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Printed Electro-Conductive Textiles

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The course is developed under Erasmus+ Program Key Action 2:
Cooperation for innovation and the exchange of good practices Knowledge Alliance

ICT IN TEXTILE AND CLOTHING HIGHER EDUCATION AND BUSINESS

Project Nr. 612248-EPP-1-2019-1-BG-EPPKA2-KA

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Contents

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Introduction

- Electrical conductive textiles are used in many applications like printed circuits, RFID, flexible sensor, wearable sensing and energy harvesting.
- Conventional textile are usually insulating materials, where they cannot be used directly for applications that require electrical conductivity.
- Electrically conductive textile can be developed by integrating metallic wires, conductive polymers, or carbon-based compounds in to textile structure at different manufacturing stage (fiber, yarn or fabric).

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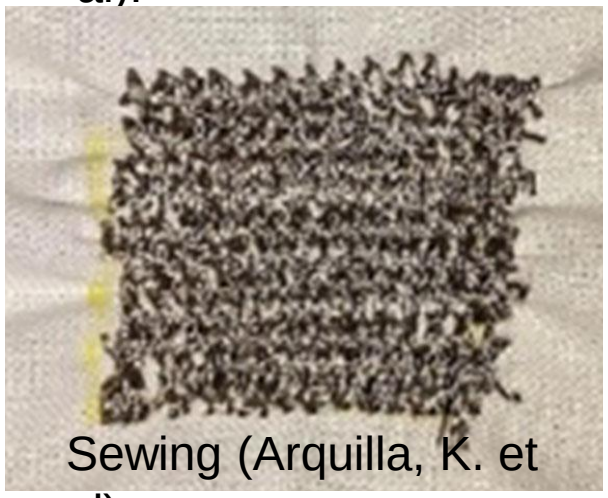
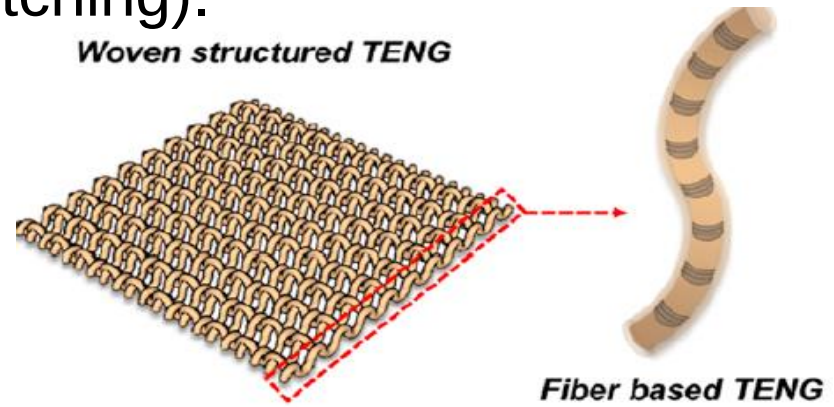
Integration techniques

- Conductive textiles can be developed by integrating conductive **thread** into fabric by knitting, weaving, embroidering sewing (stitching).

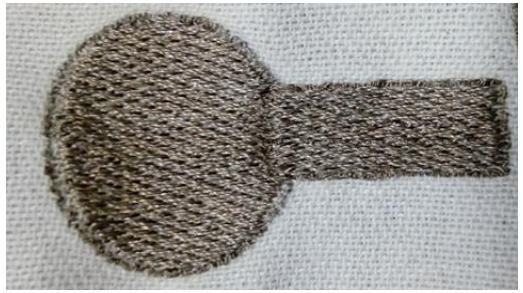
Knitting (Patron, D. et al).



Sewing (Arquilla, K. et al)



triboelectric nano-generator (TENG) (Park, J. et al.)



