E-textile handling: Should I treat my e-textile as a normal garment

Dr. Abiodun Komolafe

University of Southampton

aok1g15@soton.ac.uk

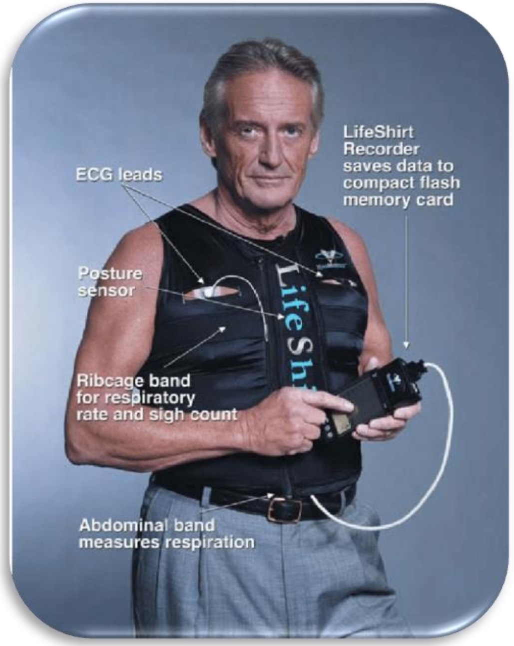
E-textile Network Webinar

20th August 2021

Overview

- Brief overview of e-textiles
- Research driven e-textiles
- Industry driven e-textiles
- E-textile transition from research to industry
- Key areas of e-textile design
- Electrical interconnects and bonded joints
- Bending and washing effects
- Conclusion

E-textiles what are they?



LifeShirt by Vivometrics (2001)

Bulky Components added to outside

ICD+ suit by Levi and Phillips Electronics (2003)

Bulky Components added to outside

LED Jacket for singer Will.I.Am by Moritz Waldemeyer (2011)

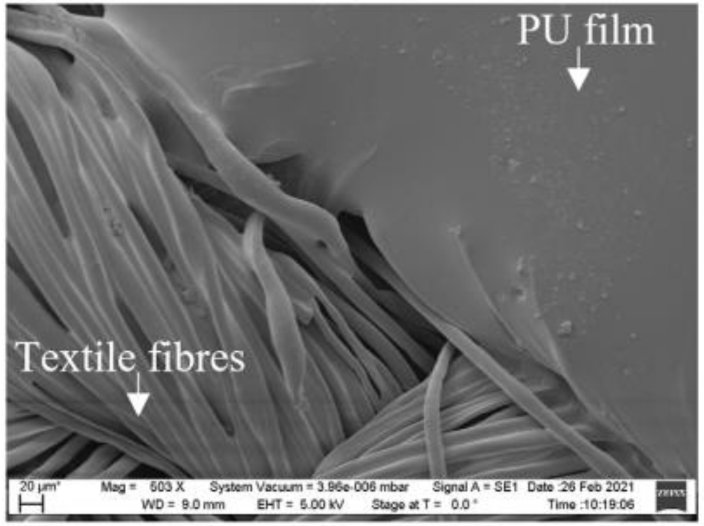
Inflexible circuitry added to jacket

Bioman+ heart rate monitoring shirt by AiQ (2017)

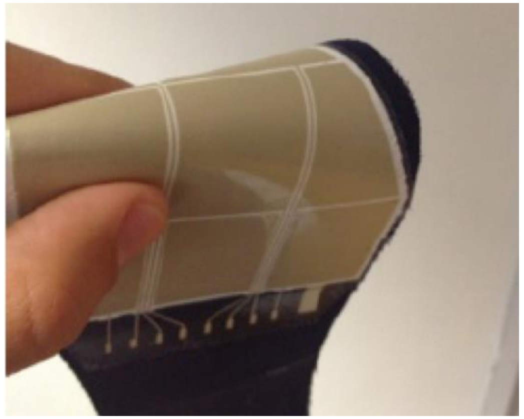
Inflexible circuitry with integrated electrodes

Research driven e-textiles

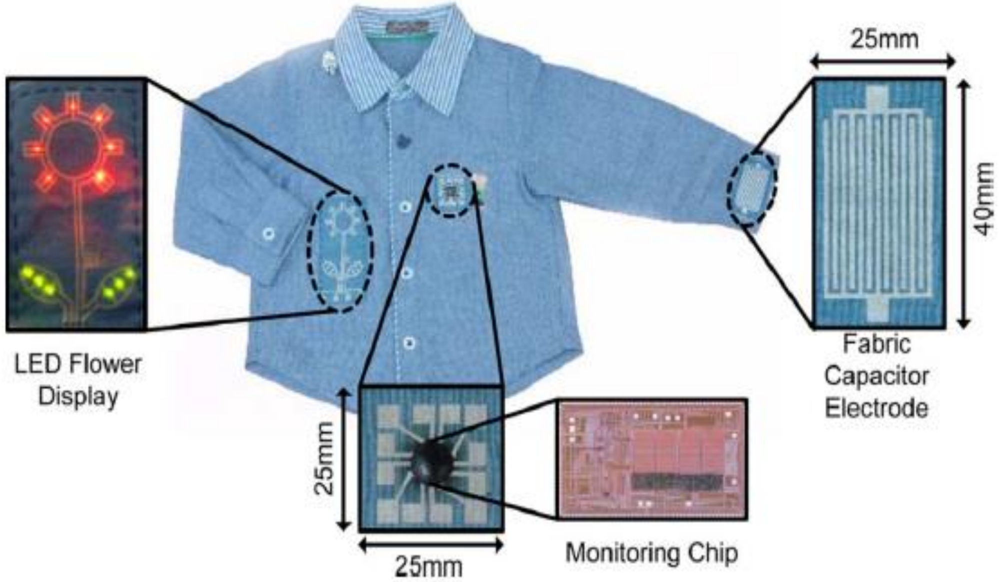
- Based on conductive and functional inks



SEM image of textile and printed smoothing layer [1]



Piezoelectric shoe insole, UoS [2]



