# Conformable Heart Sensors using Graphene-infused Silly Putty™

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## Motivation

- Touchscreens & other modern sensors offer sensitivity at the expense of **flexibility** and **cost**
- A composite sensor made from graphene offers unparalleled **flexibility & conductivity** w/out sacrificing sensitivity
- The demand for robust wearable sensors calls for sensors that are more **conformable** and **sensitive**
- To detect **blood pressure** & **heart rate** with a singular sensor it must be able to accurately resolve skin pressures of ~**40 mmHg**


## Methods

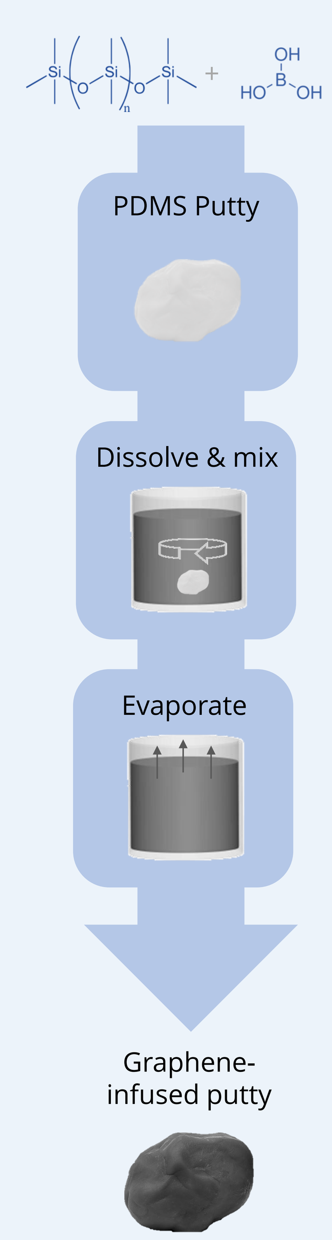
### Graphene Preparation



- An organic solvent (NMP) stabilizes the exfoliation of the graphite sheets by means of tip sonication for 72 hrs
- Re-dispersing graphene in chloroform allows for easy evaporation after mixing

