Smart Textiles for Wearable Technology

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September 2015
Why Conductive Fabric’s?

Increasing demand for wearable electronics from industries such as:

- Medical and Healthcare
- Sport and fitness
- Consumer electronics
- Defence applications
Market Value and Growth

- The wearable electronics business powers from over $14 billion in 2014 to over $70 billion in 2024. *(IDTechEx)*

- The overall size of the global smart textile market was estimated to be USD 289.5 million in 2012 and expected to exceed USD 1,500 million by 2020 *(PRWEB)*

- *Smithers Apex* are forecasting the Compounded Annual Growth rate (CAGR) of 30% 2016-21

*Source: IDTechEx*
Sports & Healthcare

Philips Blue Touch Pain Relief Patch

Talktomyshirt.com

Edema ApS
Fashion

Sound reactive Thunderstorm dress
Amy Winters

Photo by Reuters
Interconnect solution
Conductive Fabrics

Current technologies used for conductive textiles include:

• Weaving of separate metal threads into the textile.
• Printing/deposition of conductive polymers.
• Printing metallic inks on to the surface.
• Plasma deposition on the threads
• Electroless plating
Fabric types

Knitted

Woven

And non-woven!
Attachment

- Conductive yarn
- Printing
  - Physical attach
  - Hydrogen bonding
  - Penetrating system

These systems perform very poorly when the underlying fabric is stretched, bent or twisted.

What is needed is a conductive medium that can follow the fibres, ideally without affecting their ability to deform.
Available Technologies

1. Weaving or knitting metal wires into the textile

- E.g. Plug&Wear, 100% metal knitted fabrics. Either tin/copper or silver/copper

- However, metal wires can break easily during the manufacturing and during use
- Limited elasticity, adds weight to garment
Available Technologies

2. Weaving or knitting conductive threads into the textile

- Most threads are metallised with an alloy of metals, such as silver, copper, tin, nickel
- The core is normally cotton or polyester
- Examples include Shieldex (nylon/silver)
- Swicofil (aluminium metallized polyester)
- Karl Grimm (threads have thin flattened wires wrapped around them, stiffer than metallised yarns)
- ARACON® brand metal clad fibres, outer metal coating on Kevlar fibres
Available Technologies

2. Weaving or knitting conductive threads into the textile

(conductive threads sewn, from “How To Get What You Want” website)
Available Technologies

2. Weaving or knitting conductive threads into the textile

- Significant differences in conductivity/resistivity
- Commonly sold as 2-ply or 4-ply (4-ply contains twice as much metal as 2-ply)
- Issues with robustness, e.g. can’t always withstand elongation stresses during textile manufacturing or use
- Possible stress cracks in metal plated yarns
- Conductive thread tends to fray and the stitches can become loose
Available Technologies

3. Deposition/coating of conductive polymers

• E.g. polyaniline (L), polypyrrole (R)

• Either purchased as solids or disperse solutions. Can be applied via polymer coating, or polymerisation of monomer on the textile surface also possible

• E.g. Textronics, “Textro-Polymers”, which can take the form of a fibre, a film, or a coating, provide a predictable conductivity change with stretch
Available Technologies

3. Deposition/coating of conductive polymers

- E.g. EeonTex™ conductive textiles from Eeonyx. A propriety coating system suitable for a range of substrates (e.g. wovens, non-woven, polyester, nylon, glass, spandex, aramids)

  - Fibres coated with doped polypyrrole
  - Controllable surface resistivity between $10^4$ and $10^6$ Ω/sq

Bomb suit made with EeonTex™, eliminates static
Available Technologies

4. Printing conductive inks

• Conductive component can be copper, silver, carbon (ink, paint, pastes, pens)
• Application methods include screen printing, inkjet printing, flexography
• Suppliers include Dupont, Henkel, GEM
Available Technologies

4. Printing conductive inks

- Good conducting ability, e.g. DuPont CB200 copper conductor for screen printing, sheet resistivity is 20-30 mΩ/sq
- The main issue with inks is cracking on the uneven fabric surface → loss of conductivity
- Also processing, some need heat/UV curing
Patterning

- Future requirements will be to run a connection in any direction on any textile.
- Weaving and knitting present severe limitations in this regard
- Additive processes are more flexible, and in principle will work with all textiles
Invented at NPL

Conductive Fabrics

Stretch Nylon Fabric processed using NPL technology
Conductive fabrics:

- Processes
  - Fabric surface pre-treatment
  - Fabric surface charge modification stage
  - Metal seed layer deposition
  - Electroless plating to thicken metal layer
  - Surface passivation

- Alternatives:
  - Conductive polymers, printing inks, conductive yarns

NPL technology
Stage 1 – Nano-Silver Coating of Fibres

- Fibres within textile are chemically functionalised
- Functionalised fabric is immersed in solution containing dispersed silver nanoparticles
- Silver nanoparticles attach to functionalised fibre
- Functional groups attract silver nanoparticles
- Fibre is coated with silver nanoparticles
Stage 2 – Electroless plating

- Nano-silver coating is catalytic to electroless Cu plating

- Electroless copper plate fibres to 0.5-2.0 µm

- Final finish – Immersion silver or other anti-oxidative coating
Nano-silver coated fabric
Nano-metal deposition

NaOH (aq)

Mercerization

NaBH₄ (aq)

Linker ~ cationic polyelectrolyte

AgNO₃ (aq)

= Nano silver
Additive metallic layer thickening

SEM images of electroless plating

- Electroless plating to bring conductor layer to >1µm
  - Resistivity  \( R = <0.2\Omega/sq \)
- Additive deposition is throughout the fabric with excellent adhesion, that allows the fabric to stretch and not effect the drape and handle
Patterning

Additive process is successful on most fabrics
Stretch Fabric

http://www.youtube.com/watch?v=skgGYFpT1Vc
NPL Process

1. Charge modification of the surface of the fabric.
2. Surface modification of the fibres using a charged polymer.
3. Chemical attachment of Silver nano-particles to individual fibres.
4. Secondary additive processing to thicken metallic layer.
5. Passivation
Coating a wide range of fabrics

Polyester Satin (R=0.5 Ω/□)

Jersey Cotton Tubular (R=0.2 Ω/□)

Linen (R=0.06 Ω/□)

Lycra (R=2.0 Ω/□)

Polyester (R=0.1 Ω/□)
Coating a wide range of fabrics

Polyester Cotton (R=0.2 Ω/□)

Polyester Viscose (R=0.2 Ω/□)

Silk Bupion (R=0.1 Ω/□)

Stretch Nylon (R=0.1 Ω/□)

Non Woven (R=0.006 Ω/□)
Dyed fabrics are conducting
Stretch tests

Stockinette stitches

Commercial Nylon

Resistance (Ω)

Extension (mm)

sample 1
sample 2
Wash Cycles (Cotton Jersey)
Conductive Thread

Fibres before Cu plating of threads

Cu plated thread
Summary

- Smart textiles for wearables is in its infancy.
- Many potential material solutions exist
- Applications are proliferating
- NPL solution offers highly conductive fabric, with excellent flexibility
- Can be used on large areas, or patterned
- Good washability: 100 cycles with acceptable change in resistance.
- Stretchable fabrics retains conductivity
- Different metals can be used
Thank you