Wearable Printed Strain – Temperature Sensor for Erectile Dysfunction Monitoring

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Background

Erectile dysfunction (ED) affects over 50% of men aged 40–70. Current assessments (questionnaires, RigiScan) are subjective or cumbersome. This work introduces a dual-sensor patch combining strain and temperature sensing for objective, skin-conformal ED monitoring. [1] – [4]

"I quantify deformation with precision. Every micron of elongation is translated into resistance change. My role: to monitor axial rigidity and mechanical response in real time."

[6]
- Flaccid length: 7-10cm
- Erect length: 12-16cm

Length increases by **60-100%**

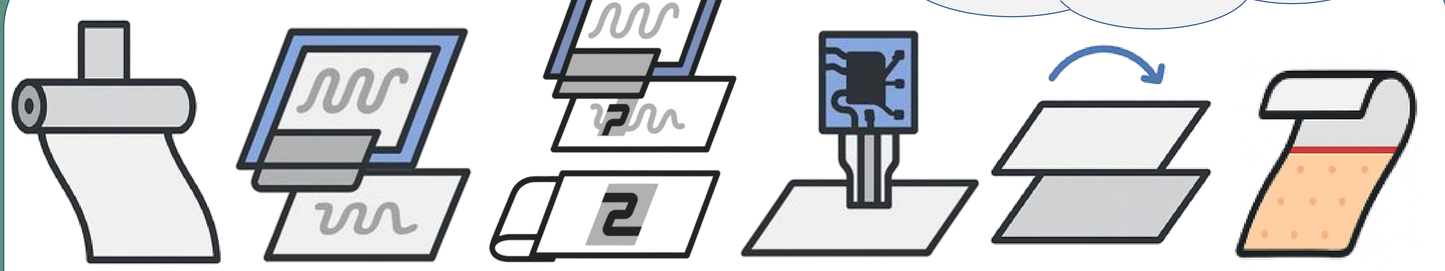
- Flaccid circumference: 9-10cm
- Erect circumference: 11-13cm

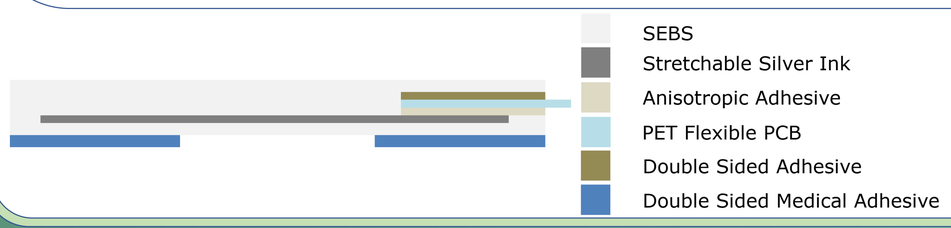
Circumference increases by **15-25%**

"I detect perfusion through thermal variation. Subtle shifts in skin temperature reveal underlying vascular activity. My function: to correlate physiological heat patterns with erection dynamics."

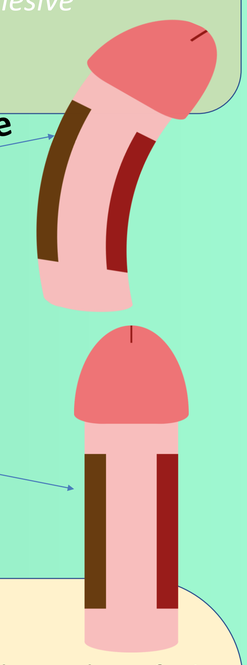
Sensor Fabrication Process

[5]
- Baseline (Flaccid) Penile Temperature: ~32 – 34°C
- During erection (full tumescence): ~34.5 – 37°C
- Average Rise: +0.5 – +2.5°C
- Typical mean rise: +1.5°C in healthy men





