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Supplementary Information

Highly sensitive metal-grid strain sensors via water-based solution processing

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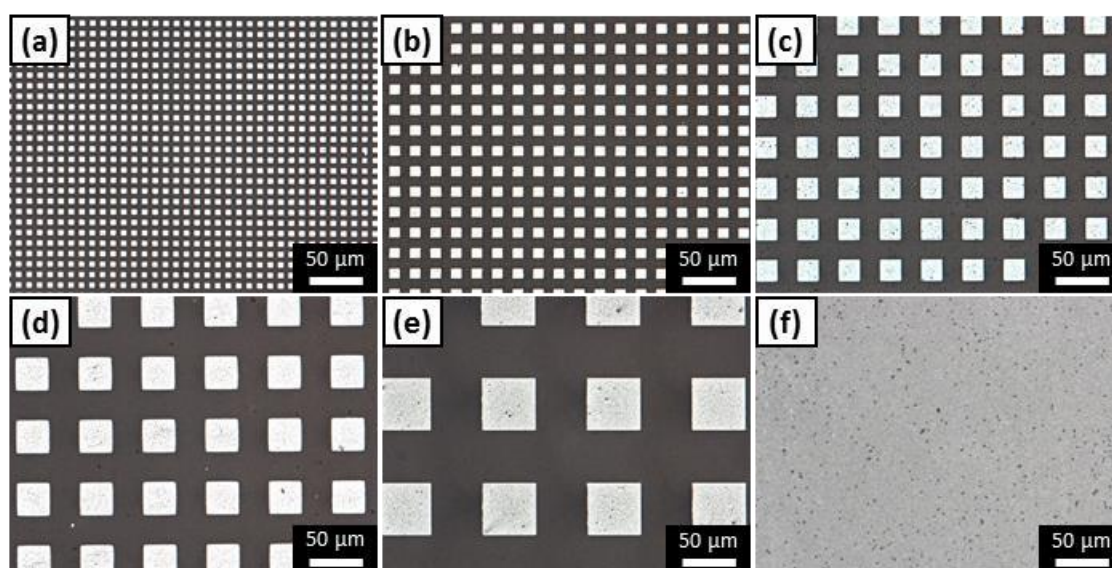

Fig. S1. Optical microscopic images of metal grid structures on PDMS with sizes of (a) 5:5 (width:spacing, µm), (b) 10:10 (c) 20:20 (d) 30:30 (e) 50:50 (f) complete metal film without pattern.

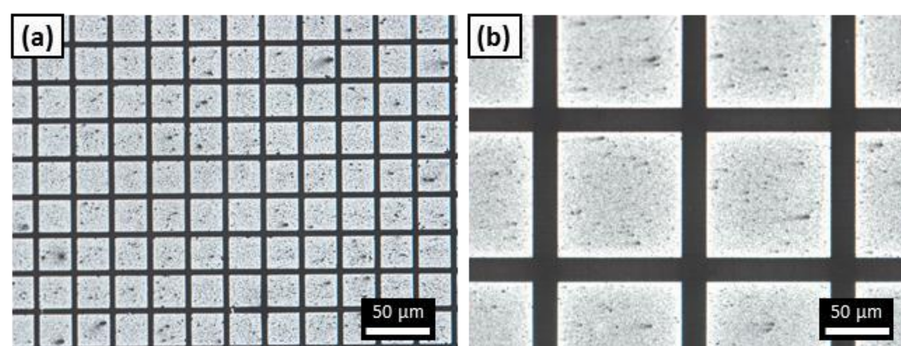

Fig. S2. Optical microscopic images of metal grid structures on PDMS with sizes of (a) 5:25, (b) 20:100.