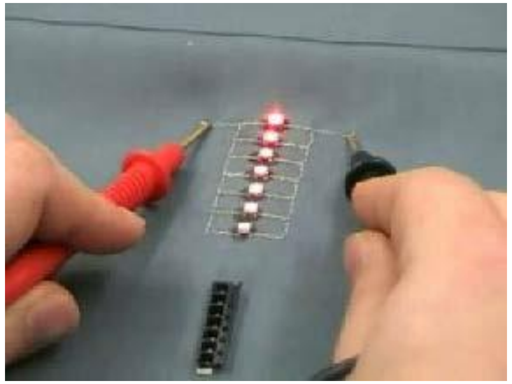
Planar-fashionable circuit board with capacitive sensor, chip and LED display in 2010 based on screen printed conductive films [4]

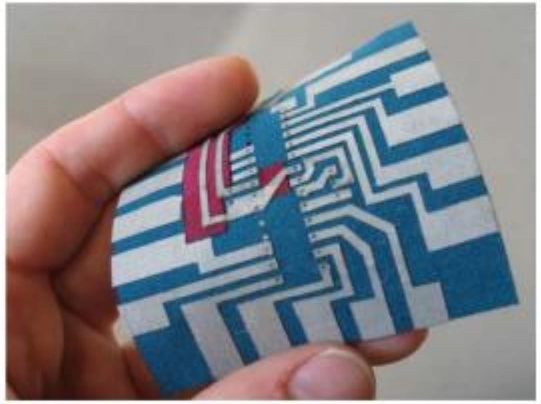
Printed Watch Display on Fabric (UoS) [3]

Research driven e-textiles

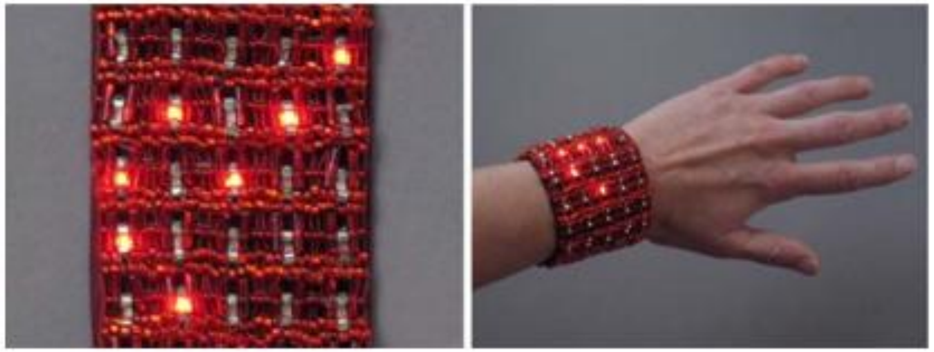
- Based on conductive yarns and fabrics – weaving, knitting, embroidery etc

Embroidered ECG shirt
with silver yarns [5]





Textile circuit with heat pressed
conductive fabric [6]

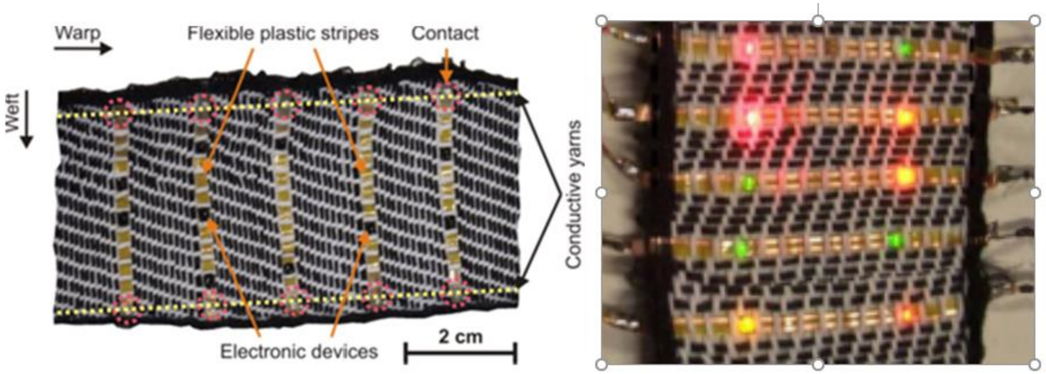


Knitted LED bracelet [6]

Woven Carbon nanotube yarns [7]