Embroidery

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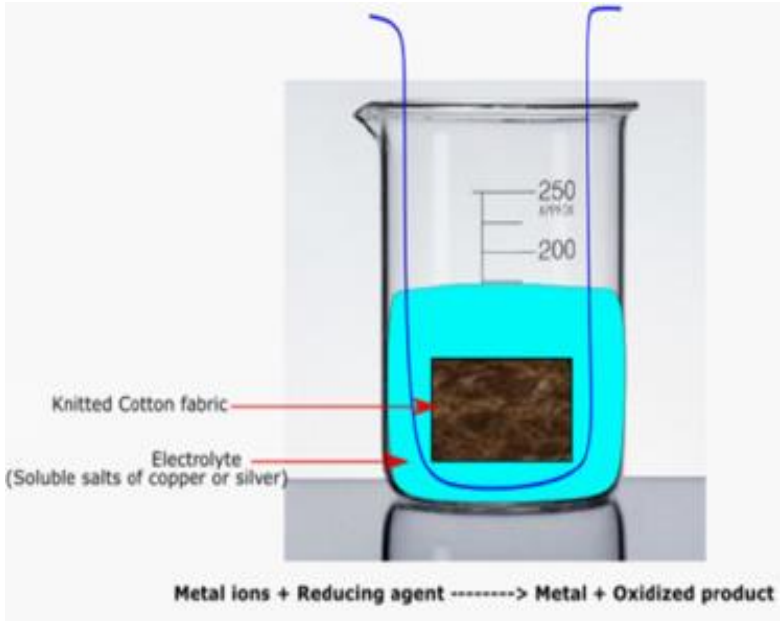
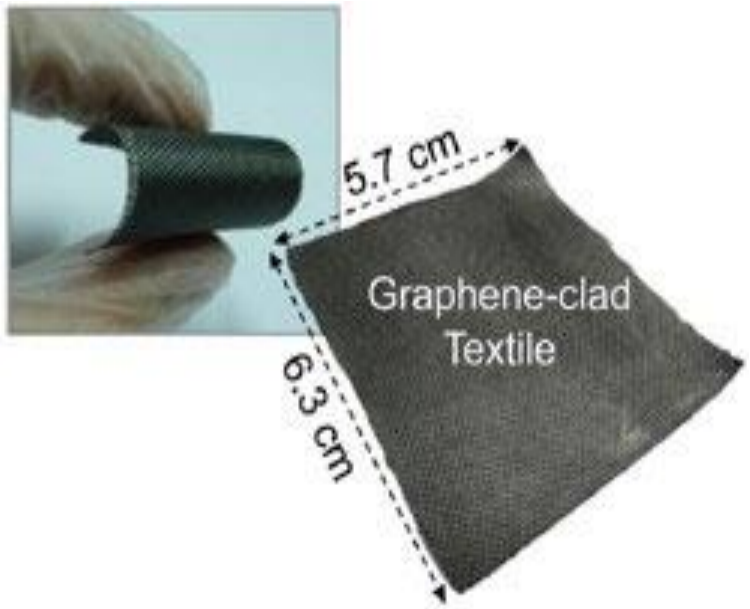
Integration techniques

- **Conductive particles** can be incorporated into the textile structure by coating, printing or plating techniques.



Electroless Platting
(Tseghai, G.B. et al.;2020)



Dip coating (Yapici, M. K. et al.;2015)

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Conductive printing

- Due to the **ever-growing demand** on smart textile for printed circuits, RFID, flexible sensor, wearable sensing and energy harvesting applications, the need for electrically conductive textiles has become ever larger.

- Conductive textiles can be developed by integrating conductive yarn or by coating conductive material on the fabric surface.

- But the fabrication processes are complicated, not systematic, **unsuitable** for mass-production, and expensive.

- **Printing** which is used to deposit a conductive material on a selected fabric area gain importance to create such conductive textiles.

