FACULTY Agriculture / Environment / Chemistry

Material Development for Biodegradable Sensors for Monitoring of Temperature, Strain and Humidity

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Motivation and Objectives

- Widespread use of sensors leads to a sharp increase in electronic waste [1]
- Conventional sensor materials are often fossil-based, non-biodegradable and environmentally harmful
- Replacing conventional materials with bio-based and biodegradable materials is crucially needed
- **This study:** Production of resistive galatin-based sensors for the detection of humidity, temperature and bending for timber construction monitoring.

Sensor Design

- Sensitive layer: Crosslinked gelatin derivate (Typ B, Bloom ≥ 220; crosslinker: Tannic Acid; plasticizer: Glycerol; conductive material: Carbon Black [CB])
- Film substrate: Polylactic acid (PLA, thickness 500 µm)
- Improvement of adhesion: Activation of the PLA substrate via electron beam and grafting with 2-hydroxyethyl methacrylate (HEMA) [2]
  - → Improvement achieved (Cross-cut and X-cut tests)
  - → Future studies with alternative grafting agents (Acrylic Acid)

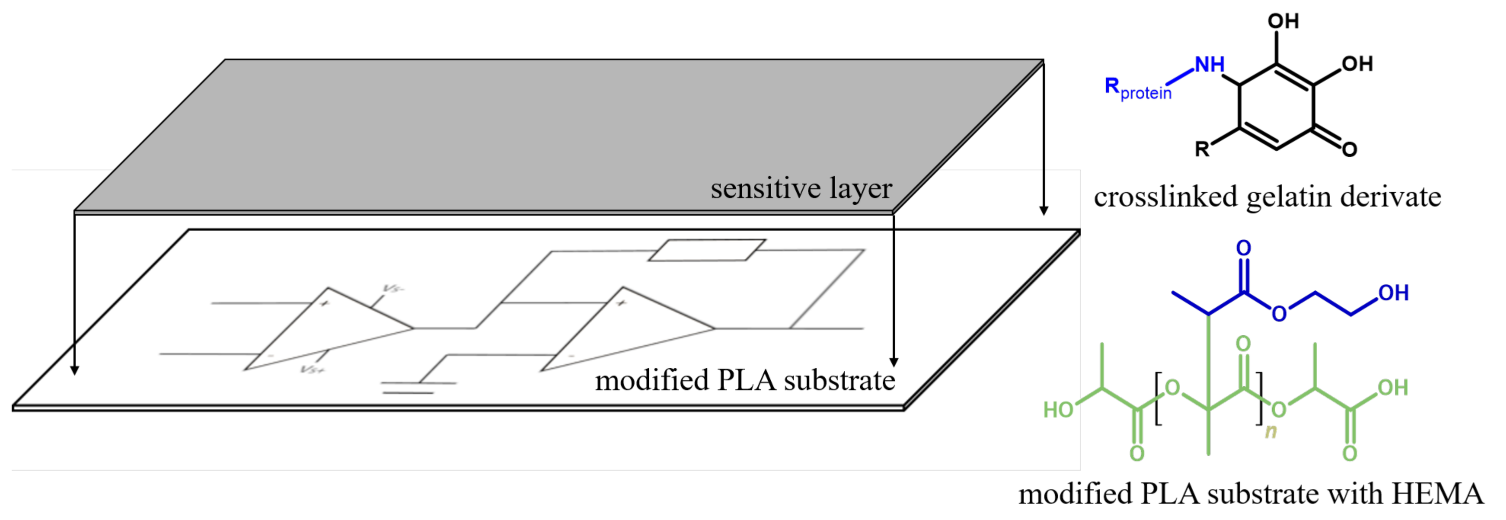


Fig. 1: Scheme of Sensor Design and Applied Materials

Production of Sensitive Layers

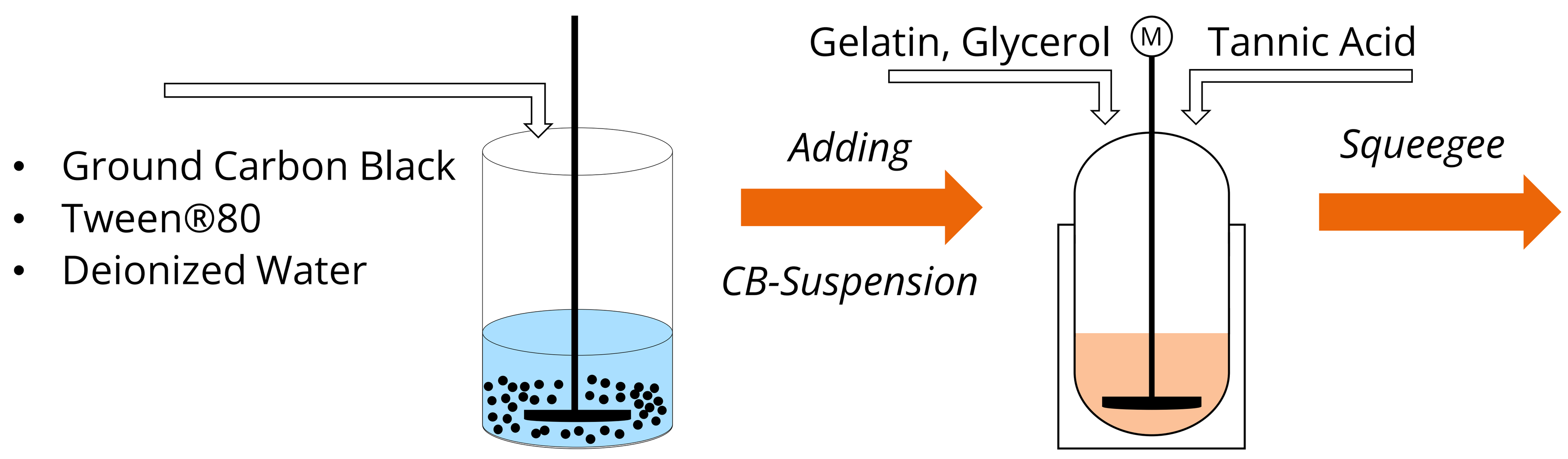
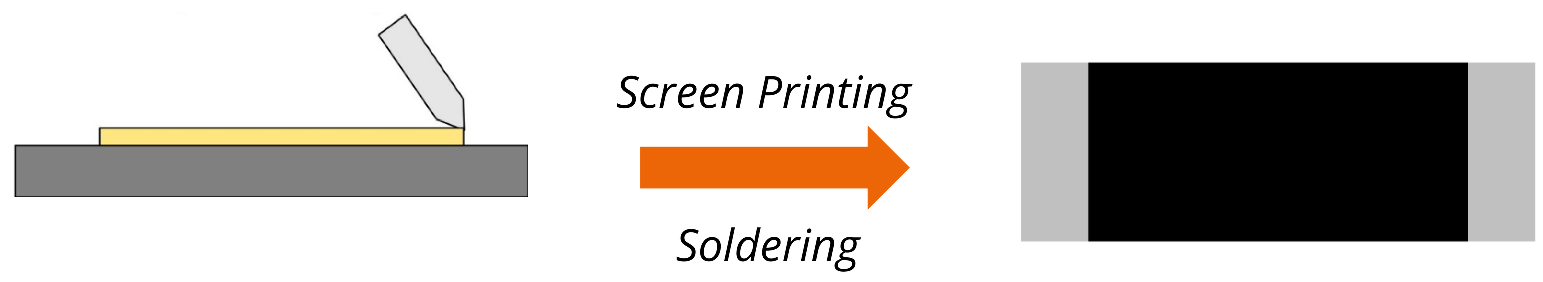


Fig. 2: Production of Gelatin-based Sensitive Layers according to Kettwig et al. [3]



Screen Printing Process / Chemical Soldering

- Sieve: 24 mesh; 140 µm
- Ink: mixture of cellulose and silver microparticles
- Annealing: 32 °C for 24 h
- Attachment copper wire by chemical soldering
- Additional annealing: 32 °C for 24 h