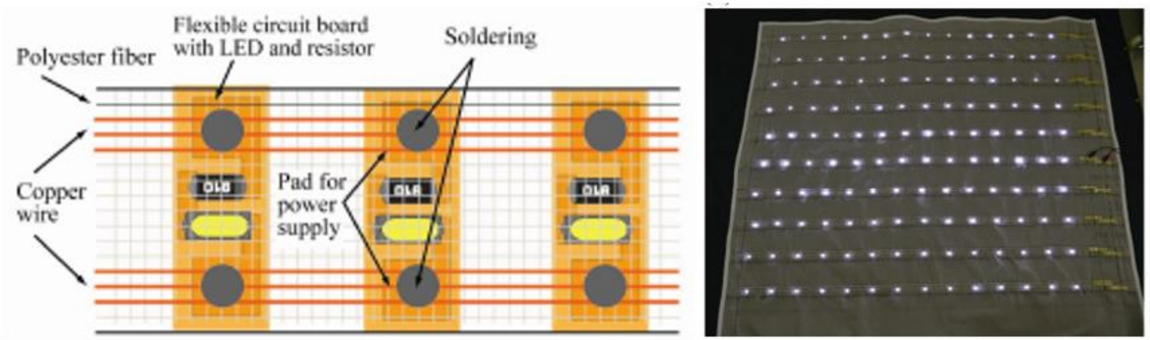
Research driven e-textiles

- Based on flexible filaments

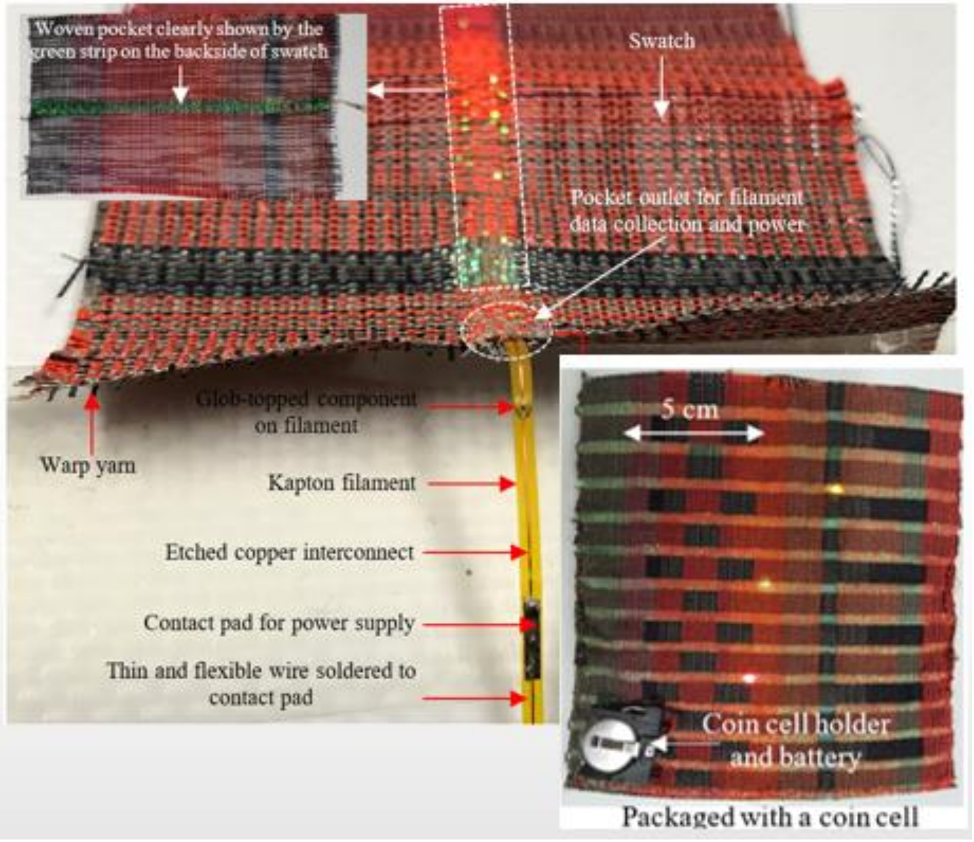


Woven e-fibres for humidity sensing and LED circuits [8]

E



An functional array of LED plastic strips woven on textiles [9]



Woven flexible temperature sensors and LEDs UoS [10]

Recent e-textile products from the industry

Haptic Glove (Bebop Sensors)

