned. For example, some sensors fail as a short circuit between the electrodes appears in some configurations and others fail due to the high impedance connection between the measuring wires and conductive fabric. The sensors have also not been completely characterized (baseline capacitance depending on the configuration, capacitance-to-strain relationship, drift, hysteresis, susceptibility to EMI, functionality in a humid environment, …).

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Work

This master thesis aims to design the manufacturing process of a capacitive strain sensor to measure the bladder wall's deformation and assess its feasibility and performance with a test bench. A specific mechanical anchoring device must also be designed for the sensor to be well attached to the bladder wall and to accurately measure its deformation.

This will require a complete state-of-the-art review to select the best capacitive sensor designs for the application, followed by the actual implementation and assessment of the sensor and the anchor. The main assessment criteria are the power required to measure the deformation, the range of deformation, the elasticity of the sensor, the durability, the hysteresis behavior, and the anchoring capabilities.

Current prototypes will need to be reproduced to understand their functionality and to assess their failure points or limitations. Fabrication parameters (electrode gap, dielectric thickness, size, …) will be varied on new prototypes to optimise the design.

Additional solutions, such as using conductive ink, silicone, or silicone mix, can also be investigated. Additional evaluation criteria, design requirements, and improvements can be discussed during the work.