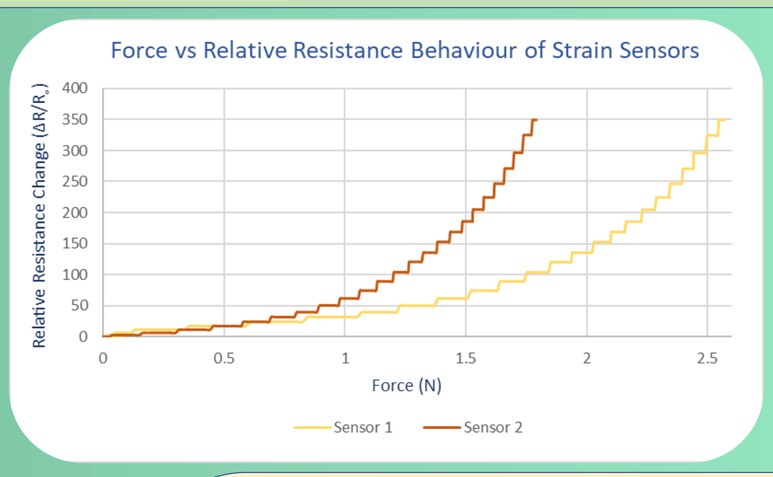
Step 1: *SEBS extruded into a thin elastic sheet*
Step 2: *Stretchable silver ink screen printed on the SEBS to form strain sensor*
Step 3: *Silver ink printed on PET to form temperature sensor*
Step 4: *Both sensors are connected to FPCB using anisotropic adhesive*
Step 5: *Patch is encapsulated with additional layer of SEBS*
Step 6: *Double sided skin adhesive is integrated*



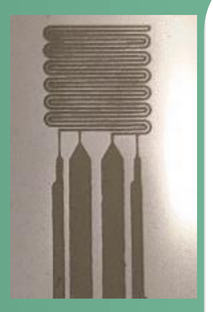
Results

Specimen Number		Specimen	Peak Load (N)
1	✗	SEBS Single	1.652
2	✓	SEBS Double	3.579
3	✗	Flexdym Single	1.291
4	✓	Flexdym Double	2.464
5	✓	Flexdym Triple	3.561
6	↷	SEBS Single Flexdym Single	3.003
7	↷	SEBS Double Flexdym Single	4.602
8	?	SEBS Single Dragon Skin	4.161
9	?	Flexdym Single Dragon Skin	3.343
10	?	SEBS Single Ecoflex	2.619
11	?	Flexdym Single Ecoflex	1.902

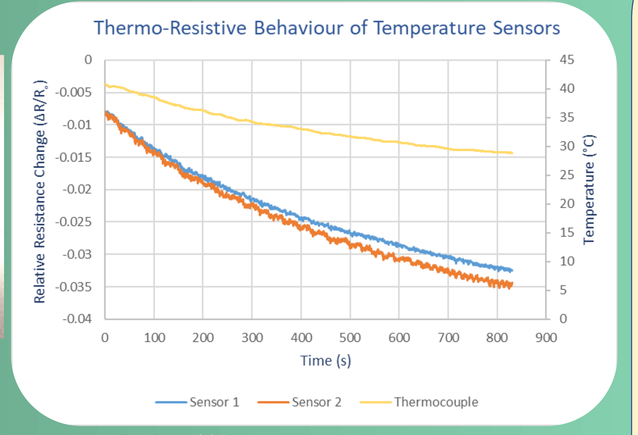
[7] Rigidity Category	Force Range (N)	Interpretation
Insufficient	< 3.92	Flaccid / weak rigidity
Borderline	3.92 – 4.9	Partial rigidity, borderline ED
Sufficient	4.9 – 9.8	Functional rigidity for penetration
Optimum	> 9.8	Full rigidity / healthy function

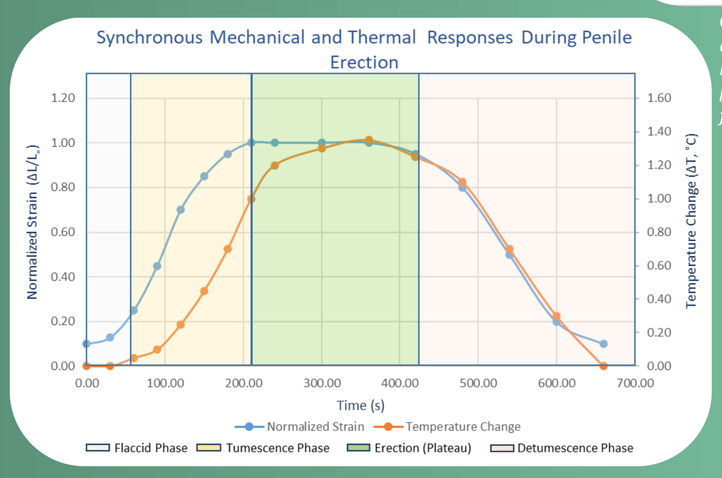


Caption: *(a) Force-dependent resistance behavior of SEBS based strain sensors. Both sensors exhibit a nonlinear increase in relative resistance ($\Delta R/R_0$) with applied force. Sensor 2 exhibits higher sensitivity, indicating greater strain transfer efficiency due to its lower modulus and smoother surface characteristics.*

