Assessment of 1D and 2D Materials for Health Monitoring Wearable Devices

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Project Goals

- Cardiovascular diseases (CVD) remain the leading cause of mortality and a major cause of morbidity in Europe. There is a growing demand for a reliable **cardiac monitoring system**.
- The objective of the **SmartVista project** is to develop and demonstrate a next generation, cost-effective, smart multimodal sensing platform to reduce incidences of sudden death caused by CVD.
- In this context, we aim at integrating **1D/2D nanomaterials based sensors** to monitor the heart in a self-powered device, which will autonomously monitor patient's vital signs.

SmartVista

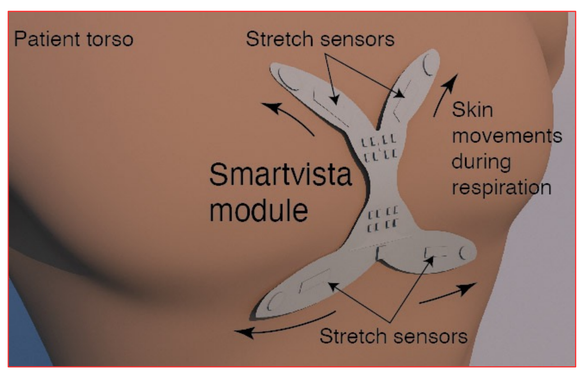
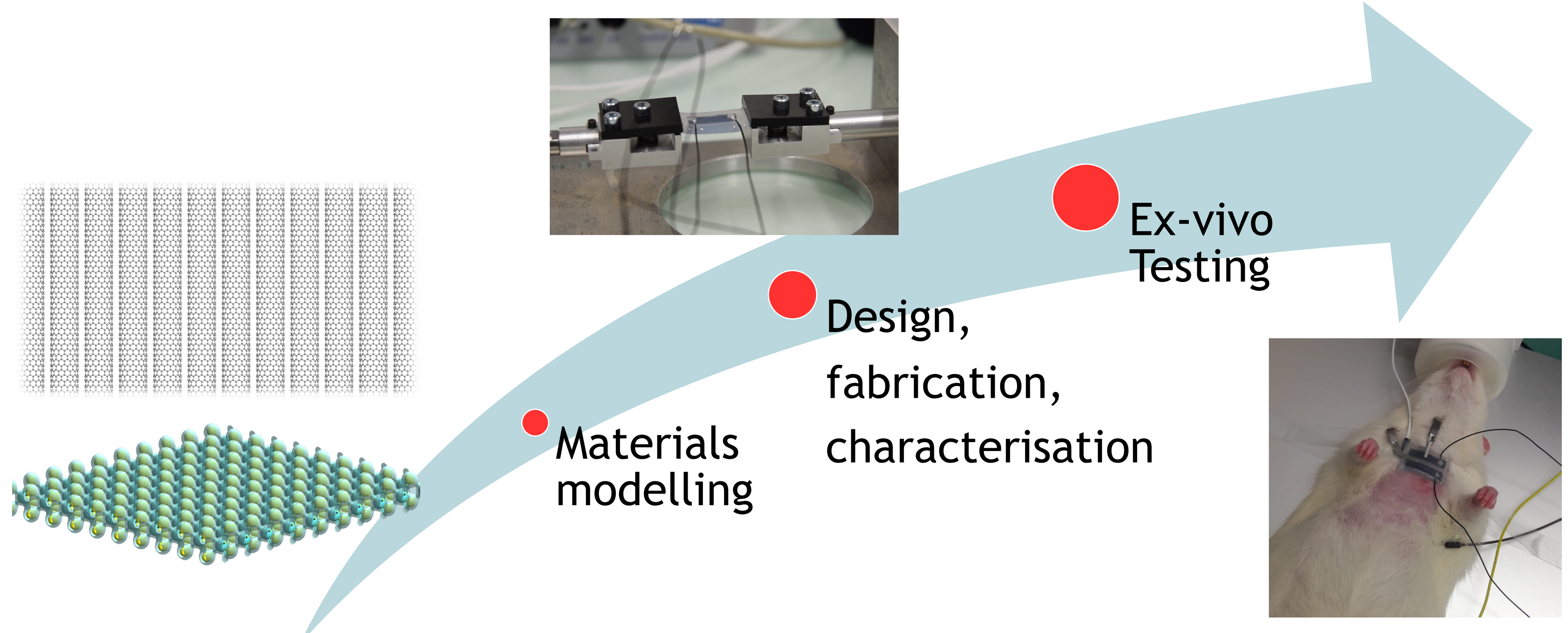


Figure 1. Schematics of the SmartVista device.

