ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY
AUTONOMOUS INSTITUTION
Approved by AICTE & Affiliated to Anna University
NBA Accredited for BE (ECE, EEE, MECH) | Accredited by NAAC with A+ Grade
Anjugramam - Kanyakumari Main Road, Palkulam,Variyoor P.O. - 629 401, Kanyakumari District.

Department of Biomedical Engineering

VI Semester

CBM 370 - Wearable Devices

Unit- 4 SMART TEXTILE

4.2 Fabrication Techniques- Conductive Fibres

- Initially, conductive threads were mainly used in technical areas:
  - ✓ clean room garments,
  - ✓ military apparel,
  - ✓ medical application and
  - ✓ electronics manufacturing.
- Textile structures that exhibit conductivity or serve an electronic or computational function are called electro-textiles.
- They can have a variety of functions, like antistatic applications, electromagnetic interference shielding (EMI), electronic applications, infrared absorption or protective clothing in explosive areas].
- The conventional process to produce metal fibers is wire drawing, a mechanical production process. This process is characterized by its various drawing steps, called coarse, medium, fine and carding train.
- The drawing die, used to draw the fiber, consists of a steel mount with a core out of ceramics, carbide or diamond.
- The initial diameter of the metal wire varies depending on the material. For copper, for instance, it is usually is 8 mm, while for iron it is 5 mm.
- After drawing, the wire is annealed at temperatures ranging between 600 and 900 °C. Subsequently, they are quenched. The fine metal wire is then wrapped onto a revolving wire drawing cylinder .

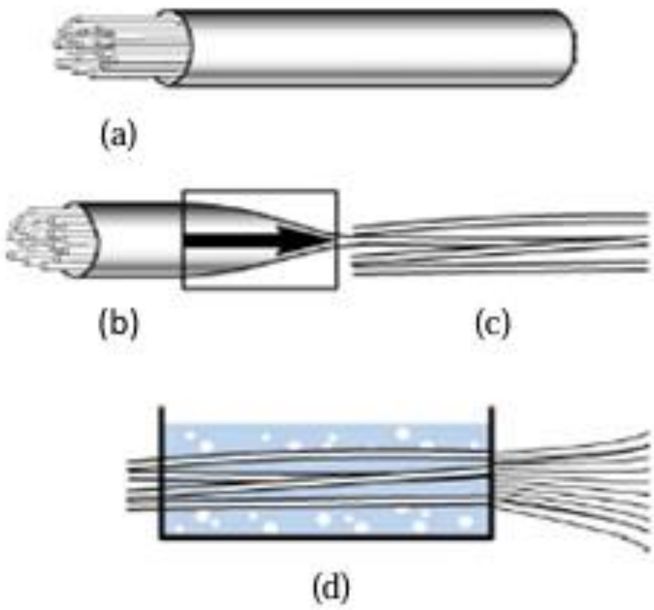


Figure 4.2.1. (a) Metal coated wire combined in iron tube; (b) Several diameter reductions of tube; (c) Bundling of tubes; (d) Leaching, realizing fibers.

Conductive fibers play a crucial role in the development of smart textiles, enabling functionalities such as sensing, actuation, and communication. Various fabrication techniques are employed to create these conductive materials, each with distinct advantages and applications.

Fabrication Techniques:

1. Coating and Printing

Metal Coating: Fabrics can be coated with conductive metals like silver, copper, or nickel to enhance conductivity. This method is straightforward but may affect the fabric's flexibility and comfort.

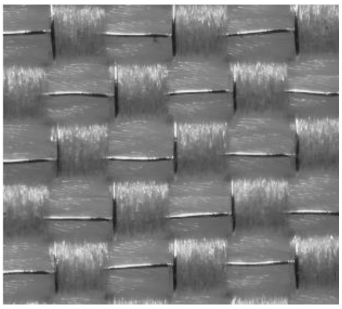


Figure 4.2.2 Conductive path made of copper wires in a woven fabric

Dip Coating:

Dip coating is a simple and cost-effective process commonly used in various industrial fields for depositing coating material onto any substrate, along with metallic and ceramic polymer film and textile materials. The process could be interpreted as depositing aqueous liquid phase coating solutions on the surface of any substrate. Conductive materials are typically dissolved in solutions that are immediately deposited on the surface of the substrate, after which, to obtain the dry film, the sedimentary conductive wet coating has to be evaporated. The technique associates submerging the textile material in the solution of the conductive coating materials, ensuring that the textile material is completely penetrated and then withdrawn from the solution materials. Solution dip coating is the most straightforward technique of forming a film on textile materials' surfaces and is typically used in increasing production. The dipping process is shown in **Figure 3**.