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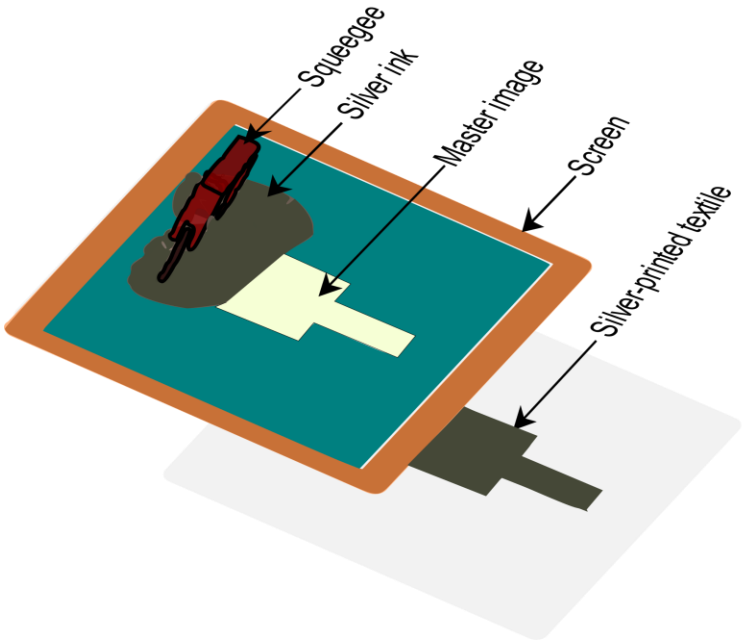
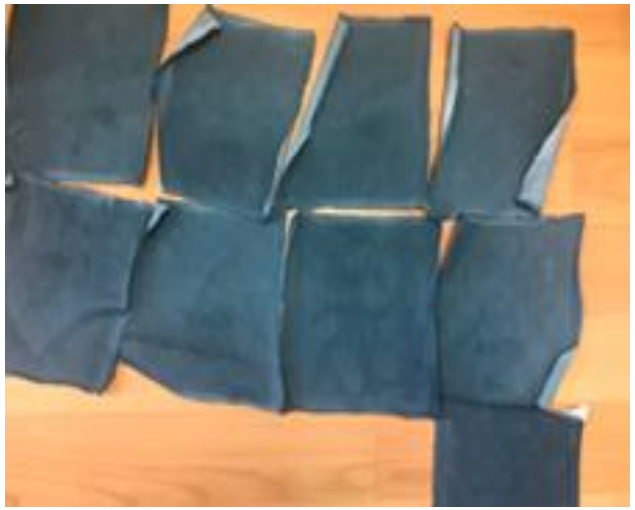
Screen printing

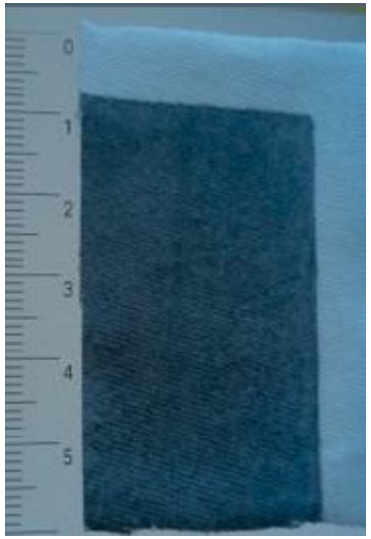
- Is a widely used technique to develop conductive textiles



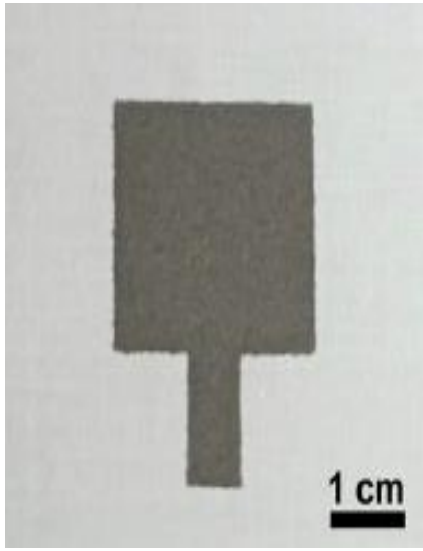
Silver printed ECG electrodes (Nigusse, A.B. et al.; 2020)



PEDOT:PSS printed fabric (Ankhili, A. et al.; 2018)



PEDOT:PSS/PDMS printed fabric (Tseghai, G.B. et al.; 2020)



Graphene-printed fabric (Xu, X. et al.; 2019)