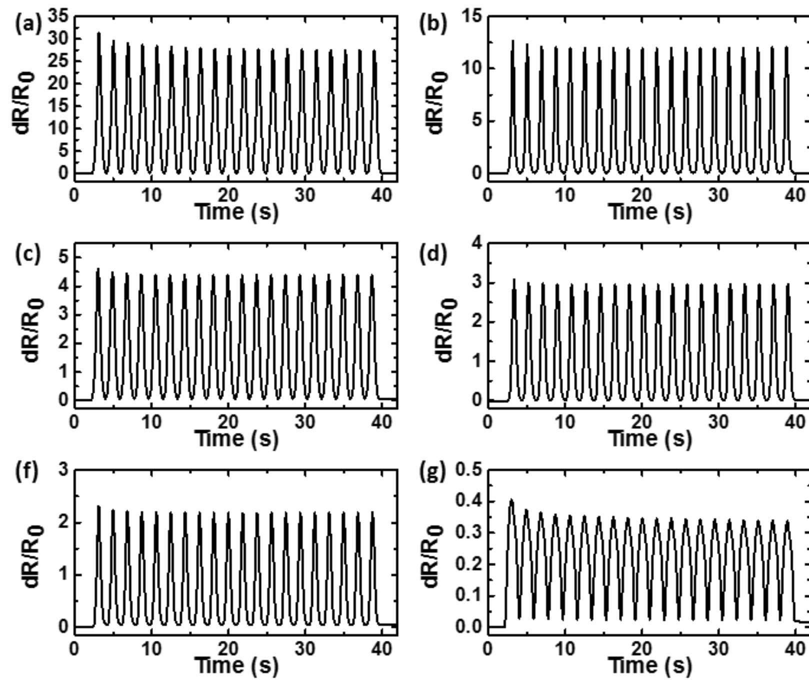

Fig. S3. Piezoresistance curves from repeated stretch/release cycles up to a strain, ε = 3% using strain sensors with different width and same width/spacing ratio. (a) 5:5, (b) 10:10, (c) 20:20, (d) 30:30, (e) 50:50, (f) whole film.

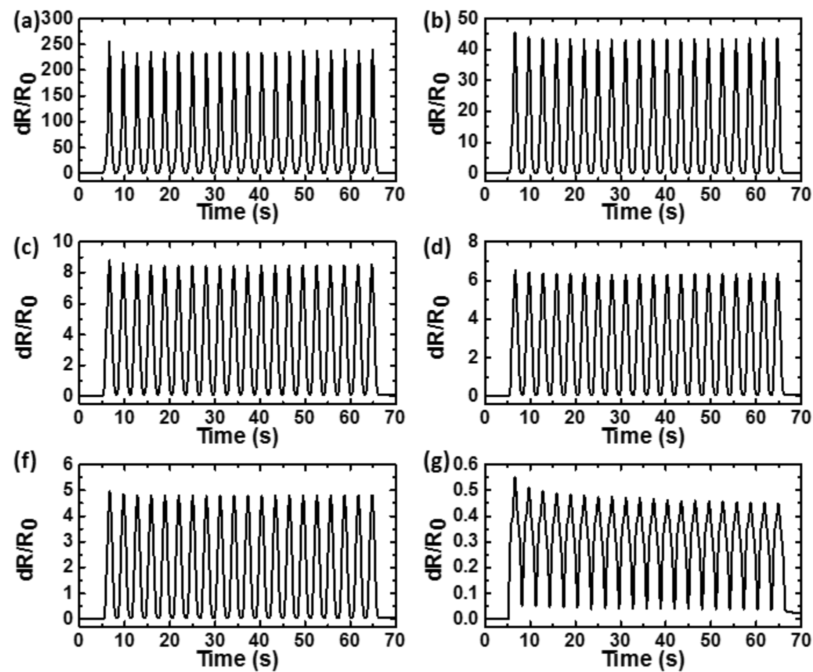

Fig. S4. Piezoresistance curves from repeated stretch/release cycles up to strain, ε = 5% using strain sensors with different width and same width/spacing ratio. (a) 5:5, (b) 10:10, (c) 20:20, (d) 30:30, (e) 50:50, (f) whole film.