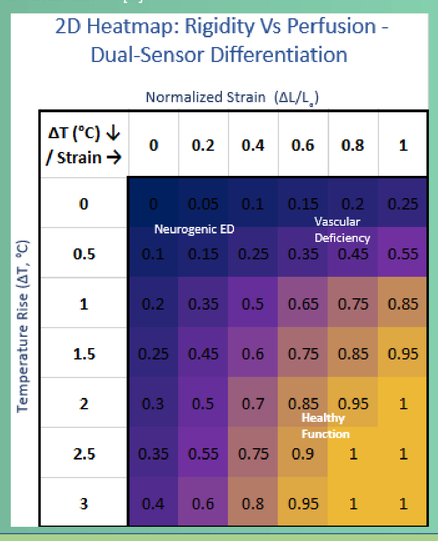


Caption: *(b) Thermo-resistive response of temperature sensors under a 10 mA current source. The sensor exhibits a monotonic resistance decrease as temperature drops from 40.9 °C to 28.9 °C, closely following the thermocouple profile. The approximate sensitivity is ~0.0006 °C⁻¹, enabling detection of temperature variations as small as 0.1 °C.*





Caption: *(c) Synchronous strain and temperature responses during penile erection. Normalized strain reflects rigidity buildup, while a delayed temperature rise (~1.3 °C) indicates perfusion, highlighting distinct physiological phases from flaccid to detumescence. [8]*



ΔT (°C) ↓ / Strain →	0	0.2	0.4	0.6	0.8	1
0	0	0.05	0.1	0.15	0.2	0.25
0.5	0.1	0.15	0.25	0.35	0.45	0.55
1	0.2	0.35	0.5	0.65	0.75	0.85
1.5	0.25	0.45	0.6	0.75	0.85	0.95
2	0.3	0.5	0.7	0.85	0.95	1
2.5	0.35	0.55	0.75	0.9	1	1
3	0.4	0.6	0.8	0.95	1	1

Caption: *(d) 2D heatmap showing rigidity–perfusion correlation derived from dual-sensor data. The Erection Quality Index (EQI) integrates strain and temperature rise to distinguish functional zones: Neurogenic ED (low strain–low ΔT), Vascular Deficiency (high strain–low ΔT), and Healthy Function (high strain–high ΔT). [8]*

Discussion

- The dual-sensor patch simultaneously detects mechanical strain and thermal perfusion during erection.
- Strain sensors show linear, repeatable response under physiological loads (<2.5 N), operating below clinical rigidity limits (3.9–9.8 N).
- Temperature sensors are highly sensitive (~0.0006 $°C^{-1}$) and fast (<10 s), resolving small perfusion-related changes (~0.1 °C).
- Flexdym substrates enhance strain transfer and reproducibility versus SEBS through smoother, softer surfaces.
- Anisotropic adhesive interconnects ensure reliable electrical contact and flexibility for skin-mounted use.
- Correlated strain–temperature signals reveal synchronous rigidity and perfusion; thermal rise (~+1.3 °C) trails mechanical elongation.
- The 2D EQI heatmap differentiates neurogenic, vascular, and healthy responses, enabling non-invasive, quantitative ED assessment.

Conclusion

- The developed printed strain–temperature patch demonstrates accurate, repeatable dual-sensing performance on flexible substrates.
- This system forms a foundational step toward objective, non-invasive assessment of erectile function, correlating mechanical and vascular parameters.

Future Works

- Integrate wireless data acquisition for real-time, untethered monitoring.
- Optimize sensor geometry and encapsulation for long-term skin adhesion and comfort.
- Conduct in vivo and clinical validation to correlate patch data with standard diagnostics (e.g., RigiScan, thermography).
- Explore machine learning–based fusion algorithms for automated classification of vascular vs. neurogenic ED cases.

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Useful Links

1. https://eden-microfluidics.com/flexdym-microfluidic-chips/
2. https://www.dycotecmaterials.com/products/stretchable-inks/
3. https://www.uhasselt.be/nl/info-voor/bedrijven-en-organisaties/technology-offers/tumescence-measuring-wearable-patch
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5. https://www.uhasselt.be/en/onderzoeksgroepen-en/imo-imomec-fme