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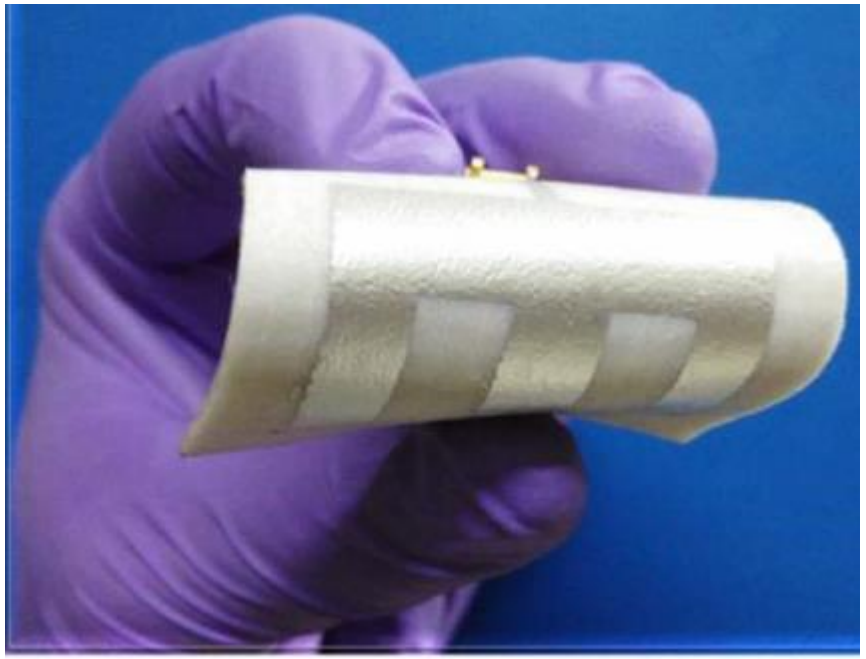
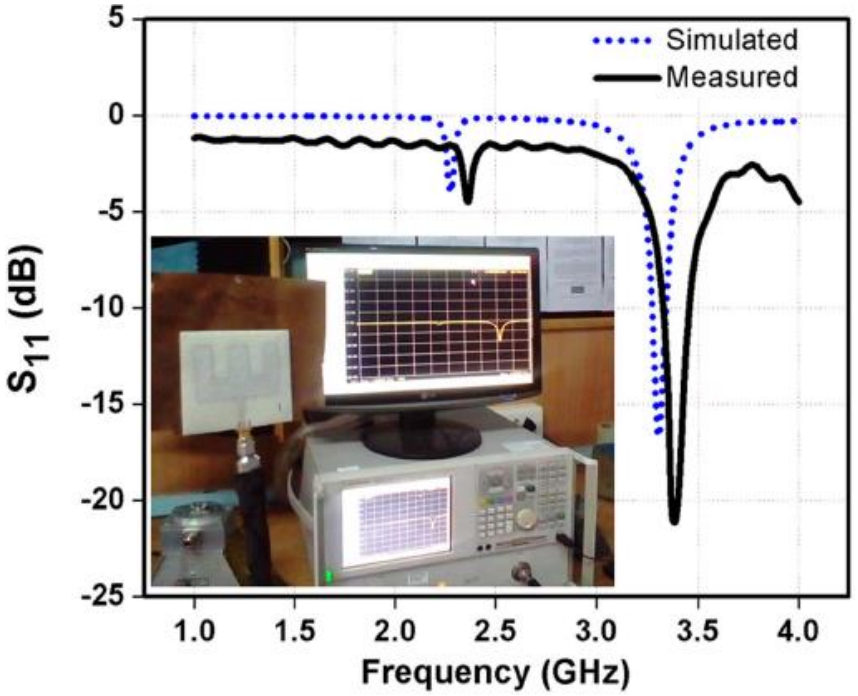
Screen printing

- **Rashni et al.;2017** developed a thin, flexible and water resistant E-shaped patch antenna fabricated by printing PVB on multilayered polyester fabric for WiMAX applications.