3-Point Bending Test

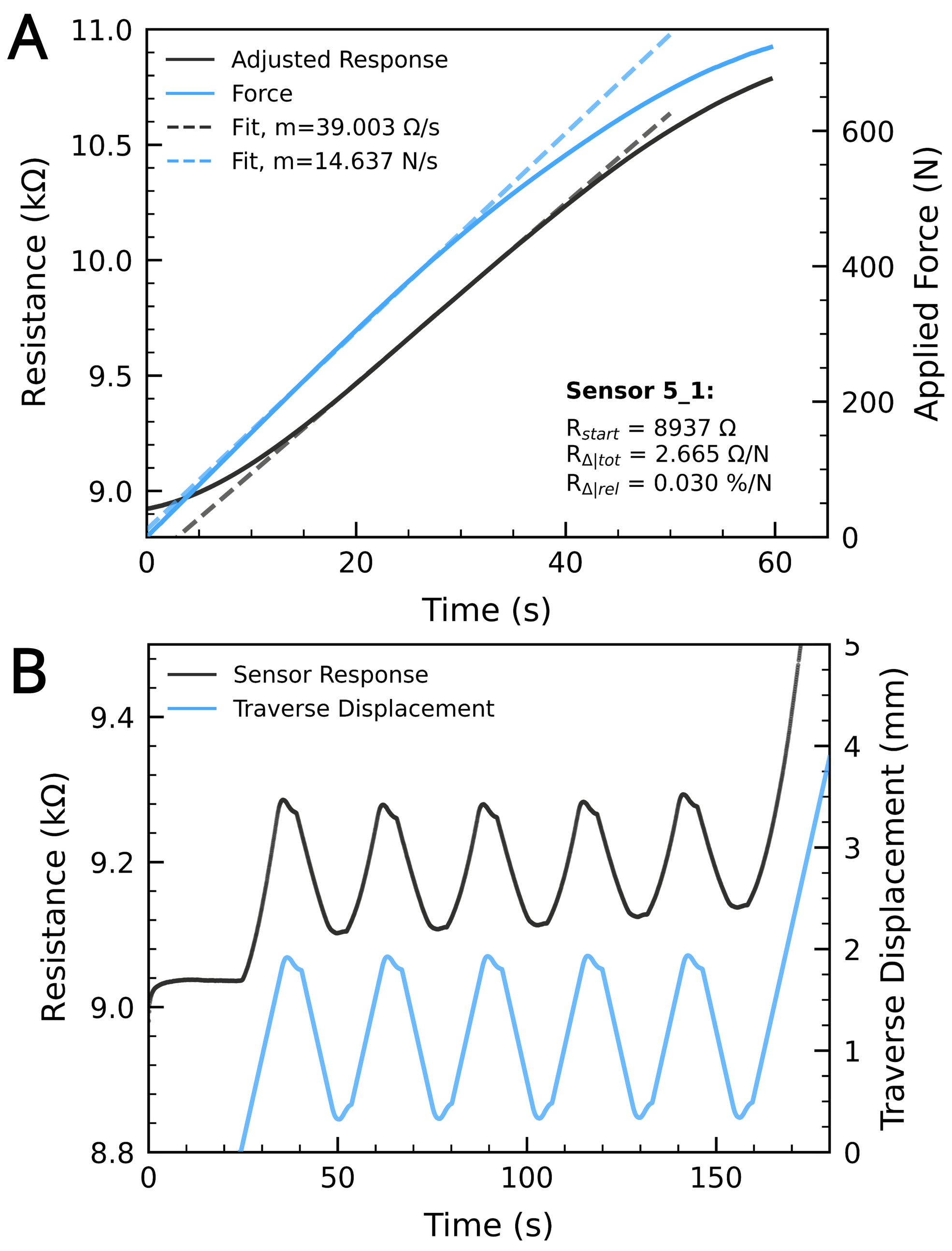


Fig. 3: A) Resistance Response to Change in Force over Time and B) Resistance Response to Traverse Displacement over Time

Temperature Test

Tab. 1: Linear Changes of the Electrical Resistance in Relation to the Temperature

	Sensor 1		Sensor 2		
T_{Ramp} [°C]	*m [Ω/K]*	*R*	*m [Ω/K]*	*R*	*Humidity Change*
35 – 30	13	0.998	13	0.998	-3.8 %
30 – 25	8	0.992	8	0.996	-1.7 %
25 – 20	7	0.995	6	0.995	-0.8 %
20 – 15	7	0.997	6	0.997	-0.7 %
15 – 10	6	0.997	5	0.997	-0.6 %
10 – 5	6	0.999	5	0.998	-0.3 %

m – slope; R - coefficients of determination

- The electrical resistance increases with rising temperature
- Behaviour can be approximately described with a linear function
- Change in humidity has an influence on the resistance

→ Repetition of the experiment with encapsulated sensors

Humidity Test

- Both sensors show a similar response pattern
- Higher humidity values increase the delay until equilibrium is reached

