Piezoresistive Textile Integrated Stretchable Breath Sensor

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Abstract:
The vision of this research is to develop a process which enables seamless integration of electronics and sensors into the mass production of next-generation textile-based wearables. The research is performed within the TEX-hype project (FFG Austria, Nr. 883859 [1]) and will open new possibilities and novel applications for the smart textiles industry. Currently, most smart textile products are available only at prototype level since they require expensive and labor-intense processes that are not scalable, and therefore, cannot be used to produce the required large volumes. Hybrid printed electronics have the ability to solve this problem by using a combination of traditional silicon-based electronic devices, flexible electronic devices and printed systems. The presented work aims to overcome these barriers of manufacturability, by developing a hybrid printed electronic process which can be easily scaled to large areas and which makes use of methods already compatible with the textile industry, namely: multi-layer inkjet printing, pick&place, knitting and embroidery to be able to realize the building blocks of future use-case specific electronic systems for vital sensor data acquisition, data storage, energy management and communication. The system will allow an analysis of remote data, collection of relevant physiological parameters, classification of relevant physiological states incl. prediction and subsequent development of early warning physiological alarms for initiating an appropriate health care system response, including web-based graphic interfaces, respectively mock-ups for the predictive clinical decision support system (CDS).
In this paper, a technology for direct fabrication and integration of strain sensitive sensors onto fabric is presented. Piezoresistive sensors are utilized for monitoring breath rate for medical purposes [2]. However, they are mostly not integrated with electronics into the garment.
The presented fabrication of the flexible breath sensor consists of a fully additive manufactured process involving dispensing of a conductive carbon- and silver-based sensing layer, its encapsulation with a flexible waterborne-TPU layer, and inkjet printing a rigid dielectric island onto a polyamide spandex-based fabric.
The carbon-based sensing layer is printed with ACI materials SE1502 ink and the silver-based sensing layer with ACI materials RD0134A [3]. The TPU encapsulation layer is printed with HAPTIC ink from Huafeng and the dielectric island is printed with Veroclear from Stratasys.
Figures 1 show the corresponding layer stack and the top view of the schematic breath sensor design, with a fully printed semiflexible footprint to connect the read-out integrated circuit, respectively. Figure 2 depicts the physical realization of the textile integrated piezoresistive sensor. Four different materials were tested in order to examine their strain sensitivity.
The sensitivity of the breath sensor was characterized by the magnitude of the change in resistance with respect to the applied strain, which can be expressed as the gage factor. Figures 3 show the characteristic resistance distribution terms of a progressively increasing number of cycles for the 1st generation breath sensor with carbon- and silver-based sensing layers, respectively. The corresponding gage factors for the carbon- and silver-based sensing layer are 3.65 and 4.40. Sensors were characterized in the longitudinal strain of 1%, which corresponds to the normal expansion of the human body in the chest area. The first results are convincing us to develop the sensor further to a fully washable system.

References

[1] "TEX-hype." https://projekte.ffg.at/projekt/3978631 (accessed May 06, 2022).
[2] R. De Fazio, M. Stabile, M. De Vittorio, R. Velázquez, and P. Visconti, "An Overview of Wearable Piezoresistive and Inertial Sensors for Respiration Rate Monitoring," *Electronics*, vol. 10, no. 17, p. 2178, Sep. 2021, doi: 10.3390/electronics10172178.
[3] "Products | ACI Materials." https://www.acimaterials.com/products/ (accessed May 06, 2022).