screen printed antenna



Reflection characteristics of E-shaped

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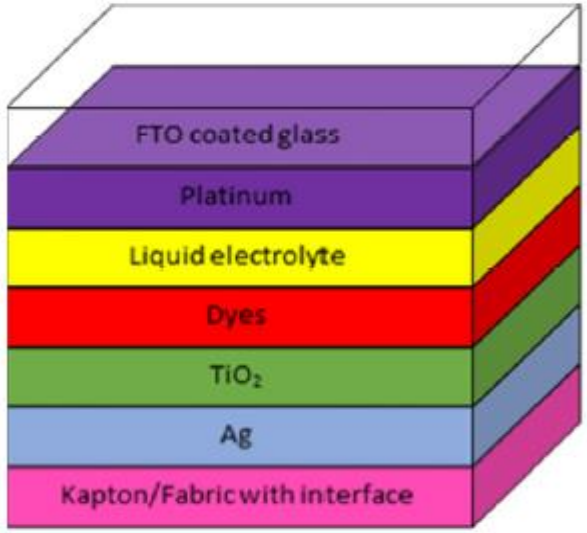
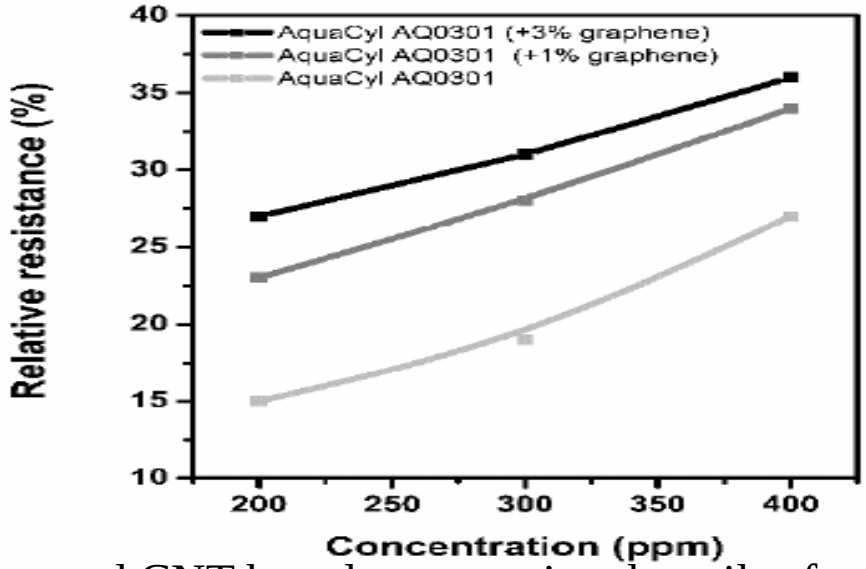
Screen printing

- **Liu et al.; 2018** reported screen printed dye-sensitized solar cells (DSSCs); silver ink was screen printed onto the Kapton/fabric on top of the interface for wearable energy harvesting applications and gave a photovoltaic efficiency of 7.03%.
- **Skrzetuska et al.; 2014** developed a printed textile sensors based on graphene and carbon nanotubes



Schematic design of screen printed DSSCs



Graphene and CNT-based screen printed textiles for vapor sensing

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Advantages and Challenges of screen printing

Advantages

- ✓ Versatile
- ✓ Easy to adopt
- ✓ Relatively cheap process
- ✓ Compatible with roll-to-roll processing of textiles
- ✓ Reduce level of environmental contamination

Challenges

- ✓ Adequate conductivity
- ✓ Form a suitable thickness
- ✓ Flexibility
- ✓ Surface uniformity and design precision
- ✓ Stability problem
- ✓ Abrasion

➢ Kazani et al.;2012 applying a protective TPU layer on top of the conductive screen printed fabric to improve washability