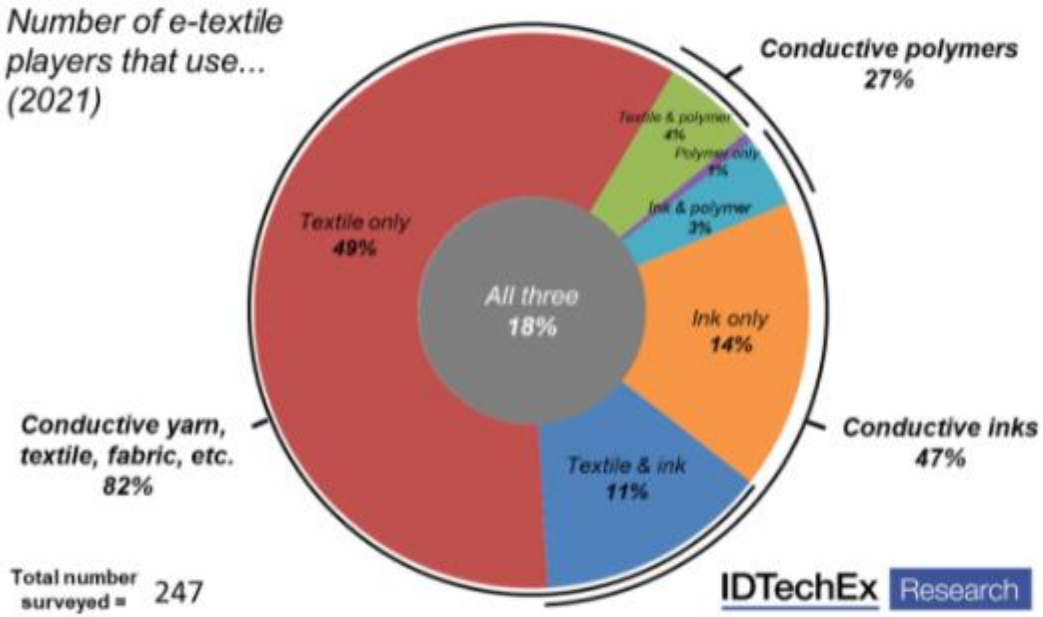
Google and Levi Jacquard

Polar seal heated Vest

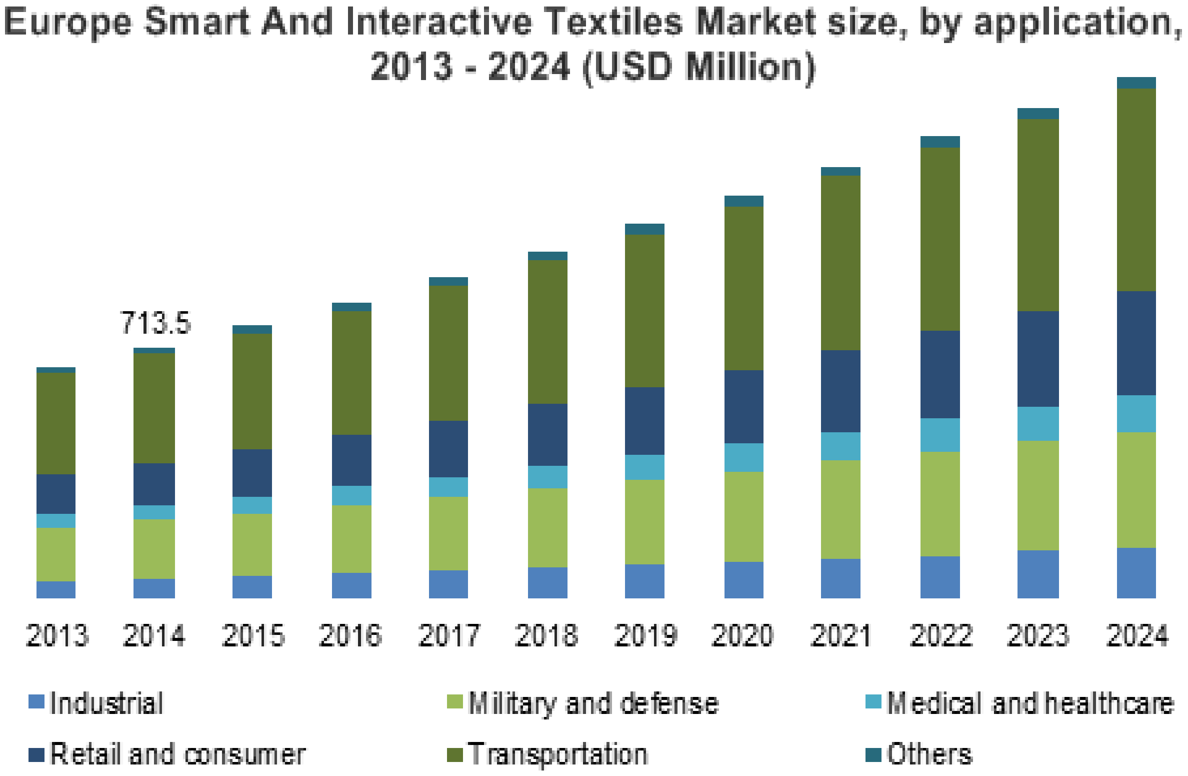
Loomia multifunctional patch

Transition from research to consumers

- Market estimates are very high (Plethora of potential applications but transition is still slow
- A plethora of potential applications but transition to the consumer still slow



Market survey by IDTechEx of 247 commercial partners [2021]



Market survey by Global Market Insight [2021]

Various forms of textile handling

Treat with care

Draping, folding and twisting

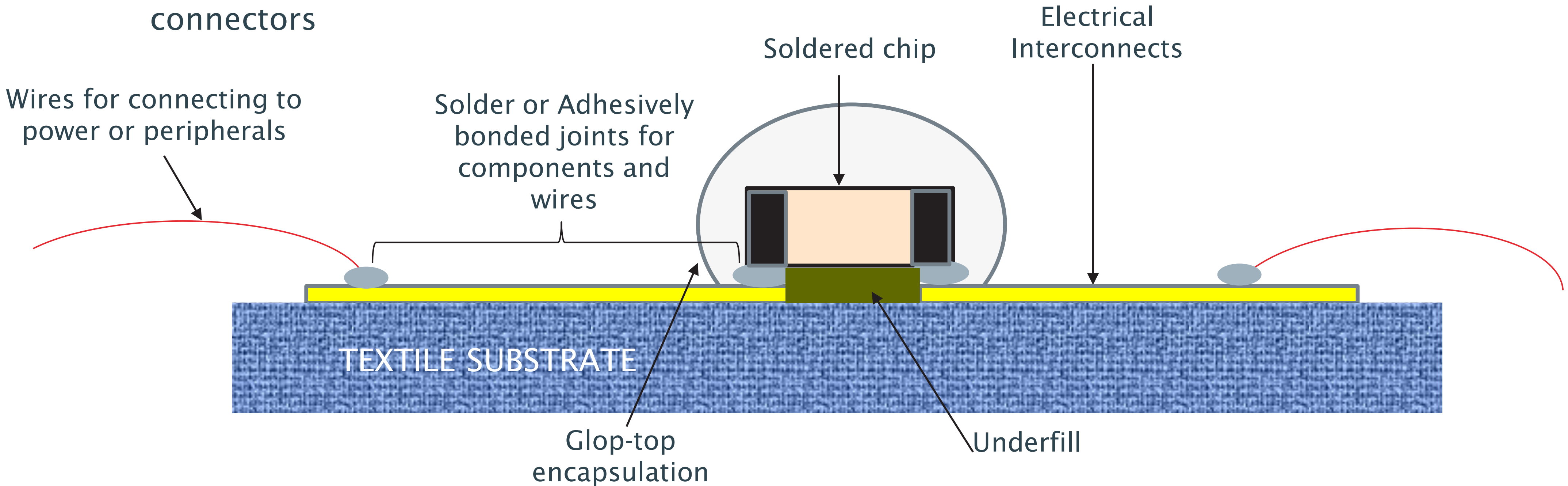
Hand washing

Abrasion / bending/ Stretching

Washing machine

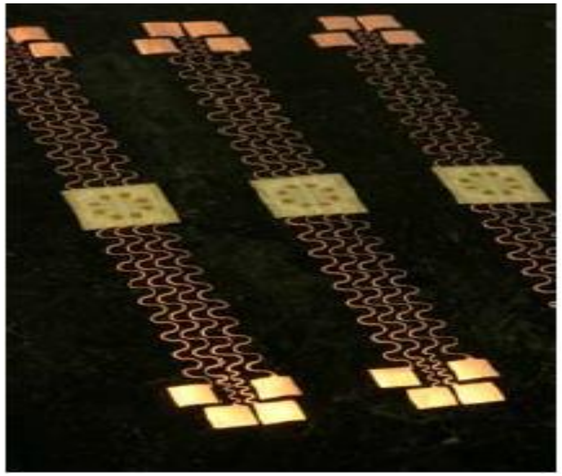
Key areas in e-textile circuit design

- Two important areas to consider in e-textiles
  - Electrical interconnects
    - Must be durable against mechanical stresses
  - Bonded joints
    - Regions linking the electrical interconnects with the required electronics, wires and connectors

