Department of Biomedical Engineering

VI Semester

CBM 370 - Wearable Devices

Unit- 4 SMART TEXTILE

4.3 Fabrication Techniques- Treated Conductive Fibres

Treated conductive fibers are essential in advancing smart textiles, enabling continuous integration of electronic functionalities while retaining flexibility and durability. Below are fabrication methods derived from recent research:

1. Coating and Surface Treatment

(A) Dip-Coating/Immersion:

Fibers or fabrics are submerged in conductive solutions (e.g., carbon nanotubes, graphene, or PEDOT:PSS dispersions) to form conductive layers. For example:

- SWCNT-coated Lycra fabric achieved a sheet resistance of 35 Ω/□ after immersion in SWCNT ink and nitric acid, maintaining stability over 5,000 stretching cycles.

  CNTs are generally classified by the number of carbon layers into single-walled (SWNTs) or multi-walled (MWNTs) carbon nanotubes.

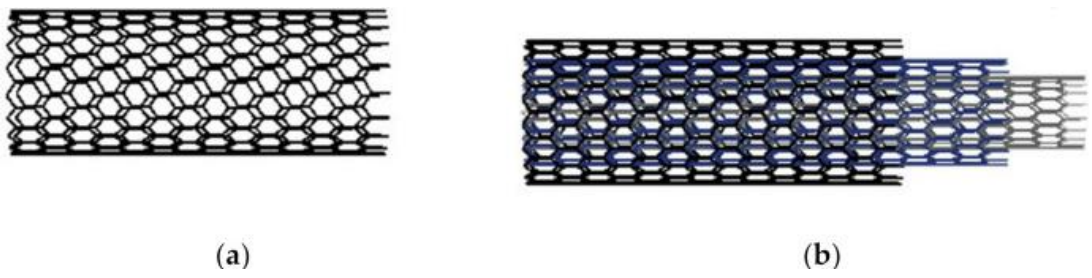


Figure 4.3.1 Structure of carbon nanotubes (**a**) SWNTs and (**b**) MWNTs

- Cotton yarn treated with SWCNTs and polyelectrolytes via immersion showed resistivity as low as 20 $\Omega \cdot cm^{-1}$. conductive fabrics made of SWCNTs have excellent electrical properties; however, SWCNTs are expensive, purification is difficult, and dispersion in liquid is also difficult. Therefore, many researchers focused on fabricating conductive fabrics using MWCNTs instead of SWCNTs because they are cheaper, can be produced in large quantities, and are more stable compared to SWCNTs.

(B). Spray/Spin Coating:

Conductive materials like PEDOT:PSS or silver nanoparticles are sprayed or spin-coated onto textiles. This method ensures uniform thin films and is scalable for roll-to-roll processing35.