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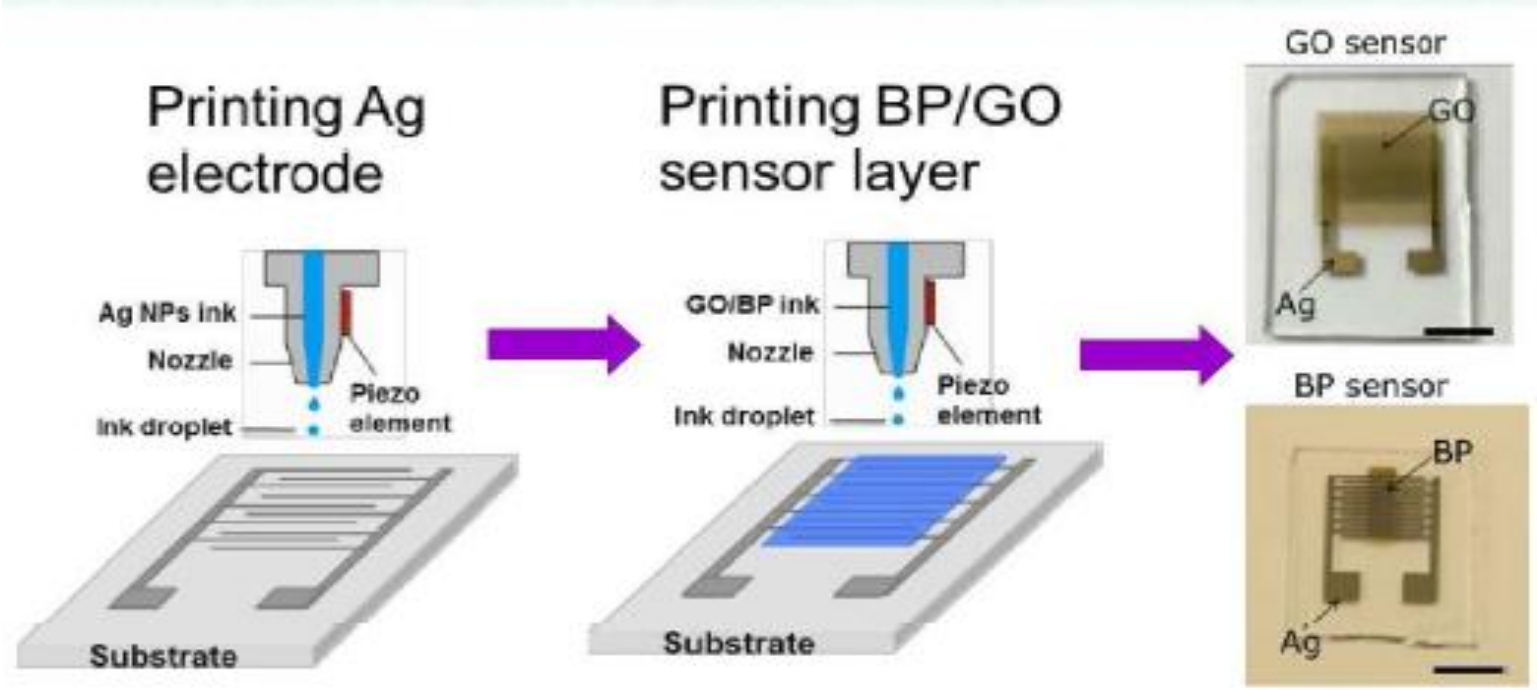
Inkjet printing

- It is a widely used direct-write deposition conducted in a droplet-by-droplet fashion.
- Relatively simple, precise and flexible design and suitable for multi-layer at low price.
- Ag (Silver) ink is mostly used, Carbon nanotube and graphene inks are also used.



Inkjet printing of humidity sensor (He et al.;2013)