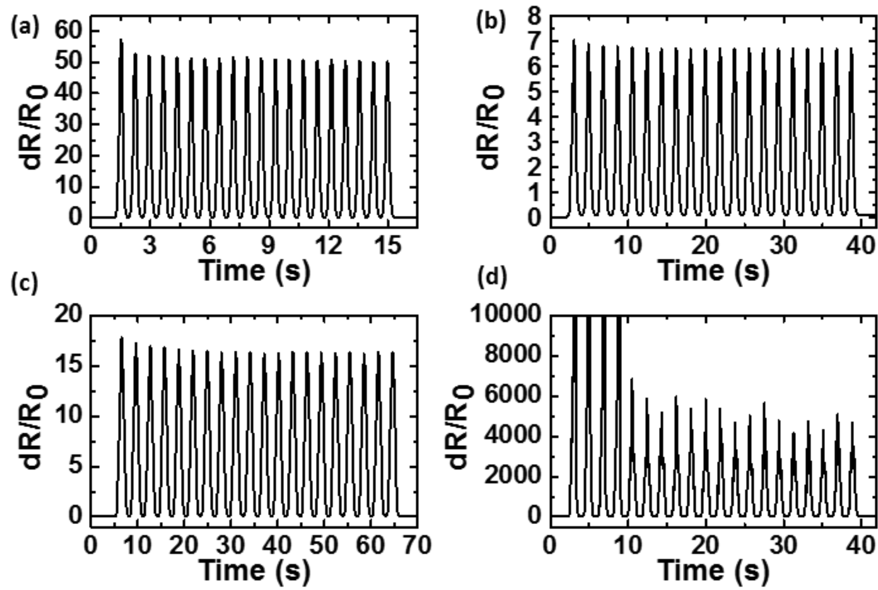

Fig. S5. Piezoresistance curves from repeated stretch/release cycles up to ε = 3% or 5% using strain sensors with different size (width:spacing, μm). (a) 20:100, up to ε = 3%, (b) 20:100, up to ε = 5%, (c) 5:25, up to ε = 3% (d) 5:25, up to ε = 5%.

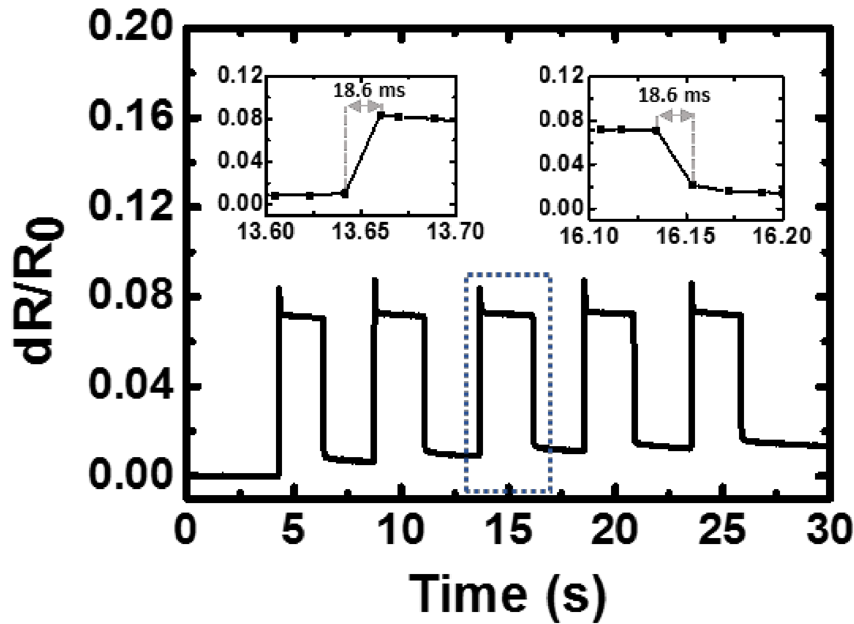

Fig. S6. Relative changes in resistance of 5:5 metal grid strain sensor as a function of time with cyclic stretch/release at ε = 0.2%. Insets show response time of 5:5 grid strain sensor at both stretch and release motion.

