Supporting Information

Stretchable and Neuromorphic transistors for Pain Perception and Sensitization Emulation

Yutong Xu,‡[a] Dapeng Liu,‡[a] Shilei Dai,[a] Junyao Zhang,[a] Ziyi Guo,[a] Xu Liu,[a] Lize Xiong,*[b] and Jia Huang*[ab]

[a] School of Materials Science and Engineering, Tongji University, Shanghai 201804, P. R. China.

[b] Translational Research Institute of Brain and Brain-Like Intelligence, Shanghai Key Laboratory of Anesthesiology and Brain Functional Modulation, Shanghai Fourth People's Hospital Affiliated to Tongji University, Tongji University, Shanghai, 200434, P. R. China.

E-mail: lizexiong@tongji.edu.cn; huangjia@tongji.edu.cn

‡ These authors contributed equally to this work.

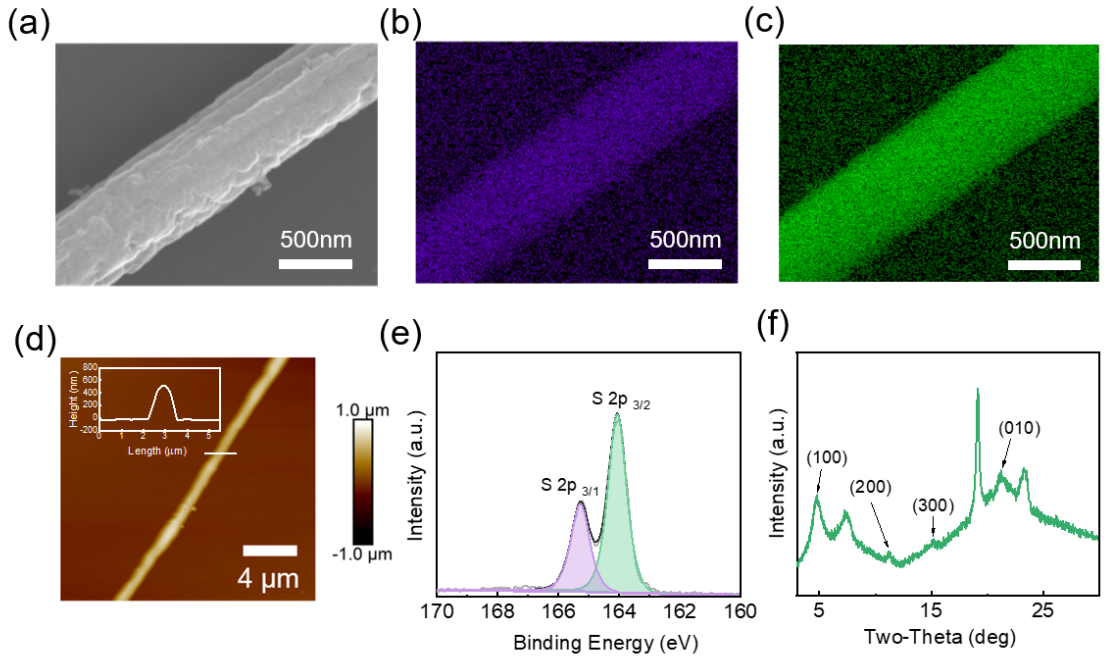

Figure S1. a) SEM image of single PQT-12/PEO nanofiber. b-c) Elemental mapping of (b) sulfur and (c) carbon in PQT-12/PEO nanofiber. d) AFM image of the diameter of PQT-12/PEO nanofiber. e) XPS spectra of S 2p peaks of PQT-12/PEO nanofiber. f) XRD pattern of PQT-12/PEO nanofiber.