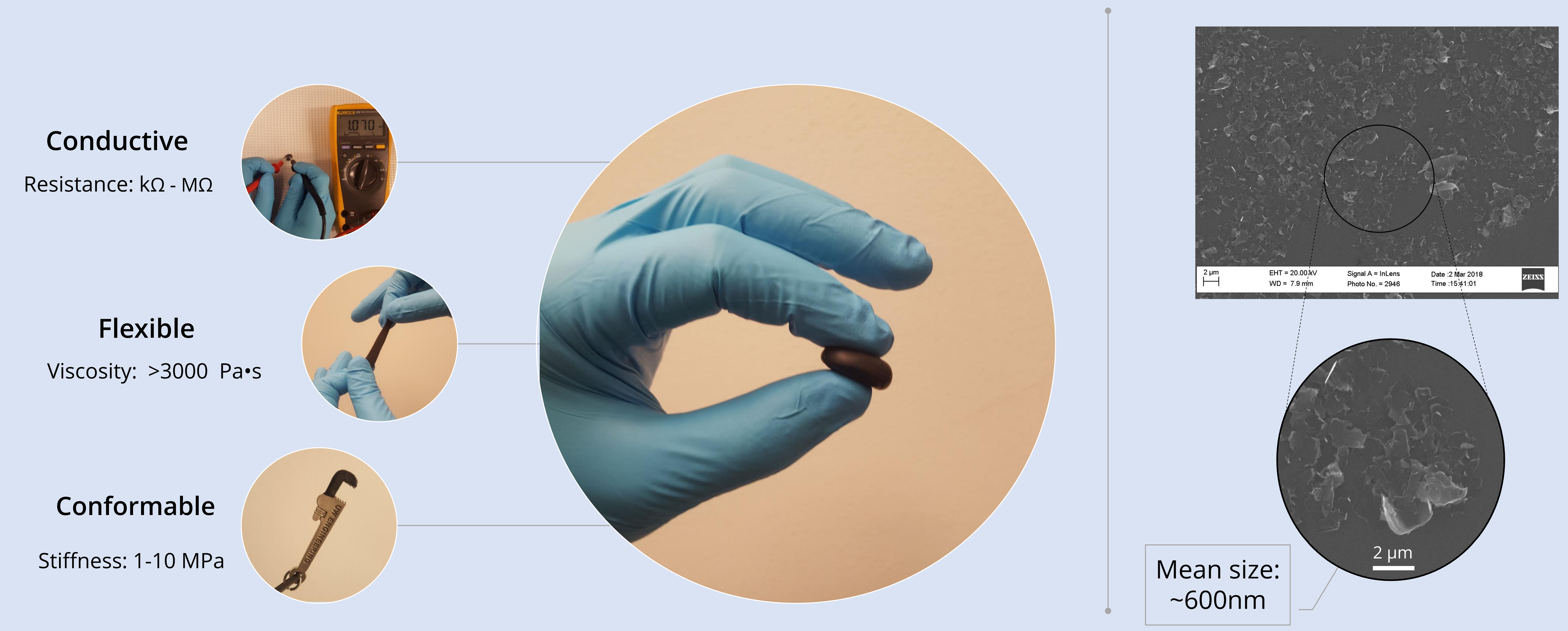
### Putty preparation

- Sylgard 184 **silicone oil** (PDMS) is mixed with finely ground **boric acid**
- Stirring under high heat causes thermal cleavage of siloxane bonds
- Boric acid forms **reversible crosslinks** with terminated bonds forming pristine viscoelastic white putty
- Putty (~2 g) dissolved in 50 -100 mL of chloroform + graphene solution (~10 mg/mL) then mixed & sonicated
- Chloroform allowed to evaporate leaving a black conductive putty with variable resistance
- Stock putty mixed with pristine putty to create samples with varied volume fractions



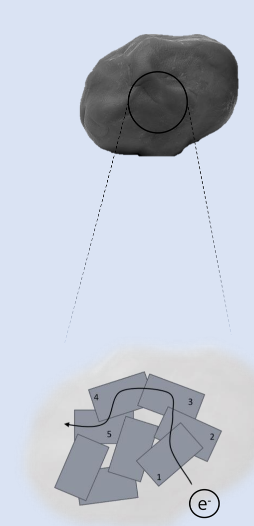

## Results

### Material Characterization



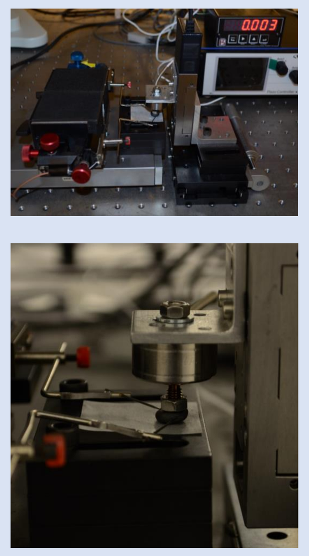

### Mechanism

- Impact can cause graphene network deformation resulting in an **increase** in overall resistance then relaxation as network is repaired
- However, for very thin sheets network is compressed and resistance **decreases**