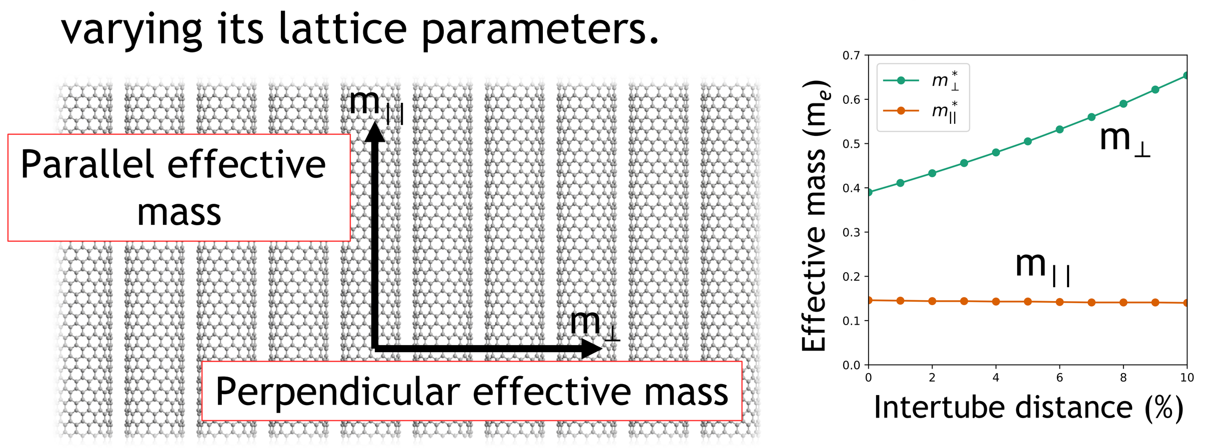
Design Workflow of the Strain Sensor

- **Wearable strain sensors** based on **flexible materials** and architectures could be well-suited to be employed for the continuous and non-intrusive measurement of biosignals.
- Here, we assess the fitness for purpose of carbon nanotube (CNT) nanocomposites and molybdenum disulfide (MoS_2) for the development of stretchable strain sensors to monitor patients' respiratory rate.
- We follow a **multi-disciplinary and multi-level approach**, tackling the problem from different perspectives:



Materials and Modelling

- We carried out first-principles atomistic simulations within the framework of **density functional theory (DFT)** by using QuantumATK software.
- We modelled tensile strain in an ideal **CNT network** by varying the intertube distance, and we modelled uniaxial and equibiaxial strain in **MoS_2 monolayer** by varying its lattice parameters.