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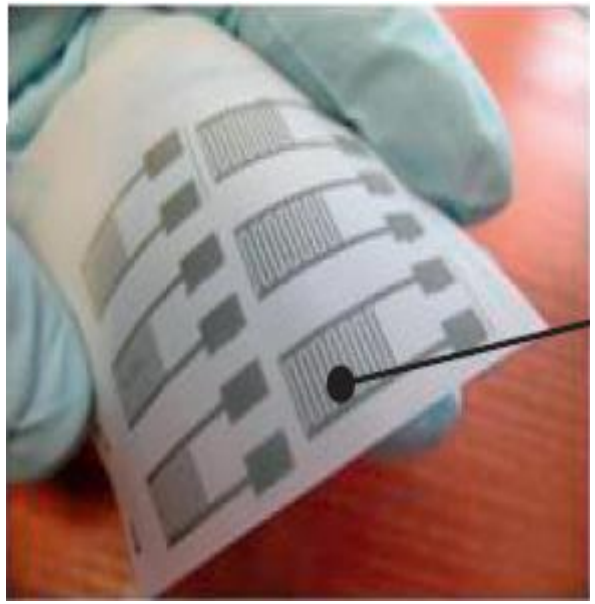
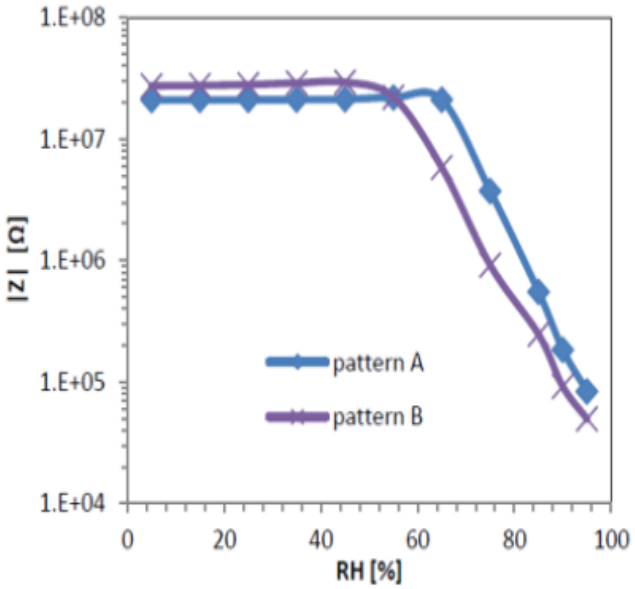
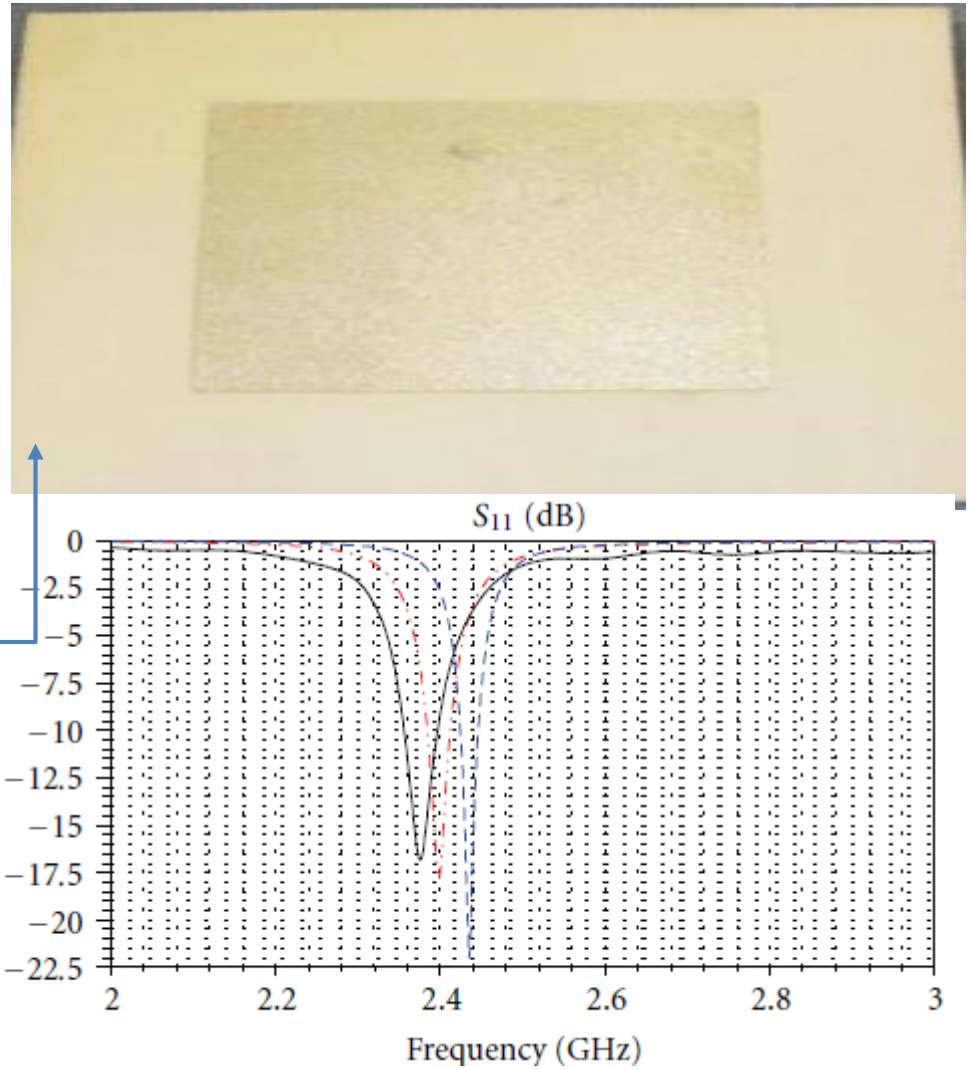
Inkjet printing