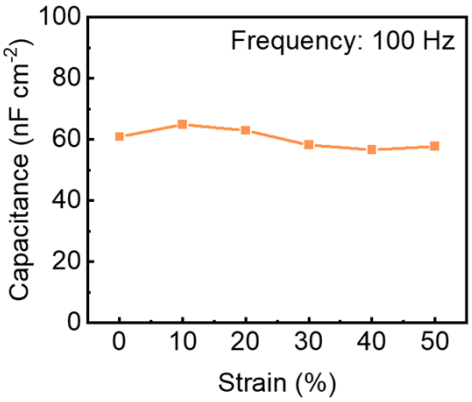

Figure S2. Capacitance of ion gel at different stretching ratios at 100 Hz frequency.

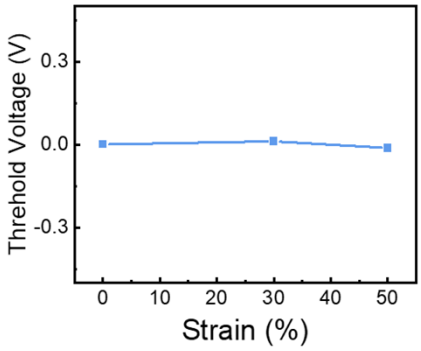

Figure S3. The transfer characteristic of threshold voltage of stretchable transistor at different strain ratios (0%, 30%, 50%).

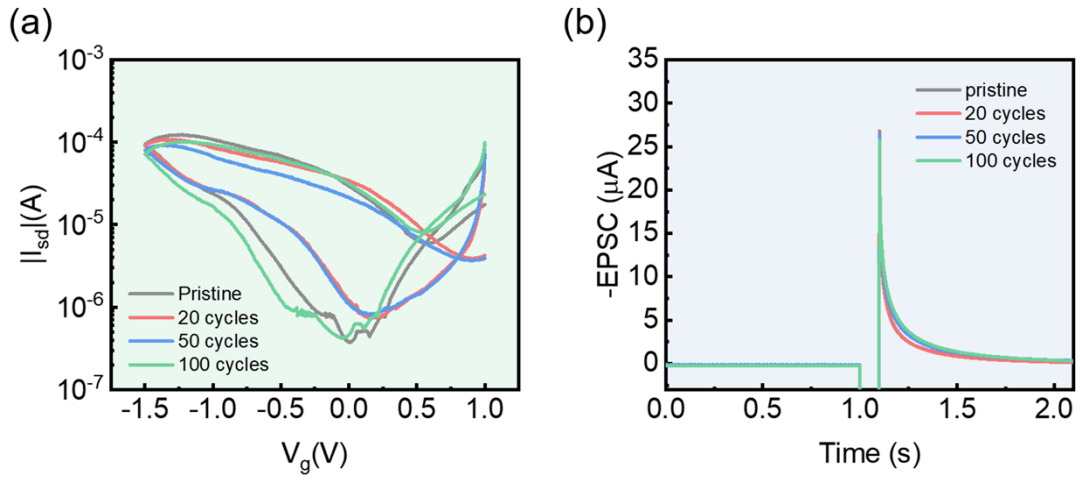

Figure S4. The transfer characteristic and EPSC (electronic pulse, -2 V, 100 ms) of the pristine state and 50% strain stretching after 20, 50, and 100 cycles.