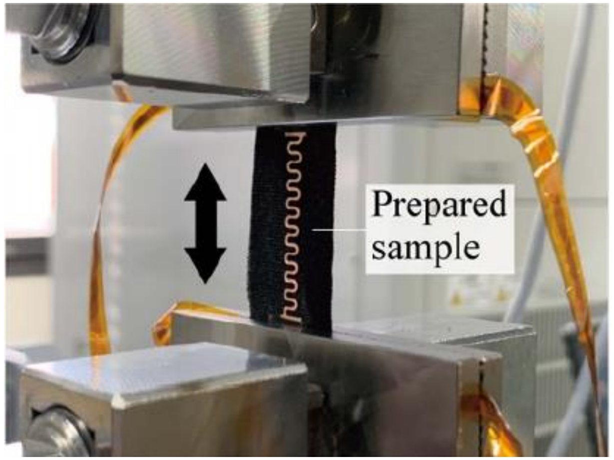


Stretchable interconnects: Serpentine Conductors

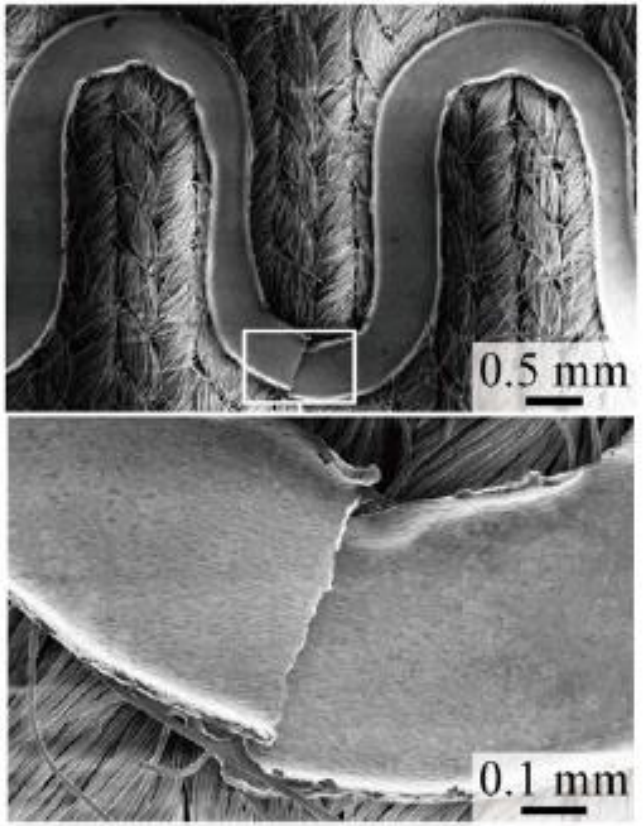
- Enhances the stretching of interconnects
  - Can survive up to 10,000 repeated tension and compression cycles for up to 50 % strain
- Not durable against bending or washing stresses
  - Up to 90 % failure rate after nine washes



Serpentine interconnects [11]



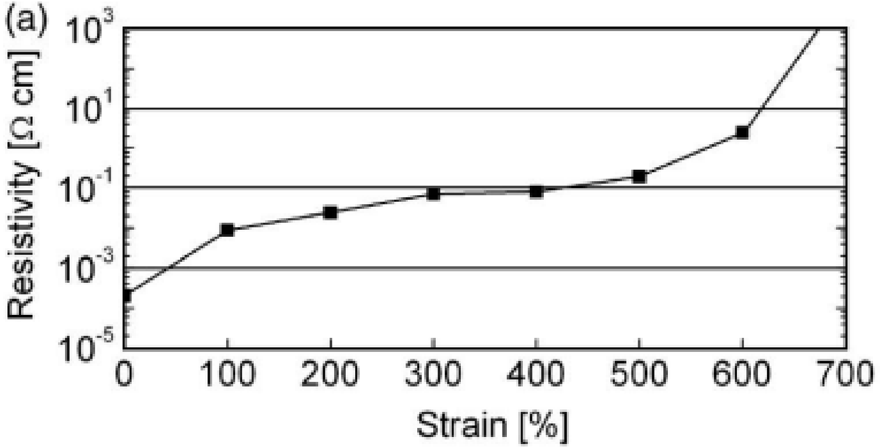
Tensile testing of laminated serpentine[12]



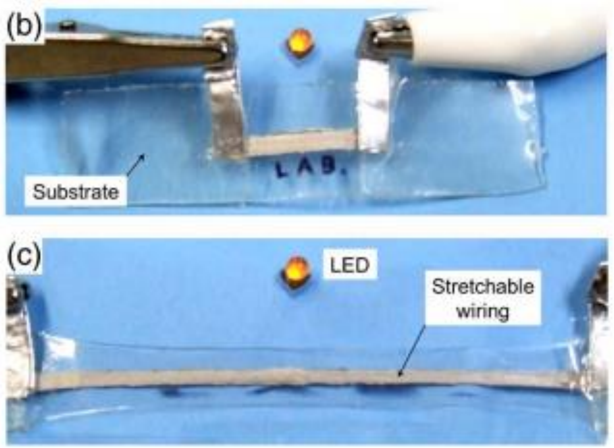
SEM images of crack along interconnect [12]

Stretchable interconnect: Elastic conductors

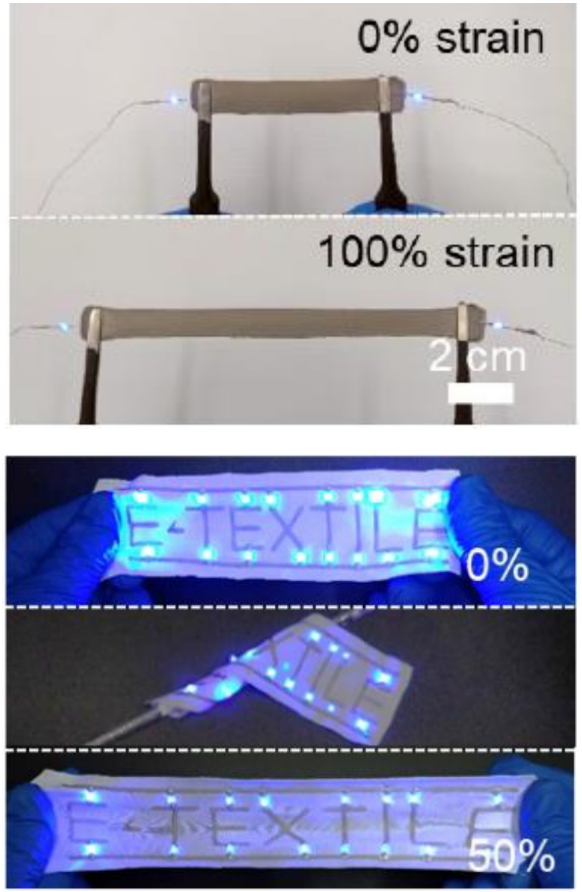
- Combining conductive particles such as AgNw, CNTs with elastomeric materials such as silicone and thermoplastic polyurethane
- Allow for more than 100 % strain in the conductor and more 20 cycles of washing without degrading performance
- Conductivity suitable for some sensing applications



