Department of Biomedical Engineering

VI Semester

CBM 370 - Wearable Devices

Unit- 4 SMART TEXTILE

4.7 -Case study-

Smart fabric for monitoring biological parameters – Respiration

Smart fabrics for monitoring biological parameters, such as respiration, are an exciting area of research in wearable technology. These fabrics integrate sensors directly into textiles to provide continuous, non-invasive monitoring of respiratory rate, breathing patterns, and potential anomalies. These systems enable real-time health monitoring in both clinical and daily life settings, offering significant potential for early diagnosis and personalized care.

Sensor Technologies and Implementations:

1. Organic Semiconductor-Based Biosensors
2. Textile Pressure Sensor Belts
3. Fiber Bragg Grating (FBG) Sensors

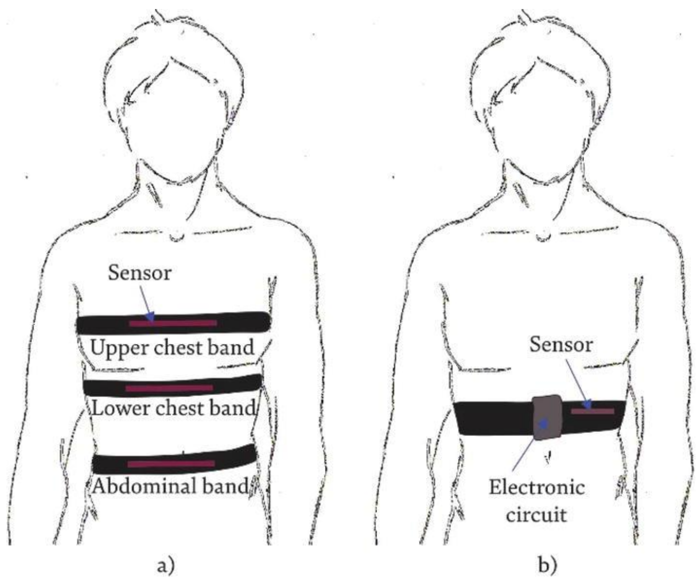
1. Organic Semiconductor-Based Biosensors:

- Developed by researchers at the University of Arkansas, these sensors are embedded into wireless "smart fabrics" (e.g., vests) to monitor respiration rate and body temperature.
- Advantages: Lightweight, flexible, and cost-effective due to organic materials, enabling large-scale production.

- Organic semiconductor, have fabricated and tested two similar but slightly different biosensors that can measure important physiological signs.
- The addition of carbon nanotubes with pentacene increases sensor sensitivity.
- The strain sensor, which would monitor respiration rate, consisted of a Wheatstone bridge, an instrument that measures unknown electrical resistance, and a thin pentacene film that acted as a sensing layer. The system would work when a physiological strain, such as breathing, creates a mechanical deformation of the sensor, which then affects the electrical current's resistance.

2. Textile Pressure Sensor Belts

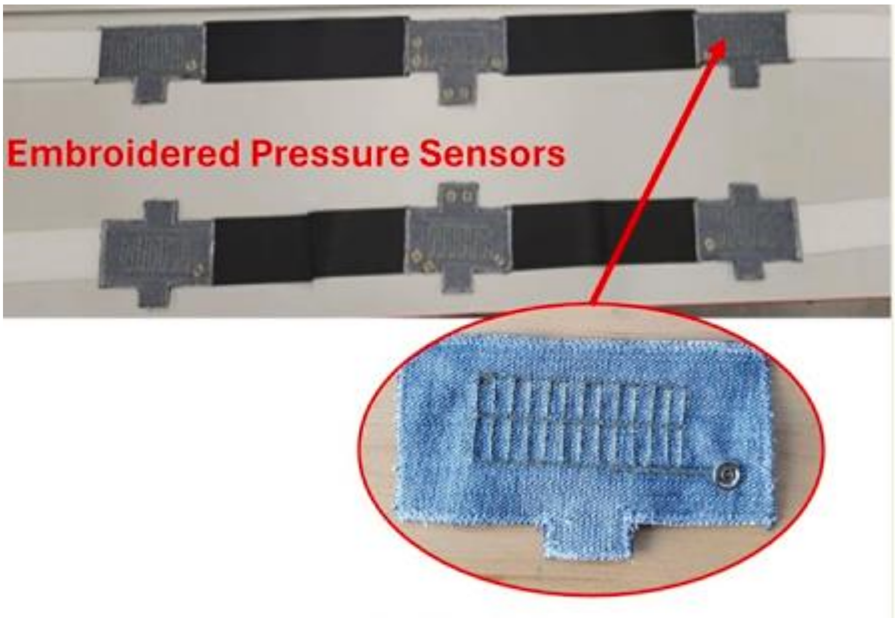
- SolunumWear (2024): A multi-sensory e-textile system using a chest belt with pressure sensors to detect chest movements.
- Validated across postures (sitting, standing, lying) with strong correlation to gold-standard optical systems (R = 0.836).
- Low latency (4.84 ms computational delay) supports real-time apnea detection.