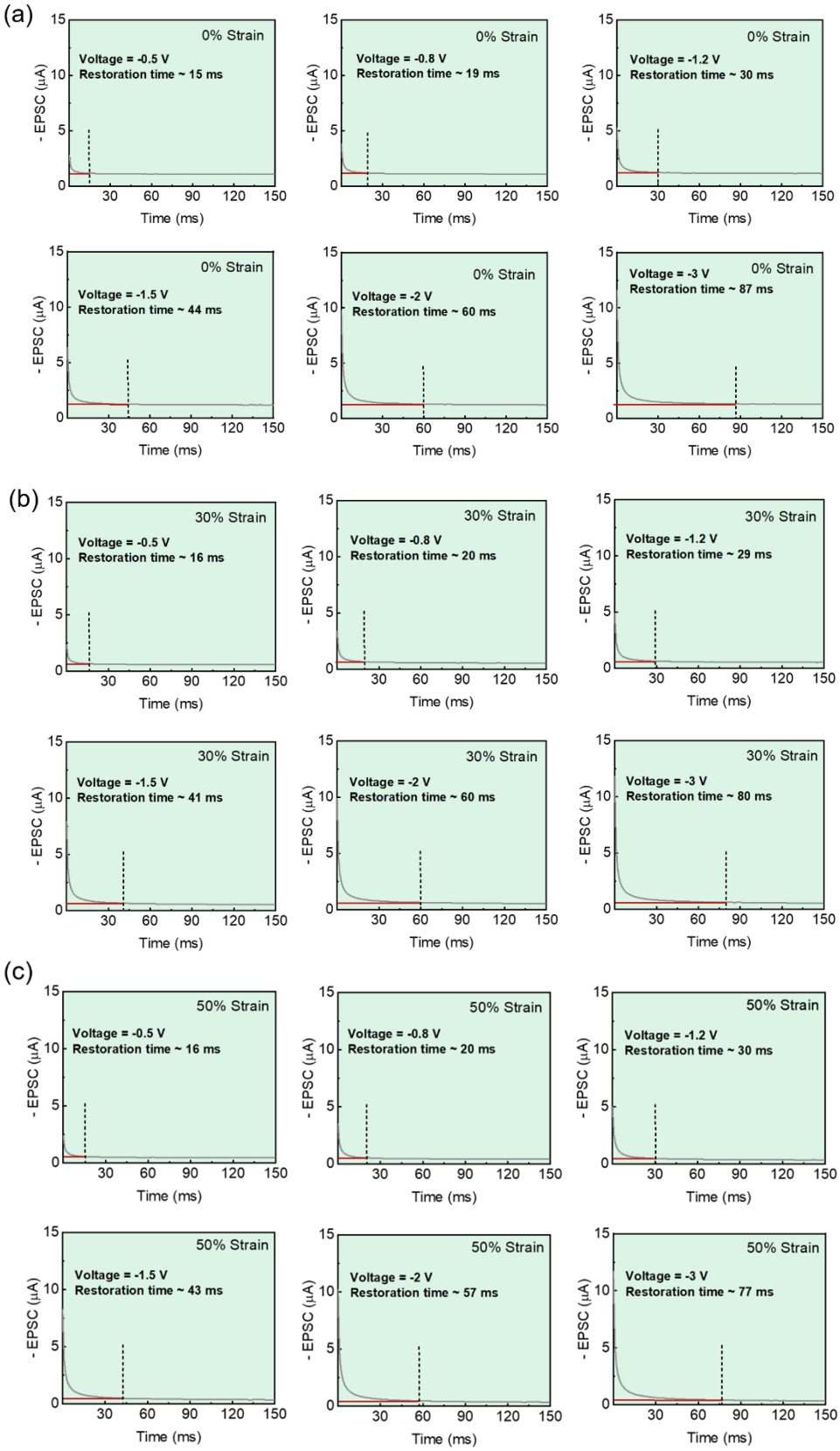

Figure S5. The current decay of different amplitude stimulus under the stretching ratio of a) 0%, b) 30%, and c) 50%.