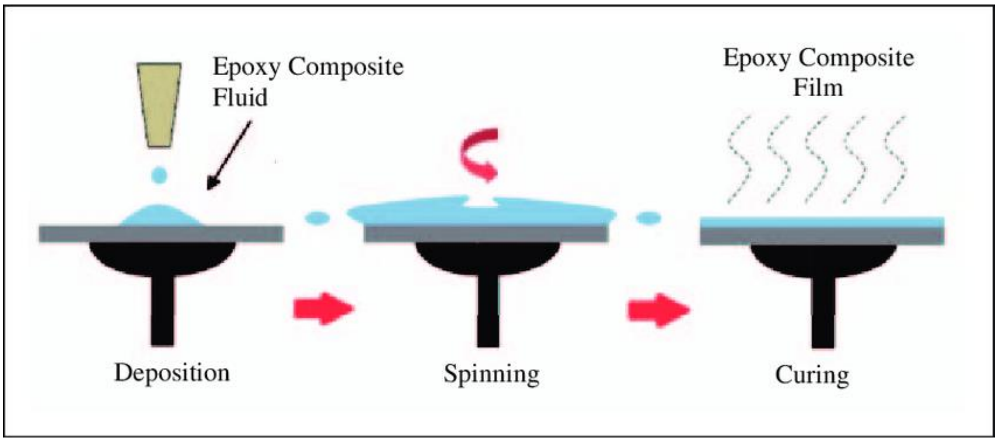
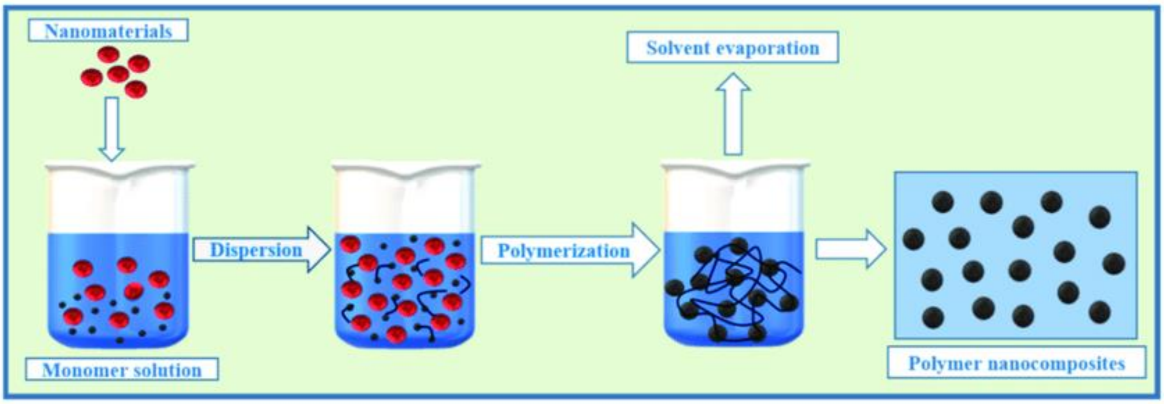


Figure 4.3.2 Spin coating process

(C) In Situ Polymerization:

Monomers (e.g., 3,4-ethylenedioxythiophene) are polymerized directly on textiles to form PEDOT:PSS layers. This enhances adhesion and conductivity, achieving sheet resistances reduced by 3–4 orders of magnitude with secondary dopants like ethylene glycol.



2. Hybrid Fiber Production:

(A). Solution Blending and Co-Extrusion:

Researchers at Washington State University merged dissolved cotton cellulose with polyaniline (PANI) solutions to create hybrid fibers. The cotton provides mechanical support, while PANI enables conductivity. This approach balances flexibility (cotton) and electrical performance (PANI), suitable for sensors and health-monitoring textiles.

(B). Composite Fibers:

Conductive polymers like PEDOT:PSS are blended with flexible polymers (e.g., polyurethane) to improve stretchability. For instance, PEDOT:PSS/polyurethane composites retain conductivity even under mechanical stress.

3. Advanced Manufacturing Techniques:

(A).Electrospinning:

Produces nanofiber mats from conductive polymer solutions. Pure PEDOT:PSS fibers made via electrospinning exhibit high conductivity and are integrated into wearable sensors.

(B). 3D/4D Printing:

Layer-by-layer 3D printing allows precise deposition of conductive inks (e.g., carbon-based or silver nanoparticles) onto textiles. This method supports complex geometries and multifunctional e-textiles, such as antennas or energy-harvesting devices.

(C). Conductive Yarn Integration:

Conductive filaments (e.g., silver-coated or carbon-based) are woven or knitted into fabrics during production. Carbon nanotube-integrated polyester fabrics achieved conductivity up to 7.4×10^2 S/m, suitable for bio-potential monitoring.

4. Functional Enhancements:

(A). Durability Treatments:

Polydopamine and silver nanoparticle coatings improve wash resistance and antibacterial properties. For example, cotton fabrics treated with polydopamine and silver showed 110 dB EMI shielding and conductivity of 1,000 S/cm.

Post-treatment with polar solvents (e.g., dimethyl sulfoxide) enhances PEDOT:PSS conductivity by reorganizing polymer chains.

Applications and Challenges

Applications:

1. Wearable sensors (strain, ECG, gas detection).
2. EMI shielding, energy storage, and RFID tags.

Challenges:

1. Balancing conductivity with mechanical flexibility and breathability.
2. Ensuring long-term durability under washing and stretching.

By leveraging these techniques, smart textiles are evolving toward seamless integration into everyday wear, offering multifunctional capabilities while addressing scalability and sustainability concerns.