Ag nanoparticles ink printed and its humidity sensibility at 1kHz measurement frequency (Weremczuk et al.;2012)

Inkjet printed textile antenna using Ag nanoparticles ink and comparison of S11 between simulated and measured
(Al-Naiemy et al.;2012)



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Challenges in inkjet printing

- It is difficult achieving a highly conductive continuous track on the rough fabric
- Majority of fabrics cannot withstand the high curing temperatures
- Resilience to stretching and bending.
- Inhomogeneous film formation, formation of cracks, irregular and deformed printed trucks

- These challenges can be avoid by:
  - ❖ Selecting inks with optimal
    - Viscosity
    - Surface tension, and
    - Evaporation rate
  - ❖ Proper printing setting
    - Voltage
    - Shape of pulse
    - Ink T_0 Viscosity
    - Size and speed of ink drops
    - Substrate

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Transfer Printing

- This system requires a design (pre-print master) which is first printed on non-textile and then transferred into/onto textile fabric by applying heat or pressure via sublimation, melt, film release or wet transfer techniques.
- Not well employed for the development of conductive textiles due to the absence of suitable volatile conductive compounds.

Transfer Printed Textile Circuit

Textile wristwatch (Shin et al.;2012)

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Conclusions

- Printing is a promising approach of creating electro conductive textiles
- Deposit the conductive component on a selected fabric area, makes the technique cost effective.
- Flat screen-printing is the most widely used technique.
- Finding suitable conductive ink (compound) is among the challenges in conductive printing.

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Thank you!

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References

- Patron, D. et al. On the Use of Knitted Antennas and Inductively Coupled RFID Tags for Wearable Applications. *IEEE Trans. Biomed. Circuits Syst*. 2016.
- Park, J. et al. Flexible single-strand fiber-based woven-structured triboelectric nanogenerator for self-powered electronics. APL Mater. 2018.
- Arquilla, K. et al. Textile Electrocardiogram (ECG) Electrodes for Wearable Health Monitoring. *Sensors* 2020.
- Tseghai, G.B. et al. Integration of Conductive Materials with Textile Structures, an Overview. *Sensors* 2020.
- Yapici et al. Graphene-clad textile electrodes for electrocardiogram monitoring. *Sensors and Actuators B: Chemical*, 2015.
- Nigusse et al. Development of Washable Silver Printed Textile Electrodes for Long-Term ECG Monitoring. *Sensors* 2020.
- Ankhili, A. et al. Comparative Study on Conductive Knitted Fabric Electrodes for Long-Term Electrocardiography Monitoring: Silver-Plated and PEDOT:PSS Coated Fabrics. *Sensors* 2018
- Tseghai, G.B. et al. Development of a flex and stretchy conductive cotton fabric via flat screen printing of PEDOT : PSS/PDMS conductive polymer composite. *Sensors* 2020.

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References

- Roshni, S.B. et al. Design and fabrication of an E-shaped wearable textile antenna on PVB-coated hydrophobic polyester fabric. *Smart Materials and Structures*,2017.
- Liu, J.et al.. Screen printed dye-sensitized solar cells (DSSCs) on woven polyester cotton fabric for wearable energy harvesting applications. *Materials Today: Proceedings*, 2018.
- Skrzetuska, E. et al. Chemically Driven Printed Textile Sensors Based on Graphene and Carbon Nanotubes. *Sensors* 2014.
- He, P. et al. Fully printed high performance humidity sensors based on two-dimensional materials. *Nanoscale*, 2018.
- Weremczuk, J. et al. Humidity sensor printed on textile with use of ink-jet technology. *Procedia engineering*, 2012.
- Al-Naiemy, Y. et al. A systematic approach for the design, fabrication, and testing of microstrip antennas using inkjet printing technology. *International Scholarly Research Notices*,2012.
- Shin, S. et al. A Flexible Textile Wristwatch U sing Transfer Printed Textile Circuit Technique. *In 2012 IEEE International Conference on Consumer Electronics (ICCE)*.