Highly stretchable and comformable conductors for on-skin multimodal sensing

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Motivation

► **Multimodal on-skin monitoring of physiological signals**
- Applications in healthcare, human-machine interfacing, robotics, and prostheses
- Easy-to-apply, stretchable and skin-conforming sensor networks

► **State of the art sensors**
- Consumable sensors: limited signal quality, not medically certified
- Medical sensors: single use or expensive; inefficient production
- Lithography microfabrication, electrode sputtering or chemical

► **We propose**
- intelligent stretchable conductors exhibiting **tunable electrical conductivities** and **surface morphologies**
- considerably increased **material and energy efficient** production
- reusable, multimodal sensing
- using **one sensor for multiple bio-signal** acquisition tasks

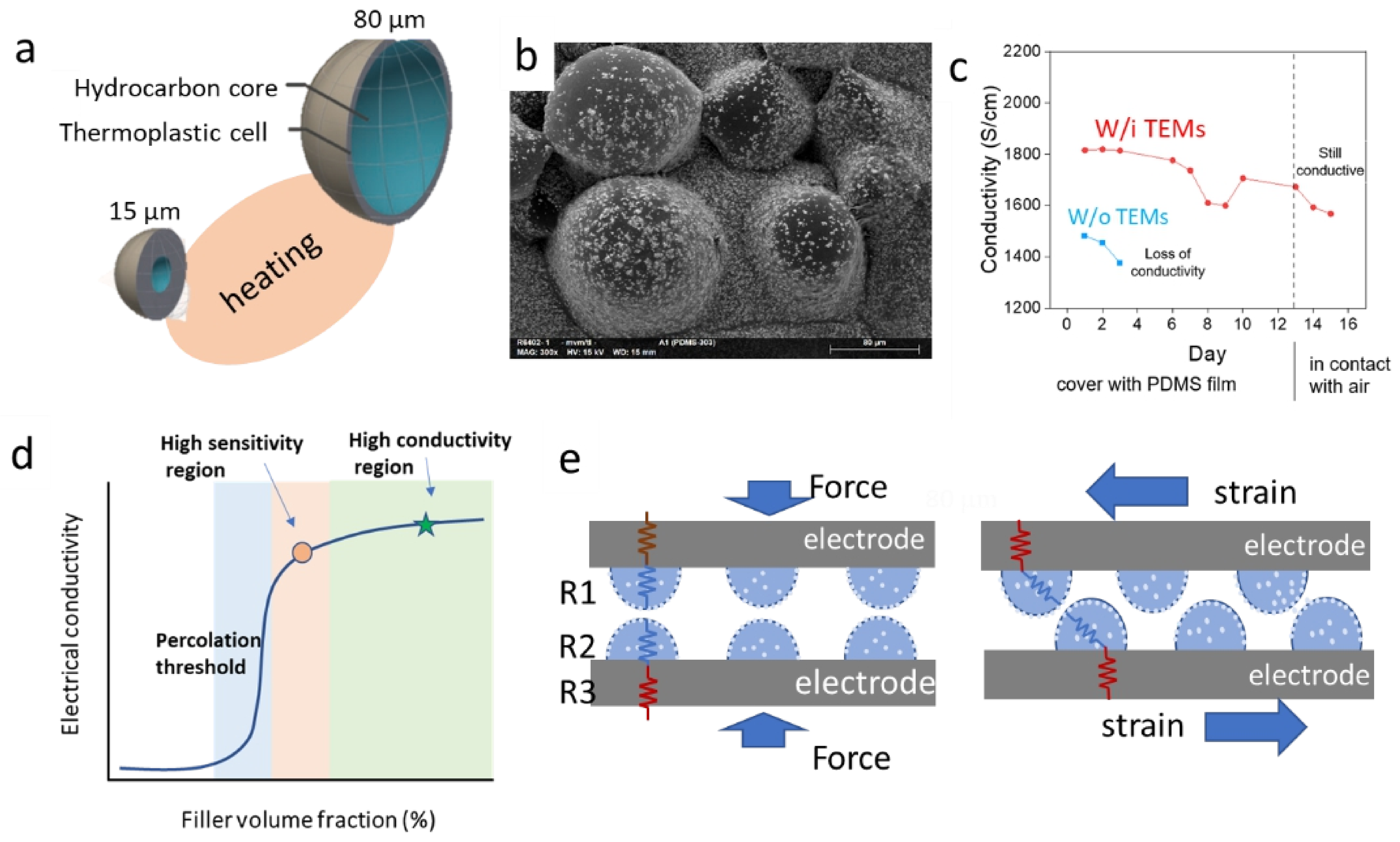

Figure 1: a) mechanism of TEMs. b) SEM of TEMs in Ag-PDMS. c) comparison of electrical conductivities between Ag-PDMS with TEMs and without TEMs. d) sensitive region and high conductive region in percolation map. e) hierarchical design of multimodal sensors.

Aims

► **1) Develop 2 types of stretchable and conformable Ag-PDMS leveraging thermable exbandable microspheres (TEMs)**
- Type A: **highly conductive** for dry electrodes (electrophysiology)
  high filler region (star sign in Figure 1d)
- Type B: **highly sensitive** for pressure / strain sensing (blood pressure, respiration effort above percolation threshold (sphere sign in Figure 1d)

► **2) Prototyping biosignal sensors for the 2 Ag-PDMS materials**
- Multimodal sensors with **hierarchical 3D semi-dome structure** (Figure 1e)
- Exposed dome: electrophysiology (EEG, ECG, EMG) sensor + hierarchical semi-dome: responsive to pressure / strain (respiration effort)

► **3) On-skin testing, validation and multimodal data decomposition**
- Sensor **evaluation in real-world** conditions (reliability, accuracy, long-term use)
- Sensor optimization (shape and mechanical conformability)
- Proof-of-principle **decomposition of multimodal bio-signals**

Green electronics

„Energy-efficient computing" + „Intelligent Materials"

► **1) Relevance & thematic coverage**
- **Material & energy saving** (production, multimodal)
- **Long-time stable & reusable** intelligent materials
- **Energy-efficient** multimodal **signal computing**

► **2) Scientific excellence**
- **Novel concept of adopting microspheres** to tune the conductor morphology
- **Hierarchical** structural design
- Multimodal **mechanical and electrical sensing**

► **3) Strategic perspective**
- Initial project with planned **follow-up DFG proposal**
- **Transfer projects** with medical industry
- Potential for **multiple technology patents**

Work packages and interdisciplinary approach

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Material science, chemical + mechanical + electrical characterization, prototyping and production considerations

WP1: Ink Formulation & Characterization
- Material selection and characterization
- Capillary suspension concept
- Ag and PDMS parameter optimization
- TEM concentration effect investigation

Year 1-2

WP2: Sensor prototyping
- 3D additive manufacturing
- Hierarchical foamy structure
- Self-adhesive stretchable circuits
- Lab tests and optimization

Year 2-3

WP3: On-skin testing and signal processing
- Validation and signal characterization
- Physical phantoms + on-skin testing
- Motion and long-term applicability
- Multimodal signal decomposition

Year 3-4

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Application requirements, medical characteristics and durability, signal quality assessment, validation and signal processing

Prior work and references

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