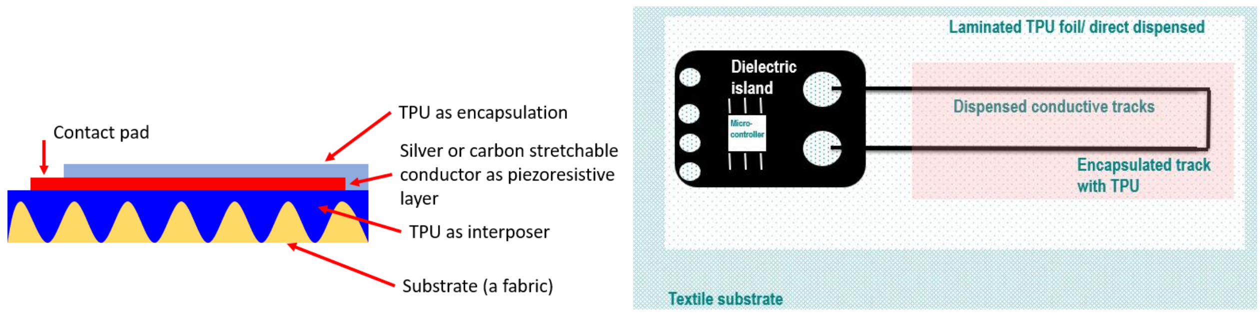

Figure 1: Layer stack of breath sensor (left) Schematic design of breath sensor with dielectric island for fitting read-out electronic integrated circuit (right)

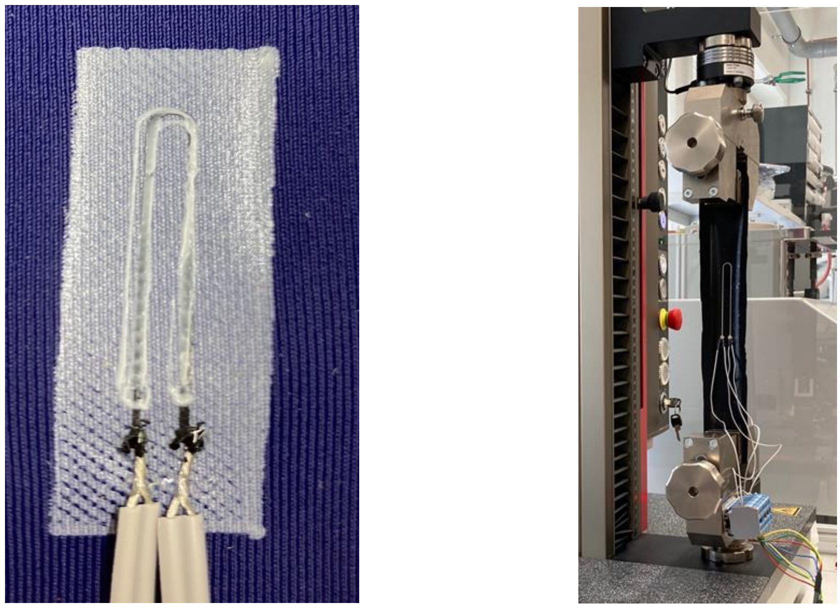

Figure 2: Example of realized textile integrated breath sensor (left), Zwick / Roell equipment of cyclic tensile characterization (right)

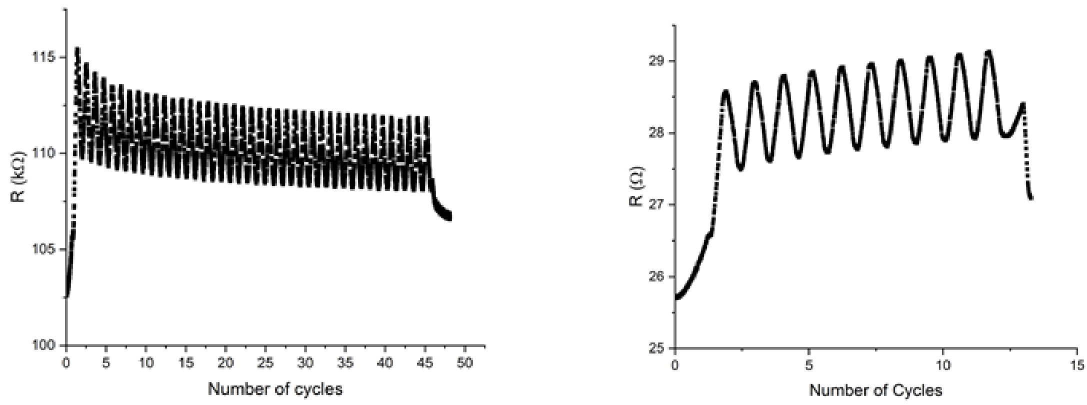

Figure 3: Typical response of carbon (left) and silver (right) piezoresistor under the cycling tests