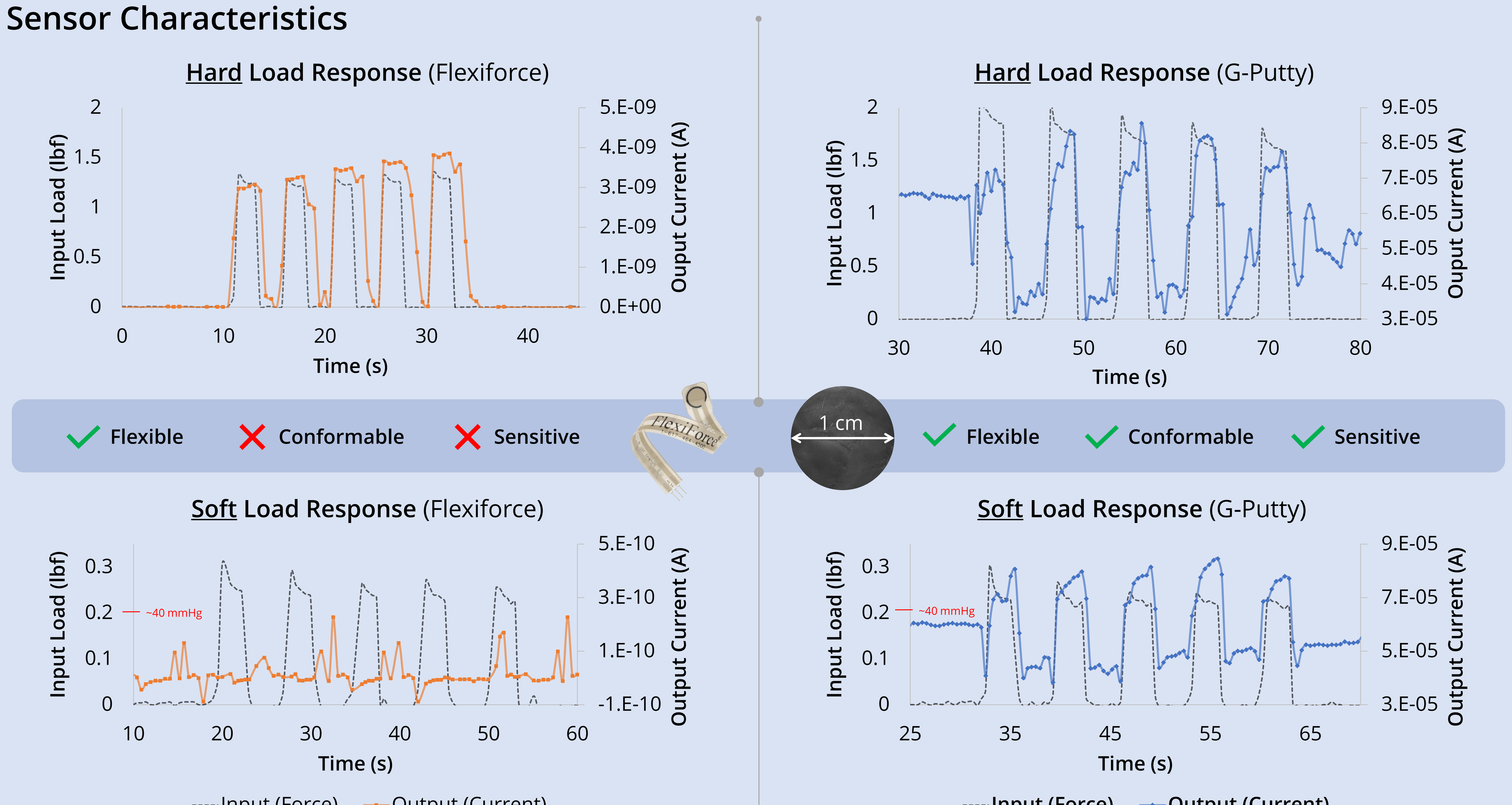


### Measurement Setup

- Piezoelectric load tester applies uniform normal force to active surface of sensors; precision power supply/DMM measures current for a fixed voltage
- Hardware interfaced with LabVIEW software for automatic data acquisition



### Sensor Characteristics




**Comparison sensor** (PFS, piezoresistive)

**Putty sensor** (thin circular disk)

## Limitations

- Trade off between sensor **stiffness** & **resistivity**
- Relaxation makes it difficult to obtain long term measurements without additional digital signal processing (DSP)
- Response behavior depends heavily on morphology, and sensor preparation (i.e. graphene loading factor)

## Conclusion

- Successfully resolved pressures as low as **40 mmHg**
- Sensor was **flexible**, **conformable**, and **sensitive**
- Sensing performance extremely sensitive to loading factor making it versatile but also potentially imprecise
- Graphene preparation (72 hr exfoliation) requires significant time investment, prone to overheating
- Relatively low cost to create functional sensor
- Using this putty as a heart sensor would require some extra data processing, careful consideration, and special equipment


- Reconstructed signal compatible with machine learning classifiers for use in short-term arrhythmia diagnoses

## Acknowledgments

- Professor **Vivek Maheshwari** for lending his expertise and offering us his lab space and equipment for tests
- **Velocity** for allowing us to use their equipment
- **Dr. Coleman** and his team at Trinity College Dublin for being the first to demonstrate the potential for this material and providing help when needed

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