Fabrication Process: Example: ***F**abricating a conductive textile sensor by coating yarns with CNTs and then integrating them into a knitted structure*

(a) Stirring: CNTs are initially mixed in a liquid solution using a mechanical stirrer. This ensures a uniform dispersion of the nanotubes.

(b) Sonification: The solution is then subjected to sonification, likely using an ultrasonic bath. This process further breaks down any CNT agglomerates and improves dispersion quality.

(c) CNT Impregnation: Yarns are passed through the CNT solution, allowing the nanotubes to coat and impregnate the fibers.

(d) Two-way Drying: The CNT-coated yarns are dried using a two-way drying process. This likely involves both heat and airflow to ensure even drying and prevent clumping. The result is conductive yarns.

(e) Conductive Yarns: These conductive yarns, along with non-conductive yarns (used as spacing yarns) and two electrode threads, are knitted into a fabric structure.

(f) Knitted Sensor Layer: The knitted structure is then laminated between two layers. The conductive yarns, along with the spacing and electrode threads, form the sensing elements of the knitted sensor layer.

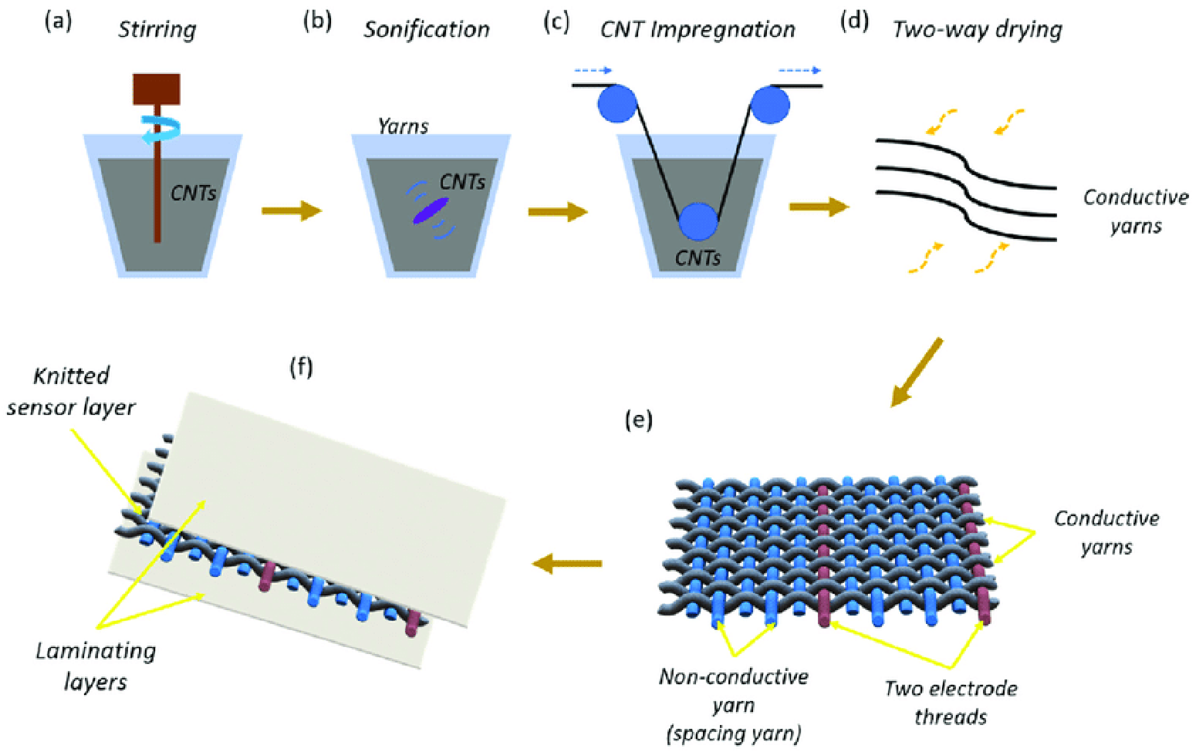


Figure: Creating conductive yarns using carbon nanotubes (CNTs) and their integration into a knitted sensor fabric.