Serpentine interconnects [13]



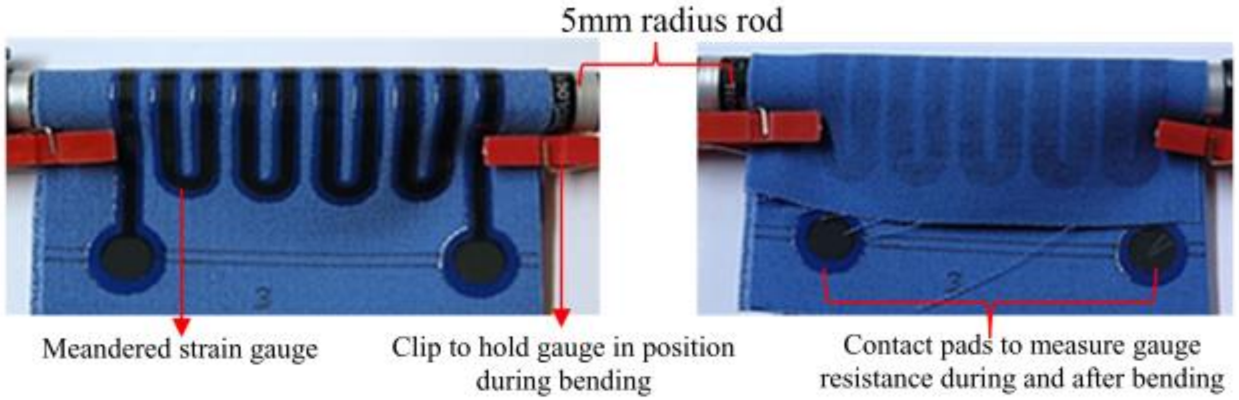
Conductors based on microsized silver flakes and polyurethane [13]

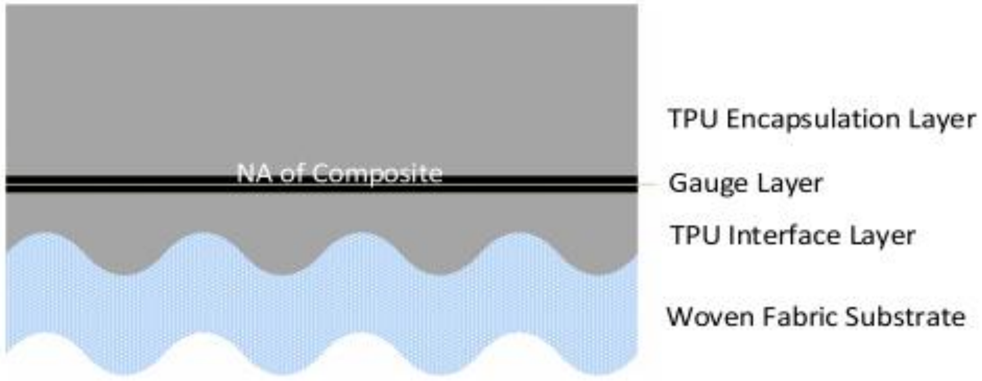


Conductors based on AgNW and TPU ink [14]

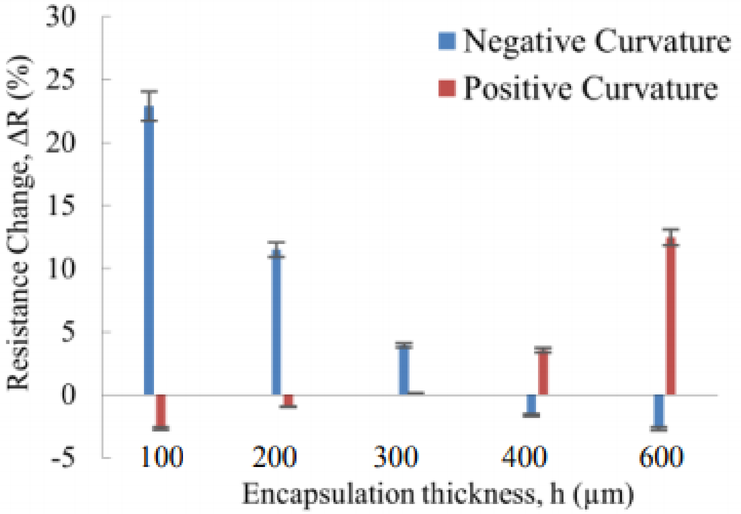
Bending performance of electrical interconnects

- Positioning the electrical interconnect at lowest stress region
- Induced stress is dependent on the bending direction
- E-textile design must be tailored to application for optimal performance



