Silicone based sensors and actuators for medical diagnosis

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The Fraunhofer Society at a glance

- Largest organisation for applied research in Europe
- 69 research institutes in Germany
- Appr. 24,000 staff, in majority engineers and natural scientists
- Budget 2016:
  - 2.1 Mrd. € in total
  - 1.9 Mrd. € by contracted research
  - 70 % by industrial projects and publically founded projects
  - 30 % basic financing by the federal state and federal countries (90 : 10)
Material-based solutions

- **Materials Chemistry**
  - Inorganic Sol-gel-materials
  - Hybrid materials
  - Barrier coatings
  - Particles

- **Application Technology**
  - Micro-optics/Electronics
  - Specialty glass
  - Dental/Micromedicine

- **Services**
  - Applied Analytics
  - Device Development
  - Cultural Heritage

- **Center for Applied Electrochemistry**
  - Battery materials and components
  - Testing
  - Post mortem analysis

- **Center Smart Materials**
  - Adaptive Materials
  - Sensors
  - Energy harvesting

- **Fraunhofer-Center HTL**
  - High temperature lightweight materials, energy efficient heat treatment
  - Bayreuth

- **Project Group IWKS**
  - Materials recycling, substitution, and resource strategies
  - Alzenau/Hanau

415 Employees (2016)
29.5 Mio € Budget (2016), including 21.7 Mio € venue from contract research
approx. 10,000 m² labs and technical space
5 sites centrally located within Germany
Dielectric elastomers: “smart rubber“

- Dielectric elastomer sensors (DES) consist of a very elastic elastomer film (silicone), coated on both sides with highly elastic electrodes (carbon black, graphite, metal particles)

- Highly stretchable (up to 100 % elongation)

- Soft and flexible characteristic is the basis for the integration into woven or knitted textile fabrics
Processing of Silicone

- Laboratory scale:
  + Compounding
  + Doctor blading
  + Silicone films (single- or multilayer)

- Upscaling:
  + modular slot - die - coating unit for large scale production of thin single- or multi-layer films
  (width up to 0,5 m, length up to 200 m)
  + adjustment of processing parameters:
    pot life, viscosity, curing
  + reduction of material and production costs
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Dielectric Elastomers as Strain Sensors (DES)

- Mechanical deformation (elongation or compression) leads to a reduction of thickness and simultaneously to an increase of surface.
- Electric capacitance as measured parameter increases.
- Applicable to measure breathing or posture on the body or in clothings.
Dielectric Elastomers as Pressure Sensors

Adding a special profile (naps) to the DES increases the sensitivity under compression load.
Textile-integrated elastic sensor for foot pressure measurement

- Development of a foot pressure measurement system for medical application:
  3-dimensional pressure distribution inside a shoe for long-term measurements e.g. diabetic foot syndrome

- Dielectric elastomer sensors are extremely suitable for textile integration: soft and flexible behaviour does not create additional pressure points while wearing the textile
Textile-integrated elastic sensor for foot pressure measurement

Stocking:

- Processing of the highly stretchable stocking on a flat knitting machine

- Properties of the knitted fabric: hard-wearing, flexible, elastic and moisture-regulating
  → highly suitable for the application in clothing, even under strong mechanical stress
  → high wearing comfort

- Pressure sensor integration by gluing, bonding or sewing

- Signal transmission to the flex-board electronics:
  → signal wires: electrically conductive and elastic yarn
  → sewed on the textile by a special machine
Technical data for DES – pressure sensors

- Pressure range 1 - 50 N/cm² (10 – 500 kPa), resolution 0.1 N/cm²
- Response time 20 ms
- Operating temperature range from -40 to +160 °C up to 80 % rel. humidity
- Thickness (~ 0.5 - 1 mm)
- Size 5 to 500 mm²

Gait analysis by two sensors placed on ball and heel

![Graph showing capacitance over time for ball and heel](image-url)
Advantages of textile-integrated silicone sensors

- Thin (1 – 3 mm), flexible, stretchable (up to 100%)
- Chemically stable to: water, washing agent, desinfectant
- Washproof up to 60 °C (tested 15 times in a washing machine)
- Antimicrobial finishing by silver ions possible
- Colouring possible
- Freedom of design, adaptable to body form
- Softness adaptable to the application
- Low cost (~ 1 € / cm²)
Medical applications for textile-integrated elastic sensors

Space resolved pressure sensors in seats / matress, preventing bedsores (bed or wheelchair), Decubitus
Medical applications for textile-integrated elastic sensors

Pressure measuring in gloves, prosthetics, orthosis or bandages prosthesis, grippers

Posture monitoring in ergonomics
Elastic electrodes

- Silicone with conductive particles for electrodes (specific conductivity ~ 0.1 S/cm)
  → thin (0.5 mm) and stretchable (100 %)
  → „softness“ adaptable to the application, no restrictions to (human) mobility
  → dermatologically proven skin compatibility

- Integration of the electrode pads by glueing into the textile guarantee a strong bonding and high wearing comfort

- Elasticity and flexibility of the soft elastomere pads ensure stable long time electrical contact to the skin without contact gel
Silicone electrodes for sensors, actuators and heating

- Monitoring of vital parameters like
  - continuous ECG measurement in clothing
  - measurement of pulse, heart rate variation
  - measurement of electromyogram (EMG) of muscles activity

- Activating of muscles (EMS) or nerves (TENS) for muscle and cardiovascular training

- Heating for rehabilitation and comfort
Medical Sensor Systems & Biosignal Processing

Sensor Integration: Ambient Assisted Living by Fraunhofer IIS

- Electrocardiogram (ECG) electrodes integrated into arm chair
- Measurement of ECG raw data → calculation of secondary parameters (Heart Rate Variation)
- Uniformly distributed pressure sensors:
  → mobility
  → posture
  ⇒ storage into patient record, trend analysis, early prevention
Thank you for your attention!

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