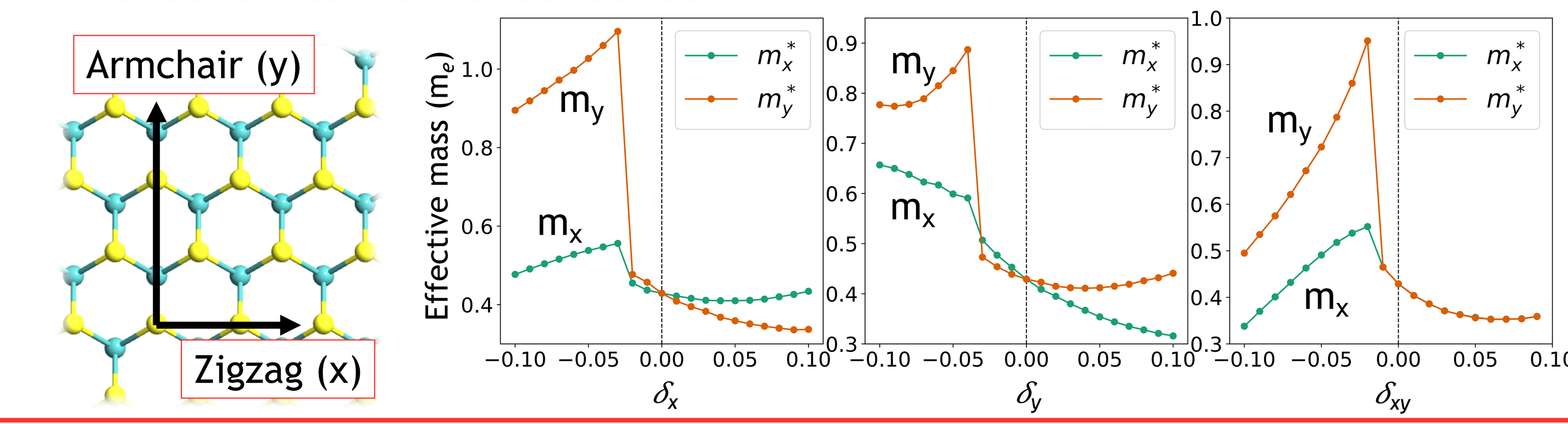


Figure 2. (Top) CNT network model and computed electron effective masses with imposed strain. (Bottom) MoS_2 model and computed electron effective masses with imposed uniaxial and equibiaxial strain.

Fabrication and Characterisation

- We fabricated the strain sensor using CNT networks encapsulated in Dragon Skin silicone polymer matrix, which is **highly deformable** and **biocompatible.**
- The CNT/DS strain sensor was tested by using the E-861 PiezoWalk® NEXACT® Controller by varying strain at rates ranging between 0.01 and 10 mm/s.
- Due to the Wheatstone bridge circuit connected to the strain sensor, the mechanical deformation during stretching test was transformed into current signal and amplified into voltage signal.

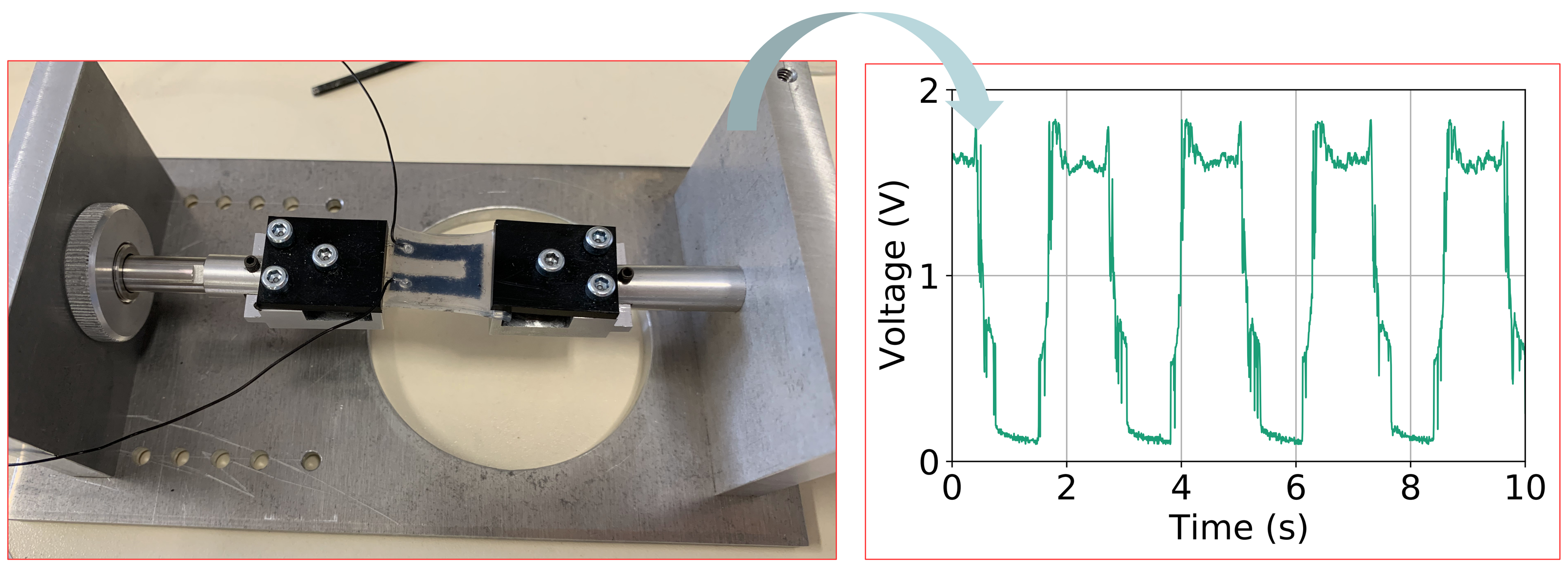


Figure 3. Experimental setup and characterization curve (stretch rate 0.5 mm/s) of the CNT-based strain sensor.