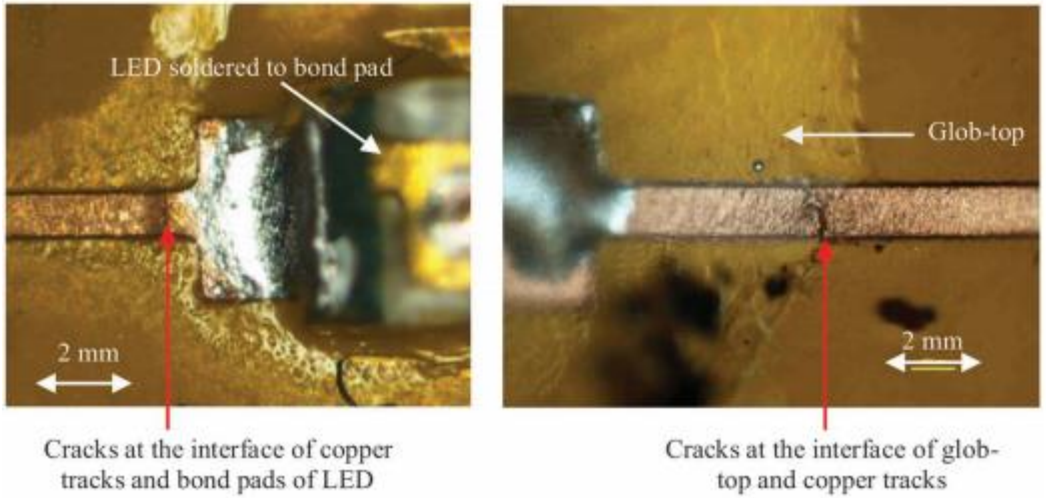


Neutral axis positioning of electrical interconnects [15]



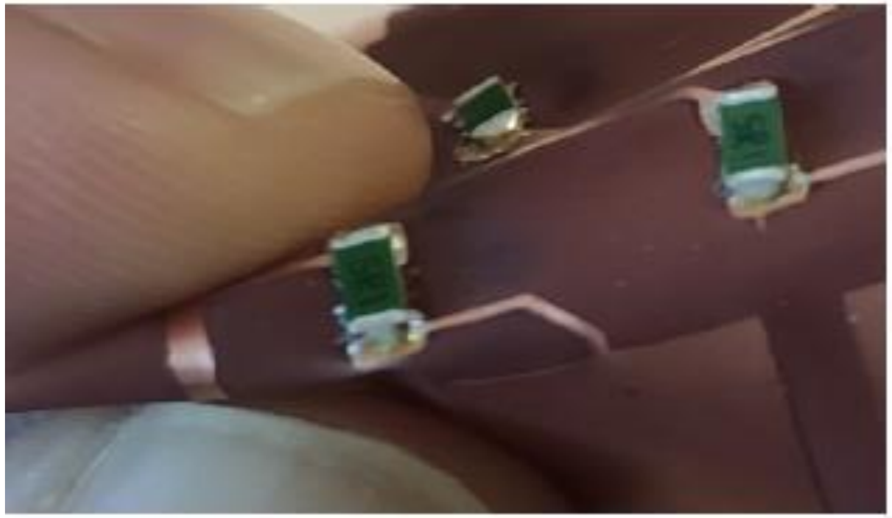
Resistance change of strain gauges for positive and negative bending [15]

Bending bonded joints



Failure modes on glob-topped components on electronic filament [10]

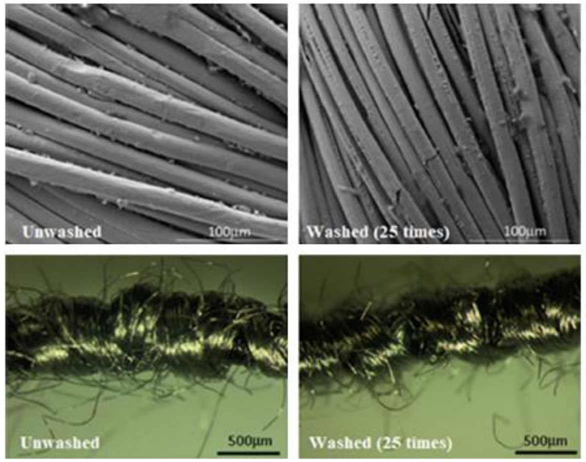
Failure at wire adhesive joints



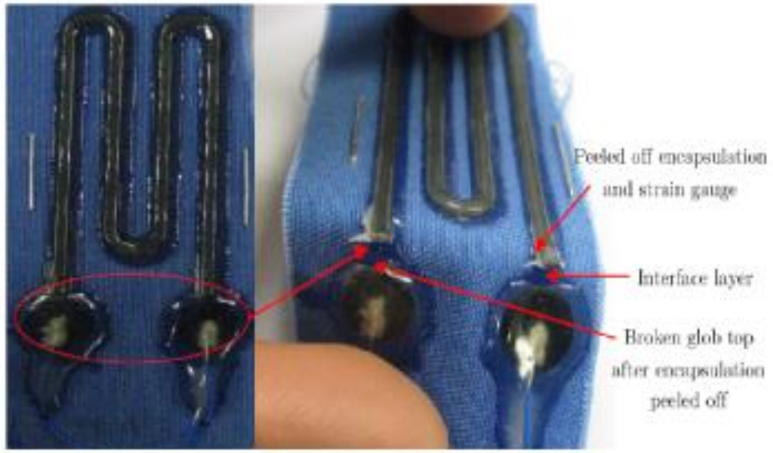
Failure due to stiffness gradient between components and tracks [16]

Failure modes due to washing e-textiles

- Lack of standard for e-textile
- Washing in research are based
  - Immersion in water
  - Gentle washing
  - ISO 6330 washing standard
- Washability up to 50 washing cycles have been achieved in literature using vacuum encapsulated filament circuits

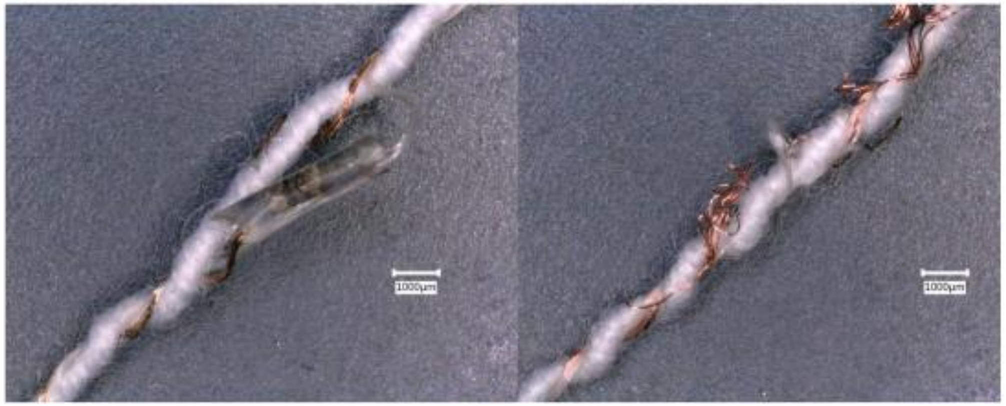


Cracking of textile fibre coatings [17]