→ Resistance increases at constant humidity

- Slower response to decreasing humidity values than to increasing values

→ Resistance at test end > Resistance at test start

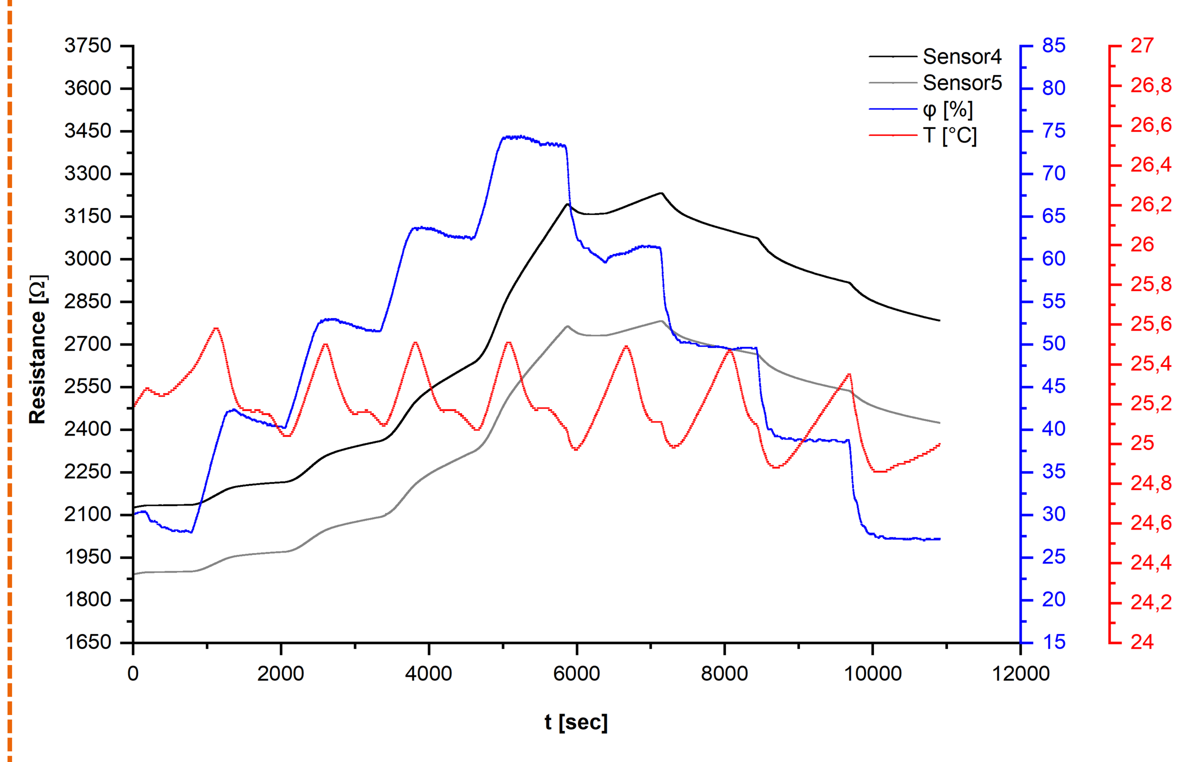


Fig. 4: Resistance Response during the Humidity Ramp (30 – 70 % and 70 – 30 °C, T = 25 °C)

Conclusion

- Improvement of adhesion between PLA and sensitive layer by electron beam activation and grafting with HEMA
- It is possible to detect changes in bending, temperature and humidity with bio-based and bio-degradable gelatin-based sensitive layers
- Thinner and smaller sensitive layers will improve the response time to humidity changes
- Future tests with encapsulated sensors can avoid cross sensitivity between measured parameters and improve the performance of the sensor

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Gefördert durch: Bundesministerium für Wirtschaft und Klimaschutz aufgrund eines Beschlusses des Deutschen Bundestages

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ACKNOWLEDGMENT

This work was funded by the German Federal Ministry for Economic Affairs and Climate Action and the AiF research association (grant number 23086 BR/2). The work was partially supported by the Saxony5 transfer project and funded by the German Federal Ministry of Education and Research (BMBF) and the Joint Science Conference as part of the "Innovative Hochschule" programme. The authors would like to thank Gelita AG for providing the gelatin and the IHD Dresden for the opportunity to use the climate chamber for the humidity tests and for carrying out the 3-point bending test.

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