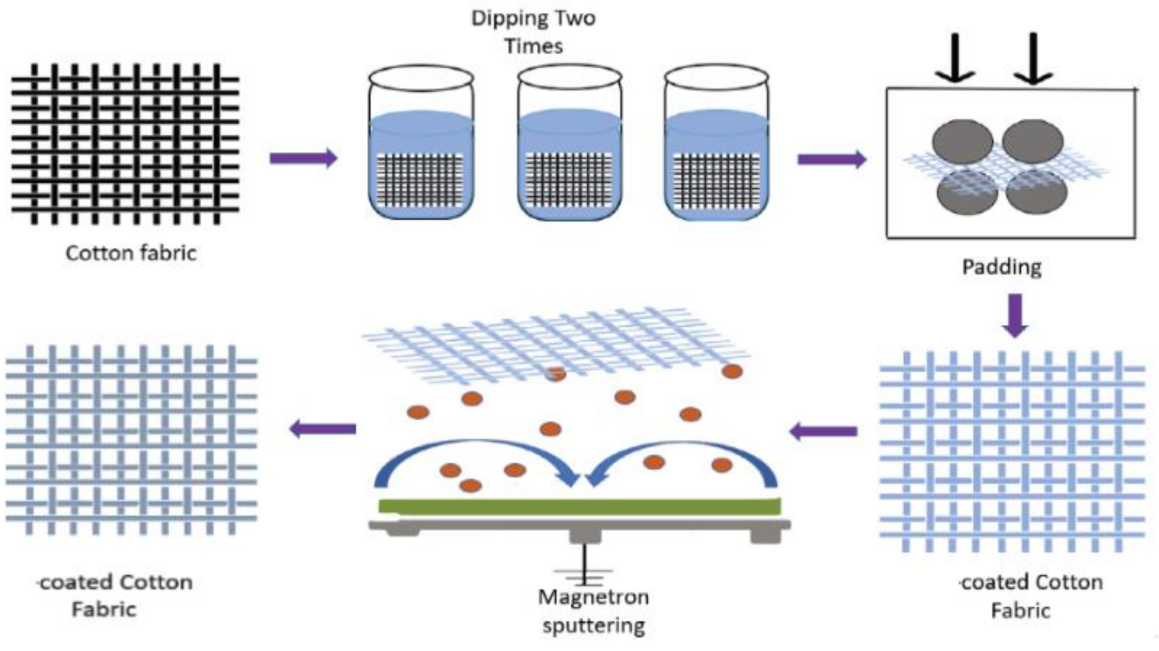


Figure 3. The preparation process of silver/graphene-coated cotton fabric

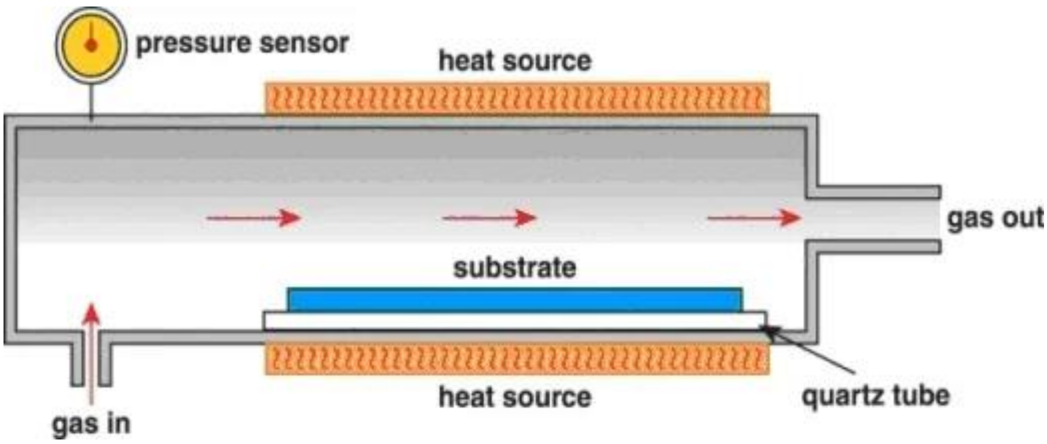
The process are,

- ❖ **Cotton Fabric:** The process begins with a piece of cotton fabric, represented as a black grid pattern.
- ❖ **Dipping Two Times:** The fabric is dipped twice into a liquid solution (presumably containing the coating material) in two separate containers.
- ❖ **Padding:** The fabric is then passed through a padding process, indicated by two rollers pressing down on the fabric. This step likely ensures even distribution of the coating material.
- ❖ **Magnetron Sputtering:** The fabric is then subjected to magnetron sputtering. This technique involves bombarding a target material with ions, causing atoms from the target to be ejected and deposited onto the fabric. The image shows the sputtering process with a target material at the bottom and the fabric positioned above.
- ❖ **Coated Cotton Fabric:** The result is a coated cotton fabric, depicted with a blue grid pattern on the fabric, indicating the added coating.