Peeling encapsulation [18]

Torn Litz wires [19]



Broken micropods and wires [20]

UNIVERSITY OF Southampton
School of Electronics and Computer Science

Summary and Conclusions

- Definite progress in e-textile manufacturing but durability is still cause for concern
- More research on e-textile reliability is still required to enable transition to consumers.
- Standards for e-textile use and handling are still required

aok1g15@soton.ac.uk

References

[1] Komolafe, A. O., Nunes-Matos, H., Glanc-Gostkiewicz, M., & Torah, R. N. (2021). Evaluating the effect of textile material and structure for printable and wearable e-textiles. IEEE Sensors Journal.

[2] Almusallam, A., Torah, R. N., Zhu, D., Tudor, M. J., & Beeby, S. P. (2013, December). Screen-printed piezoelectric shoe-insole energy harvester using an improved flexible PZT-polymer composites. In Journal of Physics: Conference Series (Vol. 476, No. 1, p. 012108). IOP Publishing.

[3] De Vos, M., Torah, R., Glanc-Gostkiewicz, M., & Tudor, J. (2016). A complex multilayer screen-printed electroluminescent watch display on fabric. Journal of Display Technology, 12(12), 1757-1763.

[4] Kim, Y., Kim, H., & Yoo, H. J. (2009). Electrical characterization of screen-printed circuits on the fabric. IEEE transactions on advanced packaging, 33(1), 196-205.

[5] Linz, T., Kallmayer, C., Aschenbrenner, R., & Reichl, H. (2006, April). Fully untegrated EKG shirt based on embroidered electrical interconnections with conductive yarn and miniaturized flexible electronics. In International Workshop on Wearable and Implantable Body Sensor Networks (BSN'06) (pp. 4-pp). IEEE.

[6] Buechley, L., & Eisenberg, M. (2009). Fabric PCBs, electronic sequins, and socket buttons: techniques for e-textile craft. Personal and Ubiquitous Computing, 13(2), 133-150.

[7] Ye, C., Ren, J., Wang, Y., Zhang, W., Qian, C., Han, J., ... & Ling, S. (2019). Design and fabrication of silk templated electronic yarns and applications in multifunctional textiles. Matter, 1(5), 1411-1425.

[8] Zysset, C., Kinkeldei, T. W., Munzenrieder, N., Cherenack, K., & Troster, G. (2012). Integration method for electronics in woven textiles. IEEE Transactions on Components, Packaging and Manufacturing Technology, 2(7), 1107-1117.

[9] Takamatsu, S., Yamashita, T., & Itoh, T. (2015, April). Fabrication of fabric LED array. In 2015 Symposium on Design, Test, Integration and Packaging of MEMS/MOEMS (DTIP) (pp. 1-4). IEEE.

[10] Komolafe, A., Torah, R., Wei, Y., Nunes-Matos, H., Li, M., Hardy, D., ... & Beeby, S. (2019). Integrating flexible filament circuits for e-textile applications. Advanced Materials Technologies, 4(7), 1900176.

[11] Loher, T., Manessis, D., Heinrich, R., Schmied, B., Vanfleteren, J., Debaets, J., ... & Reichl, H. (2006, December). Stretchable electronic systems. In 2006 8th Electronics Packaging Technology Conference (pp. 271-276). IEEE.

References

[12] Koshi, T., Nomura, K. I., & Yoshida, M. (2021). Measurement and analysis on failure lifetime of serpentine interconnects for e-textiles under cyclic large deformation. Flexible and Printed Electronics.

[13] Araki, T., Nogi, M., Suganuma, K., Kogure, M., & Kirihara, O. (2011). Printable and stretchable conductive wirings comprising silver flakes and elastomers. IEEE Electron Device Letters, 32(10), 1424-1426.

[14] Zhu, H. W., Gao, H. L., Zhao, H. Y., Ge, J., Hu, B. C., Huang, J., & Yu, S. H. (2020). Printable elastic silver nanowire-based conductor for washable electronic textiles. Nano Research, 13(10), 2879-2884.

[15] Komolafe, A. O., Torah, R. N., Yang, K., Tudor, J., & Beeby, S. P. (2015, May). Durability of screen printed electrical interconnections on woven textiles. In 2015 IEEE 65th Electronic Components and Technology Conference (ECTC) (pp. 1142-1147). IEEE.

[16] Tao, X., Cochrane, C., & Koncar, V. (2021). Wash Analyses of Flexible and Wearable Printed Circuits for E-Textiles and Their Prediction of Damages. Electronics, 10(11), 1362.

[17] Schwarz, A., Kazani, I., Cuny, L., Hertleer, C., Ghekiere, F., De Clercq, G., ... & Van Langenhove, L. (2011). Electro-conductive and elastic hybrid yarns–The effects of stretching, cyclic straining and washing on their electro-conductive properties. Materials & Design, 32(8-9), 4247-4256.

[18] Komolafe, A. (2016). Reliability and interconnections for printed circuits on fabrics (Doctoral dissertation, University of Southampton).

[19] Rotzler, S. (2018). Einfluss der Sinnerschen Faktoren sowie der textilen Substrate auf die Waschbarkeit textilintegrierter Leiterbahnen (Doctoral dissertation, Hochschule für Technik und Wirtschaft Berlin).

[20] Hardy, D. A., Rahemtulla, Z., Satharasinghe, A., Shahidi, A., Oliveira, C., Anastasopoulos, I., ... & Dias, T. (2020). Wash testing of electronic yarn. Materials, 13(5), 1228.