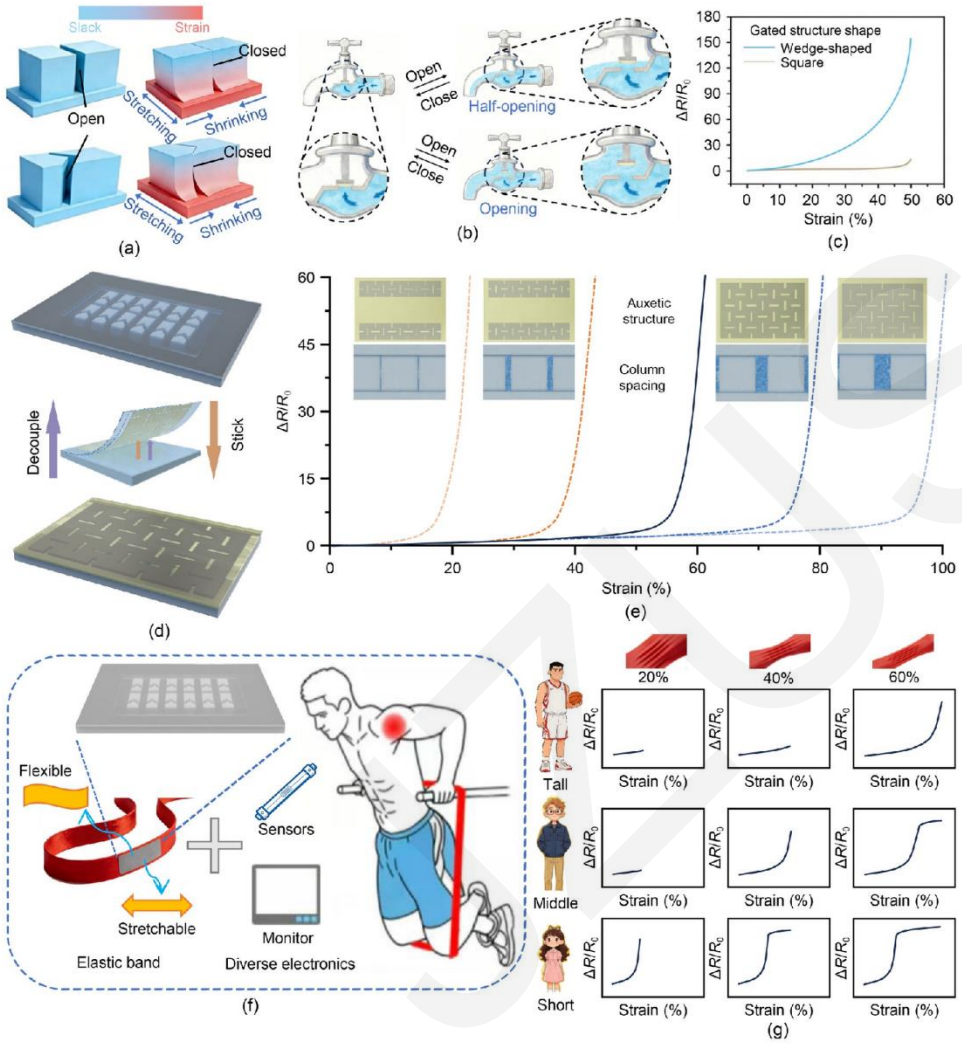
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Tunable gated strain sensor integrating detachable metamaterial structures for personalized motion recognition

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Design concept and fabrication



The device combines:

- a gated flexible strain sensor with an ionic-liquid sensing channel; and
- a detachable negative-Poisson's-ratio (NPR) metamaterial layer.

The gate controls the sensing threshold, while different detachable structures tune the response for personalized motion recognition.

Figure 1. Device concept, tunable gating, and personalized application.

Gated sensing mechanism and structural design

Mechanism:

- Stretching narrows the gaps between micropillars, constricting the ionic-liquid path.

- Wedge-shaped micropillars increase contact-area reduction and stress concentration.

- The detachable NPR layer shifts the onset strain and sensitivity.