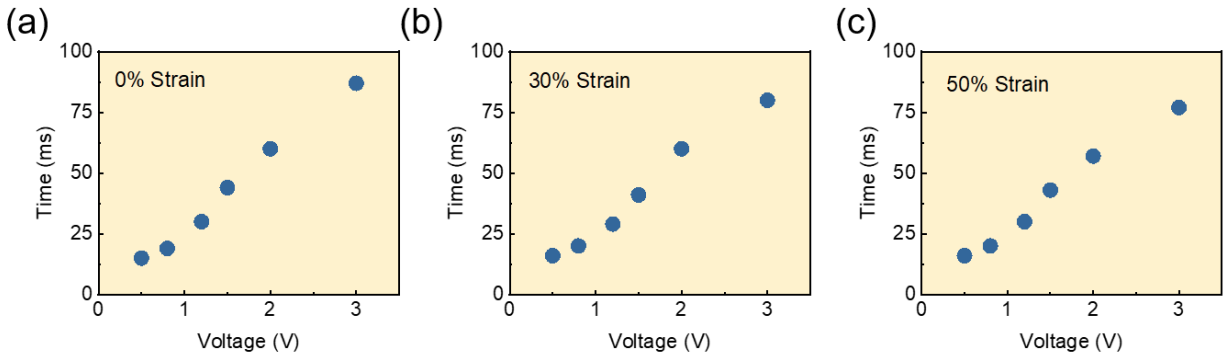

Figure S6. The current recovery time of the device after different amplitude pulses under different stretching ratios of a) 0%, b) 30%, and c) 50% strain.

Active layer	Electrolyte	Active ions	Mechanism	Threshold voltage/current level	Incubation time	flexibility	Reference	Year
ITO	Sodium alginate	H^+	EDL	~1.5 V/25 μA	10 ms	Rigid	1	2019
IZO	Chitosan	H^+	EDL	~1 V/10 nA	25 ms	Bendable	2	2020
VO_2/mica heterostructure	[DEME][BF_4]/PVDF-HFP ion gel	H^+	EDL	＞1 V/107 nA	80 ms	Bendable	3	2021
ITO	Xanthan gum	H^+	EDL	＞2 V/ 20 μA	10 ms	Rigid	4	2022
ITO	Sodium alginate	H^+	EDL	~2.7 V/1 μA	10 ms	Rigid	5	2022
ITO	Protonic silk fibroin/sodium alginate hydrogel	H^+	EDL	~0.35 V/0.5 μA	10 ms	Rigid	6	2023
PQT-12/PEO nanofibers	[EMIM][TFSI]/PEGDA ion gel	$[EMIM]^+$/$[TFSI]^-$	EDL	~2 V /10 μA	2 ms	**Stretchable**	**This work**	

*The symbol '~' indicates that the threshold current is reached at this voltage and application time, while the symbol '>' indicates that the exact voltage at the threshold is not given in the text, the range of threshold voltages can be obtained from the text.

Table S1. PPNs simulation based on the electrolyte-gated transistor in recent research works.