Printing Techniques: Methods such as screen printing or inkjet printing are used to apply conductive inks onto textiles. This allows for precise patterns and designs, which can be tailored for specific applications like sensors or circuits. The procedure involves the ejection of a fixed quantity of ink in a liquid-filled chamber in response to applying an external voltage.

2. Deposition Techniques

Chemical Vapor Deposition (CVD): This technique is utilized to deposit thin films of conductive materials like graphene or carbon nanotubes (CNTs) onto fabric surfaces. It provides high-quality coatings but may require complex setups and conditions.

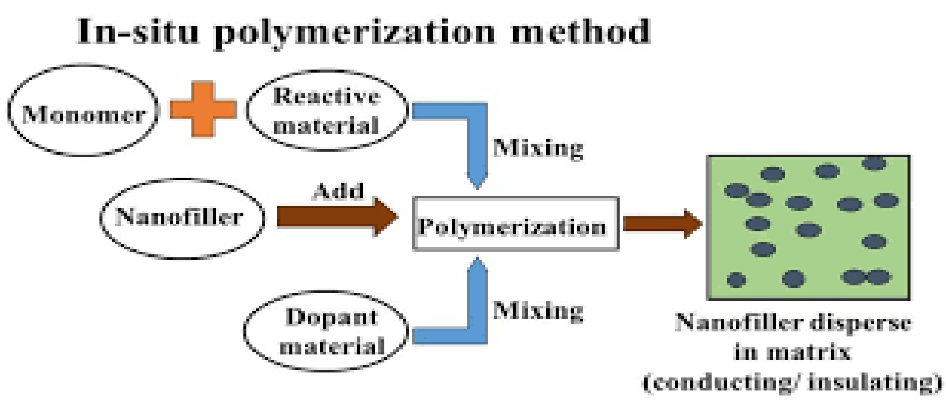


- Precursor gases are introduced into the quartz tube through the "gas in" port.
- The heat sources heat the chamber, providing the energy for the gases to react.
- The reaction produces a solid thin film that deposits onto the substrate.
- By products of the reaction are removed through the "gas out" port.
- The pressure sensor ensures the process occurs at the desired pressure.

Electrostatic Self-Assembly: This method involves layering conductive materials through electrostatic forces, enhancing adhesion and uniformity on the fabric surface. It is particularly effective for integrating graphene-based materials.

3. In Situ Polymerization

This process involves polymerizing conductive polymers directly onto the textile fibers during manufacturing. It can create a strong bond between the polymer and the textile, resulting in enhanced durability and conductivity.



- **Starting Material:** The process begins with **trans-1,4-polyisoprene (TPI)**, shown as small, granular particles. The chemical structure of TPI is provided, highlighting its repeating isoprene units in a trans configuration.
- **Melt Spinning:** The TPI is subjected to melt spinning, a process where the polymer is melted and extruded through a spinneret to form fibers. This results in a fibrous material, shown in the middle image. At this stage, the material is highly insulating, with a resistance greater than 109Ωm.
- **Iodine Doping:** The melt-spun TPI fibers are then treated with iodine, a process known as doping. This dramatically increases the conductivity of the material, reducing its resistance to approximately 10−2Ωm. The resulting material is shown as a dark, cylindrical form.

(b) Micrograph:

- **Scanning Electron Microscope (SEM) Image:** The image on the right is an SEM micrograph of the iodine-doped TPI fiber. It shows the cross-section of the fiber, revealing a network of interconnected fibrils. The scale bar indicates that the fiber's diameter is on the order of 10 μm.

4. Knitting and Weaving

Digital Knitting: Advanced digital knitting machines can integrate conductive yarns into traditional fabrics, allowing for complex designs that incorporate sensors and actuators seamlessly. This method enables rapid prototyping and scalability for mass production.

Weaving Techniques: Conductive fibers can be woven into fabrics using traditional textile methods. This approach is beneficial for creating robust textiles that maintain their mechanical properties while providing electrical conductivity.

5. Immersion and Drying Methods

Fabrics can be immersed in solutions containing conductive materials (like CNTs) followed by drying to achieve desired conductivity levels. The sheet resistance of these fabrics can vary significantly based on the concentration of the conductive material used.

<u>Applications of Conductive Fibers in Smart Textiles</u>

Conductive fibers enable a wide range of applications in smart textiles, including:

- **Health Monitoring**: Fabrics that can sense body parameters such as pressure or temperature are increasingly used in healthcare settings to monitor patients' conditions.

- **Wearable Technology**: Smart clothing equipped with sensors can track physical activity or even control devices through gestures.
- **Prosthetics**: Conductive textiles are being integrated into prosthetic devices to provide feedback on pressure distribution, improving user experience and comfort

****