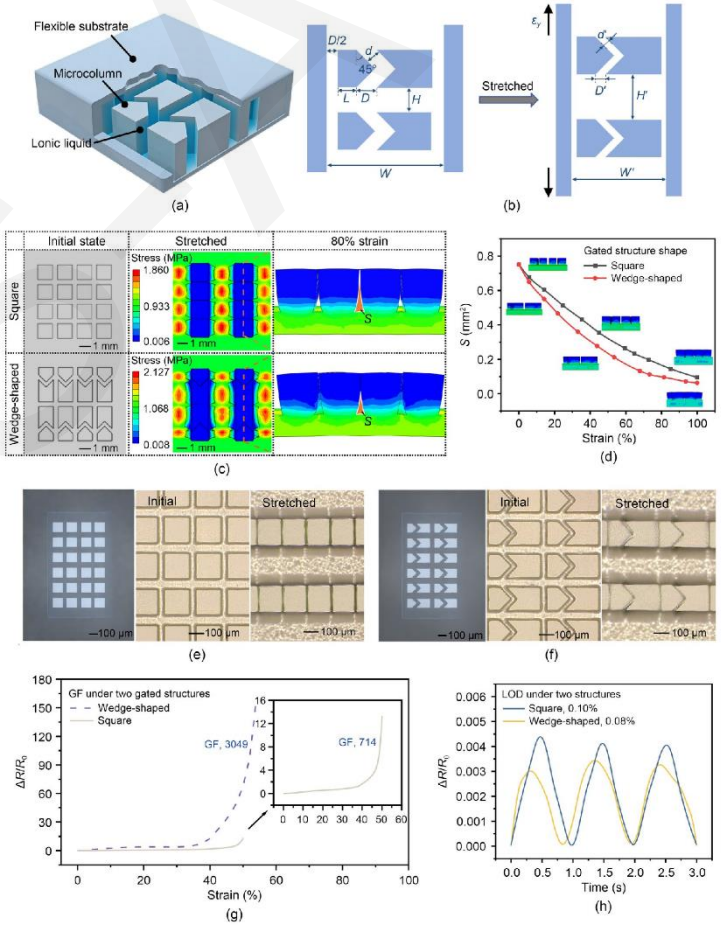


Figure 2. Gated sensor architecture and strain-dependent mechanism.

Parametric tuning of the negative Poisson's ratio metamaterial

- Parametric design and mechanical characterization of the perforated-plate NPR metamaterial.

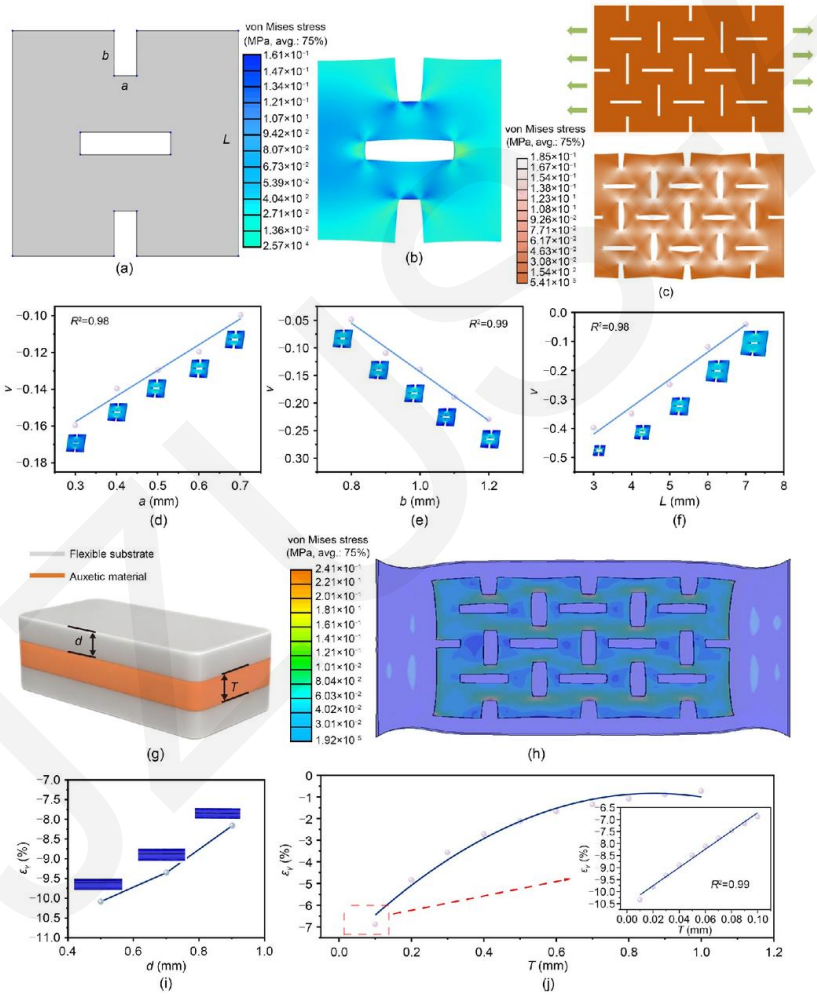


Figure 3. Structural parameters, stress distribution, and Poisson's-ratio tuning.

Performance modulation and dynamic characterization

- The detachable layer modulates sensitivity, sensing range, response speed, and cycling stability.