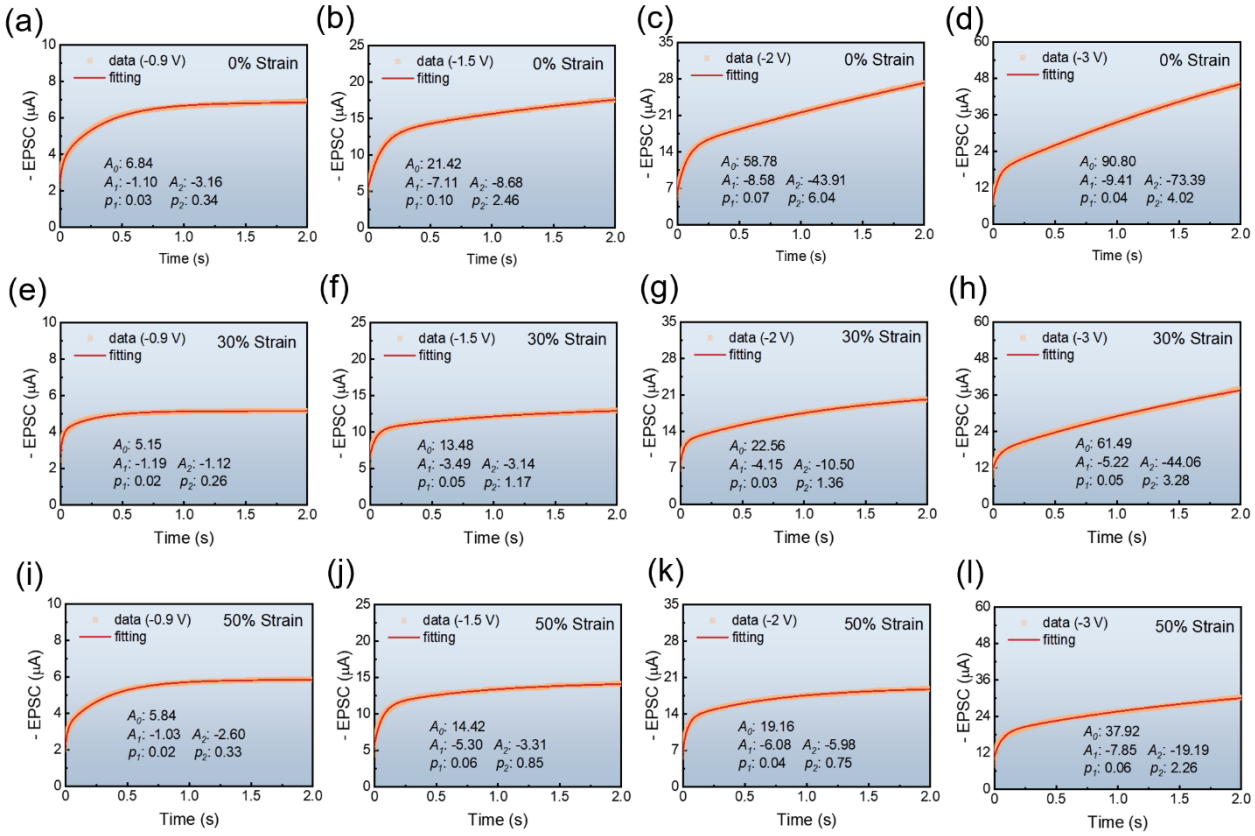

Figure S7. The fitting of two-phase sensitivity of the temporal characteristics to continuous multiple pulses at 0% (a-d), 30% (e-h), and 50% (i-l) strain. For each ratio, the pulse amplitude was set at 0.9 V, 1.5 V, 2 V, and 3 V respectively.

	Incubation time		
	0% Strain	30% Strain	50% Strain
-0.9 V	/	/	/
-1.5 V	88 ms	94 ms	84 ms
-2 V	36 ms	16 ms	2 ms
-3 V	8 ms	2 ms	4 ms

Table S2. The incubation time for excitatory current to reach the threshold at 0%, 30%, and 50% strain.

Reference:

1. G. Feng, J. Jiang, Y. Zhao, S. Wang, B. Liu, K. Yin, D. Niu, X. Li, Y. Chen, H. Duan, J. Yang, J. He, Y. Gao and Q. Wan, Adv. Mater., 2020, 32, e1906171.

2. S. Jiang, Y. He, R. Liu, C. Chen, L. Zhu, Y. Zhu, Y. Shi and Q. Wan, IEEE Trans. Electron Devices, 2021, 68, 415-420.

3. X. Deng, S. Q. Wang, Y. X. Liu, N. Zhong, Y. H. He, H. Peng, P. H. Xiang and C. G. Duan, Adv. Funct. Mater., 2021, 31, 2101099.

4. F. Z. Li, H. R. Liu, J. M. Guo, X. Y. Zhou, K. K. Liu, L. Z. Liang, X. Y. Pei, F. C. Zhou, F. Huang, H. Wang and Y. H. Liu, Adv. Intell. Syst., 2022, 4, 2200233.

5. Y. Li, K. Yin, Y. Diao, M. Fang, J. Yang, J. Zhang, H. Cao, X. Liu and J. Jiang, Nanoscale, 2022, 14, 2316-2326.

6. J. Su, Y. Li, D. Xie and J. Jiang, Mater. Horiz., 2023, 10, 1745-1756.