- **(a) Multi-band sensor system**:
  - ✓ Uses three bands (upper chest, lower chest, and abdominal) with embedded sensors.
  - ✓ Likely measures expansion and contraction in different regions for detailed respiratory analysis.

❖ **(b) Single-band sensor system with electronics**:

- ✓ A single belt-like band contains a sensor and an electronic circuit.
- ✓ Likely processes and transmits respiratory data wirelessly.



❒ SolunumWear, a smart respiration monitoring system designed with electronic textile (e-textile) sensors. The system comprises an in-house developed chest belt integrated with pressure sensors and wireless infrastructure consisting of a wearable data acquisition system and a telemonitoring communication system

3. Fiber Bragg Grating (FBG) Sensors:

❒ Fiber-optic sensors woven into elastic belts measure thoraco-abdominal movements.

❒ Accurately track breathing frequency, tidal volume, and inspiratory/expiratory phases with minimal bias (e.g., −0.02 breaths/min).

❒ Effective across body positions, though accuracy varies slightly between individuals.

❒ Fiber Bragg Grating (FBG) sensors are optical fiber-based sensors that function by reflecting specific wavelengths of light while transmitting others. These sensors can be embedded into smart fabrics for continuous, real-time monitoring of physiological parameters, including respiration.

❒ **Optical Fiber Integration**:

❖ A Bragg grating (periodic variation in refractive index) is inscribed inside an optical fiber.

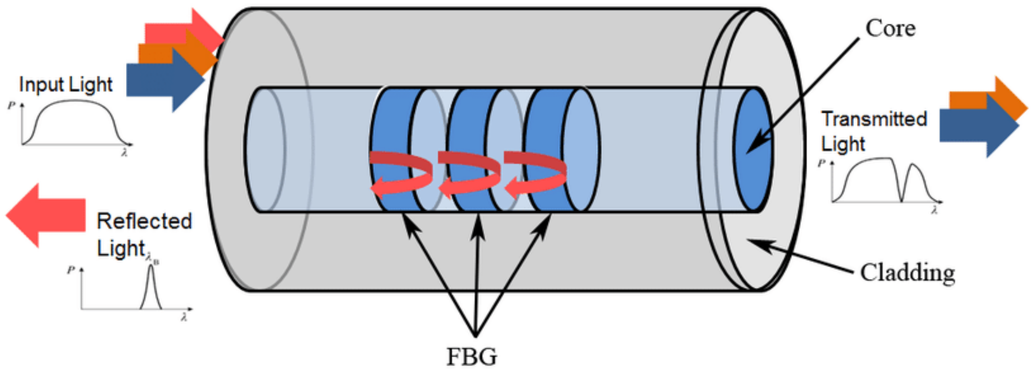
❖ When stretched or compressed due to respiration-induced chest movements, the grating changes the wavelength of reflected light.

❒ **Breathing Pattern Detection**:

❖ Inhalation: The chest expands, inducing strain on the FBG sensor, shifting the reflected wavelength.

❖ Exhalation: The chest contracts, relieving strain, and restoring the wavelength to its baseline.

❖ These shifts correlate with respiratory rate, depth, and anomalies (e.g., apnea, shallow breathing).



Fiber Bragg Grating (FBG)

<u>Components</u>:

1. **Core** – The central part of the optical fiber where light travels.
2. **Cladding** – The outer layer that ensures total internal reflection within the core.
3. **FBG (Fiber Bragg Grating)** – A series of periodic variations in the refractive index within the core, acting as a selective reflector.

<u>Working Principle</u>:

- **Input Light**: A broadband light source is sent into the fiber.
- **Bragg Reflection**: The FBG selectively reflects a specific wavelength of light (Bragg wavelength, λ_B), while allowing the rest to pass through.
- **Transmitted Light**: The remaining light continues to travel through the fiber, with a portion of it missing due to reflection.
- **Strain or Temperature Changes**:
  - When the fiber is stretched or compressed (e.g., due to respiration-induced chest movement), the spacing of the Bragg gratings changes.
  - This alters the reflected wavelength, which can be measured to detect physiological changes like breathing rate and depth.

Respiration Monitoring in Smart Fabrics:

- ❒ **FBG sensors can be embedded in textiles** to measure respiratory motion through strain detection.
- ❒ **Highly accurate, flexible, and lightweight**, making them ideal for wearable medical applications.
- ❒ **Immune to electromagnetic interference**, ensuring reliability in various environments.

Performance Comparison:

Technology	Parameters Measured	Advantages	Validation
Organic Semiconductors	Respiration rate, body temperature	Wireless, low-cost, flexible integration.	Laboratory testing.
Pressure Sensor Belts	Chest movement, breathing rate/posture	Robust in dynamic, real-world settings.	10-subject study vs. OptiTrack.
FBG Sensors	Thoraco-abdominal motion, tidal volume	High precision, immune to electromagnetic noise.	8-subject study vs. motion analysis

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