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DEVELOPMENT OF TEST METHOD FOR THE CHARACTERIZATION OF ELECTRICALLY CONDUCTIVE YARNS FOR INTEGRATION IN SMART TEXTILES

Mareen Warncke[1,a(*)], Philippa Ruth Christine Böhnke[1,2,b], Andrea Gracova[1,c], Andreas Nocke[1,2,d], Chokri Cherif[1,2,e]

[1] Institute of Textile Machinery and High Performance Materials, Technische Universität Dresden, 01069 Dresden, Germany
[2] Centre for Tactile Internet with Human-in-the-Loop (CeTI), Technische Universität Dresden, 01069 Dresden, Germany
[a(*)] *Email:* mareen.warncke@tu-dresden.de
[b] philippa.boehnke@tu-dresden.de; [c] andrea.gracova@mailbox.tu-dresden.de;
[d] andreas.nocke@tu-dresden.de; [e] chokri.cherif@tu-dresden.de

ABSTRACT

The Cluster of Excellence “CENTRE FOR TACTILE INTERNET WITH HUMAN-IN-THE-LOOP (CeTI)” [1] deals with developments and inventions concerning smart devices used in many fields, e.g. medicine and skill learning. For the integration or electrical interconnection of smart components, electrically conductive materials are often integrated into the clothing. To maintain the flexible, textile character of such smart textiles, polymer-based yarns with a metallized coating are mostly used for this purpose. In order to be able to use these yarns both in everyday life situations and in personal protective equipment with high safety requirements, it is necessary to specifically characterize and evaluate the long-term stability of the materials used. Knowledge of the electrical properties under the influence of temperature and moisture is particularly important for clothing worn close to the body, since the stress on the materials due to body and skin temperatures and user perspiration is particularly high here. At present, it is only partly possible to characterize the electrical stability of textile conductors under different application-related climatic conditions using standardized test methods. For this reason, this paper presents a newly developed measurement and test method that makes it possible to evaluate the electrical properties of yarns under defined temperature and humidity influences over a specified period of time. On the basis of different tests, the results of which are also discussed here, the measurement accuracy and repeatability of the method can be proven.

KEYWORDS

Silver-coated yarn, test method, resistance, yarn-characterisation, climate condition, textile sensor.

MATERIALS AND METHODS

Silver-coated yarns. In Table 1 the yarn materials are shortly presented due to their characteristics given by the producer. Electrically conductive yarns are used for the integration in smart textiles in terms of different smart applications, e.g. gloves or functional underwear. All yarns are PA 6.6 based and coated with silver.

Table 1. Electrically conductive yarns used for measurement method review.

PRODUCER	NAME	COMPOSITION	LINEAR DENSITY [DTEX]	RESISTANCE [Ω M^{-1}]
MADEIRA GARNFABRIK	HC40	PA 6.6	290	< 300
AMANN & SÖHNE GMBH & CO. KG	Silver-tech $^{+}$100	PA 6.6	330	< 200

Resistance measurement. To determine the resistance to quantify and assess the change in electrical resistance of electrically conductive yarns a four-wire-resistance measurement according to DIN EN 16812 [2] is used. The test procedure as well as the test setup can be found in this standard. The four-wire-resistance measuring station consists of a precision multimeter Keithley DAQ 6510 from Tektronix GmbH (Köln, Germany) to determine the measured values and a high performance calculator for data storage (Figure 1). To measure the specimens, they are fixed via four KELVIN clamps with a distance of 250 mm to each other, which also corresponds to the sample length (Figure 2a and 2b).

Figure 1. Precision multimeter Keithley DAQ 6510 with high performance calculator.

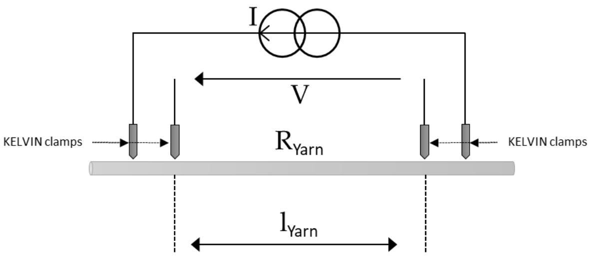

Figure 2a. Schematic measurement setup with fixed yarns in four KELVIN clamps.

Figure 2b. Fixed yarns in four KELVIN clamps.

Climate condition simulation. To simulate different applications of smart textiles with integrated electrically conductive yarns in terms of temperature and humidity, a climatic test chamber COMPACT - DY110 (TC) from Angelantoni Test Technologies S.r.l. (Massa Martana (Pg), Italy) is used (Figure 3). With this climatic chamber it is possible to simulate climatic conditions within a temperature range of -70°C up to +180°C and a humidity range of 10 to 95%. Therefor all various applications of smart textiles can be simulated.

Figure 3. Climatic test chamber COMPACT - DY110 (TC).

RESULTS AND DISCUSSION

First, the yarns were measured without climatic stress with the four-wire-resistance measuring station in order to check the functionality of the specifically manufactured frame, the KELVIN clamps, the measurement software, and to determine the basic resistance of the yarns. For this purpose, the measurement setup described in Figures 1 - 3 was used. The experimental setup is developed to measure the resistance up to 15 samples simultaneously with a sampling rate of 0.016 Hz over a given time period. A voltage is applied through the constant current source in the precision multimeter and the resistance in the measuring device is determined via the ohmic law. The measured values are transferred to the measuring computer and stored using the device's own software. Table 2 shows the statistical values from 20 individual measurements for the example yarns HC40 and Silver-tech +100.