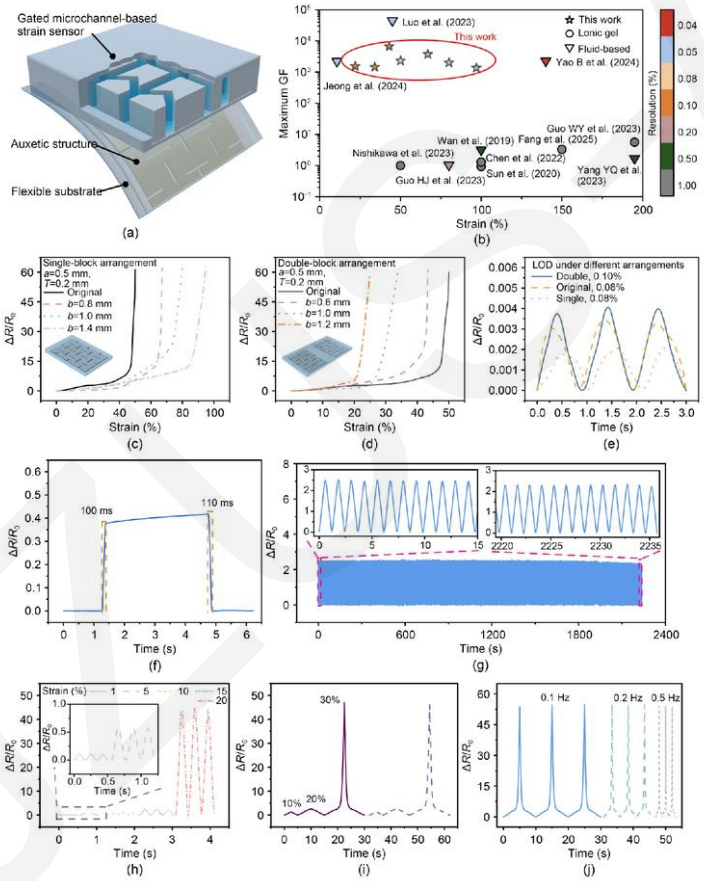


Figure 4. Performance tuning, GF,LOD, response time, cycling stability, and frequency adaptability.

Personalized motion monitoring

- A smart resistance band demonstrates personalized monitoring of dips, curls, and wrist torsion.

Application demonstration

The sensor was integrated into a smart resistance band. Its resistance signal tracks the stretching state during dips, curls, and wrist torsion.

Detachable NPR metamaterial layers shift the sensing threshold to accommodate different user heights and movement patterns.

Key performance

- Tunable strain range: 0–100%
- Maximum GF: 3049
- Limit of detection: 0.08%
- Response/recovery: 100/110 ms
- Negligible variation over 2000 cycles
- Stable response at 0.1, 0.2, and 0.5 Hz

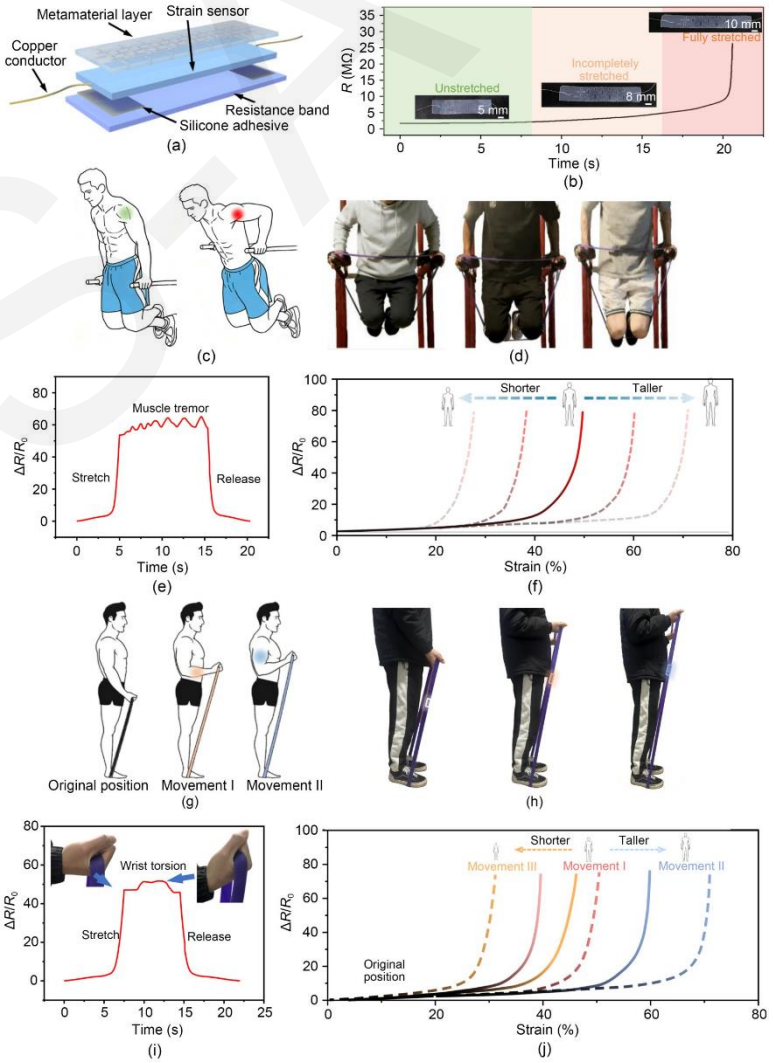


Figure 5. Practical applications of the smart resistance band-sensor system in personalized motion monitoring and sports safety

Conclusions

- Detachable NPR metamaterials enable continuous tuning from 0% to 100% strain.

- The optimized device achieves a maximum GF of 3049 and an LOD of 0.08%.

- Fast response/recovery (100/110 ms) and stable output over 2000 cycles support wearable monitoring.

- The resistance-band demonstration confirms personalized motion recognition across user heights and movement patterns.

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