Ex-Vivo Testing of Respiratory Function

- We transversally attached the CNT strain sensor to the anesthetised rat's chest, in direct contact with shaved skin.
- The **mechanical deformation** (stretch and relaxation) of the sensor during the breathing cycle was detected and converted into voltage signal.
- We found a correspondence between the number of respiratory cycles manually counted by the operator (67 bpm), and the number of peaks automatically detected by the software and the frequency (1.12 Hz) calculated by FFT.

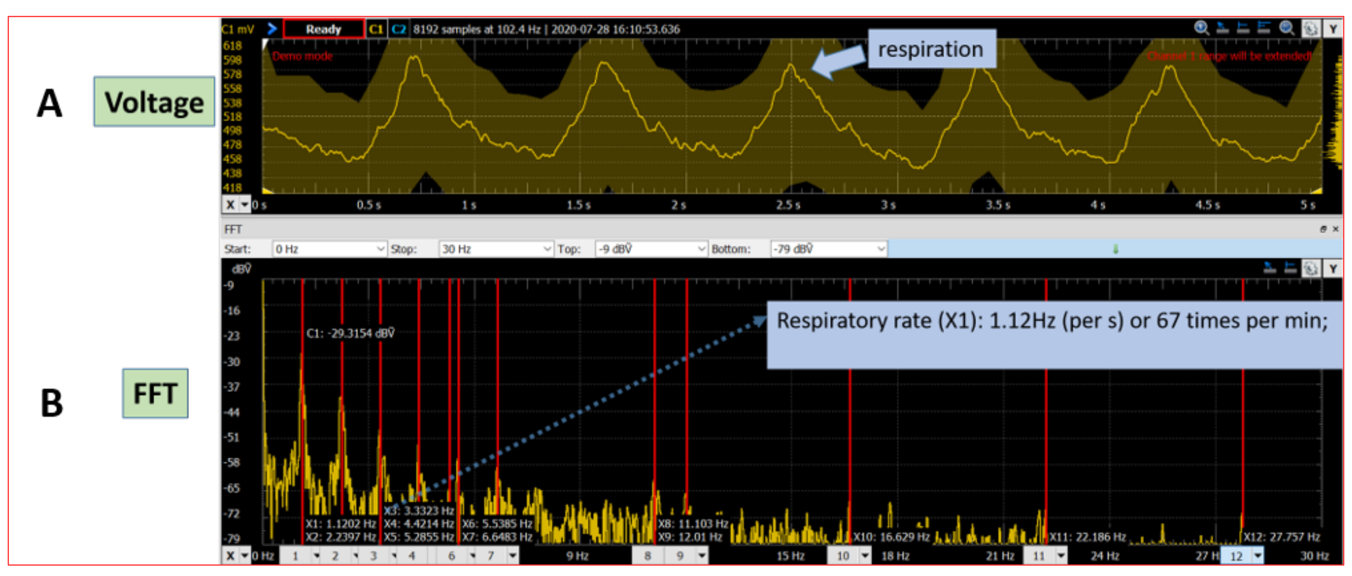


Figure 4. Voltage signal curve in monitoring the respiration of anesthetized rat. A) Peaks of voltage signal variation which correspond to breath cycles. B) FFT value (in Hz) corresponding to the number of breathing cycles per second/minute.

Conclusions and Future Work

- We successfully designed, fabricated, and tested a CNT-based strain sensor, and we showed both 1D and 2D materials to be very promising candidates for such application.
- The capacity of the sensor to detect fine deformations of the chest during respiration allows to finely monitor the respiratory rate. We expect the sensor to be adaptable to detect respiratory rate also in humans.
- As upcoming work, following the results of our simulations, we aim at fabricating and testing MoS_2-based strain sensors to monitor both heart and respiratory rates.

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