Table 2. Statistical values for the example yarns HC40 and Silver-tech +100 before climatic stress.

PRODUCER	NAME	AVARAGE RESISTANCE [Ω M-1]	STANDARD DEVIATION	COEFFICIENT OF VARIATION [%]
MADEIRA GARNFABRIK	HC40	297	6.45	0.02
AMANN & SÖHNE GMBH & CO. KG	Silver-tech +100	289	3.35	0.01

Subsequently, the yarns were transferred to the climatic chamber using the developed frame with the KELVIN clamps. Over a period of 240 h at climatic conditions of 32°C and a relative humidity of 95%, the resistance was continuously measured at a sampling rate of 0.016 Hz. The parameters presented and selected here were intended to simulate the wearing situation of clothing items close to the body, such as a glove or underwear under high physical activity. The period of 240 h corresponds to a usage period of 30 days with a wearing time of 8 h per day. Figure 4 and 5 show the results of the test using the climate chamber to simulate realistic conditions for smart textiles worn close to the body.

Due to the transfer of the yarns into the 32°C climatic chamber, the resistance increases already at the beginning of the measurement by 2% for HC40 and by 4% for Silver-tech +100. These differences result from the temperature dependence of the yarn resistances, which increase at higher temperatures. Consequently, the measurement shows (Figure 4 and 5) also that there are large differences between the initial resistances at the beginning of the climatic stress and the resistance of the climatically stressed yarns after 30d of simulated use (240 h measuring time). The resistances under climatic stress increased by 11% for HC40 and by 31% for Silver-tech +100 compared to the initial resistances. This increase in resistance is the result of oxidized silver by high humidity and oxygen r on the yarn surface [3], which reduces the electrical conductivity because less electrically conductive material is available.

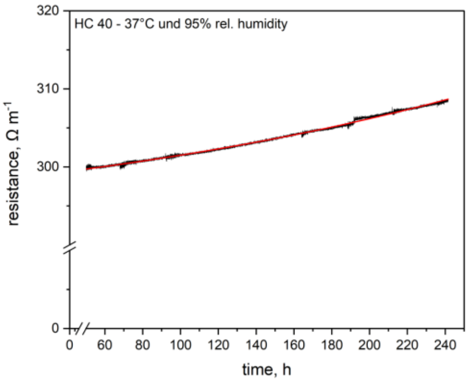

Figure 4. Resistance of HC40 silver-coated yarn during 240 h under climatic stress.

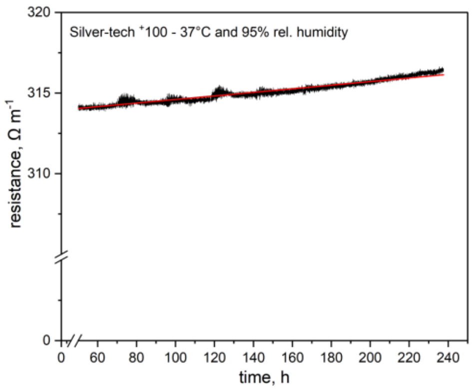

Figure 5. Resistance of Silver-tech +100 silver-coated yarn during 240 h under climatic stress.

After the climatic stress, the resistance measurement were carried out under the same conditions as for the initial measurement again. The Table 3 shows the statistical values from 20 individual measurements after climatic stress.

Table 3. Statistical values for the example yarns HC40 and Silver-tech +100 after climatic stress.

PRODUCER	NAME	AVARAGE RESISTANCE [Ω M-1]	STANDARD DEVIATION	COEFFICIENT OF VARIATION [%]
MADEIRA GARNFABRIK	HC40	311	3.38	0.005
AMANN & SÖHNE GMBH & CO. KG	Silver-tech +100	325	3.49	0.01

The resistances are further increased by 2% and by 4%, respectively. Consequently, the electrical conductivity differs depending on the prevailing environmental conditions. Because high humidity and temperature reduce the electrically conductive function of the silver-coated yarn irreversible.

The test method makes it possible to simulate any environmental condition in order to be able to characterize the change in properties of the yarns.

CONCLUSION

In summary, the self-developed test method for the characterisation of the electrically behaviour of conductive yarns, some of which are used in smart textiles, was used to simulate different application-specific environmental conditions, such as the conditions of clothing worn close to the body. It was proven that the prevailing environmental conditions affect the electrical properties. This measurement method can be applied primarily to the electrical conceptualization and design of smart clothing. Furthermore, this measurement method could be validated for different conductive yarns and the functionality could be proven. The measurement method can be adapted to all conductive materials that are thread-like in nature.

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REFERENCES

[1] Technische Universität Dresden, Centre for Tectile Internet with Human-in the-loop: Deutsche Telekom Professur für Kommunikationsnetze. https://www.ceti.one/ 2022.
[2] DIN EN 16812:2016, Textilien und textile Erzeugnisse- Elektrisch leitfähige Textilien – Bestimmung des linearen elektrischen Widerstands von Leiterbahnen.
[3] Zheludkevich M.L., Gusakov A.G., Voropaev A.G. et al. (2004) Oxidation of Silver by Atomic Oxygen, Oxidation of Metals 61, 39–48. doi:10.1023/B:OXID.0000016275.96500.2.