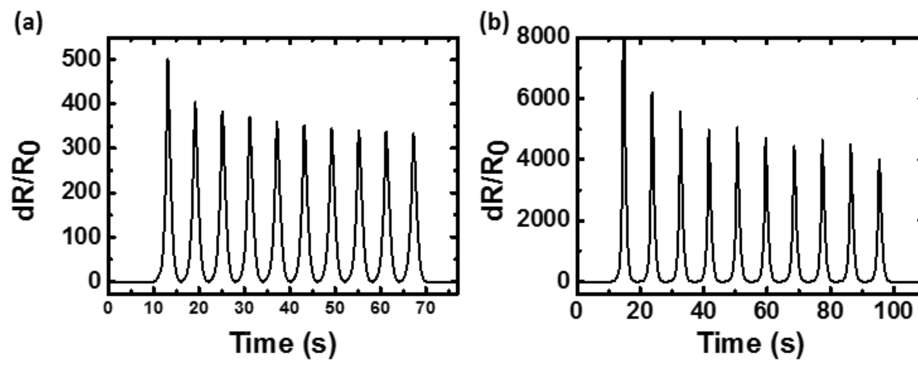

Fig. S7. Electrical response converted from tensile strain up to (a) ε = 10%, (b) ε = 15% using a 5:5 grid strain sensor.

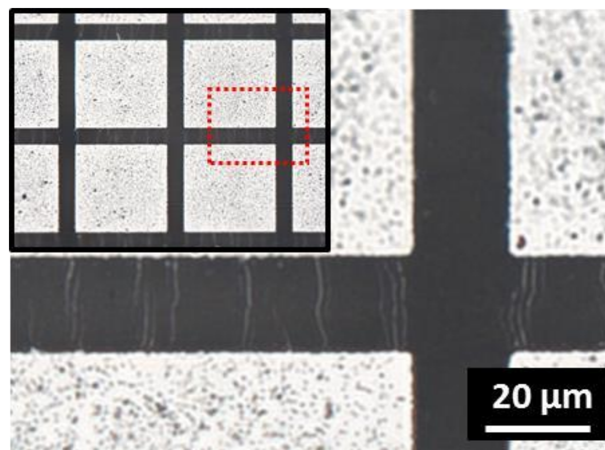

Fig. S8. OM image of 20:100 grid strain sensor as strained, ε = 3%. Inset is a lower magnification image, where the region indicated by the red box is shown in the higher magnification image.

Table S1. Comparison of the performance and methods of recently reported strain sensors.

Reference	Material	Fabrication method	Structure	Gauge Factor	Max. Strain (%)	Response Time
1	Pt/PUA	Sputtering	Metal film /Elastomer	2000	2	≥659 Hz[a)]
2	Pt/PUA	Sputtering	Metal film /Elastomer	16000	2	≥ 50 Hz [a)]
3	Pt/PU	Magnetron sputtering	Metal film /Elastomer	30	150	< 30 ms
4	Pt/PUA	-	Metal coating /Nanofiber	11.45	5	≥ 10 Hz [a)]
5	Au/PDMS	Electron beam evaporation	Metal film /Elastomer	5000	1	988 Hz [a)]
6	AuNP/PET	Convective assembly	AuNP/Film	300	-	> 20000 Hz [a)]
7	CrNP/Ag /PET	Magnetron sputtering /Mask evaporation deposition	CrNP/Interdigital electrode/Film	100	3	-
8	Ag NP /PDMS	Stamping	Metal NP film /Elastomer	2.05	20	-
9	AgNW /PDMS	Drop casting	Elastomer /Metal NW film /Elastomer	2-14	70	~ 200 ms
10	AuNW /PDMS	Dipping	Elastomer/AuNP /Interdigital Electrode (Elastomer)	7.38	25	< 17 ms
11	Graphite /Ecoflex	Bar coating	Carbon film/Elastomer	522.6-11344	>50	14 Hz [a)]
12	CB/Paper	Solvent mixing /Brushing	Carbon film/Paper	647	0.22	0.625 s
13	PEI-rGO /PDMS	Dipping /Spin coating	Elastomer /Carbon-multilayer /Elastomer	754	5	~ 0.6 s
14	CNT /PDMS	Filtering /Spin coating	Carbon paper /Elastomer	10^7	50	300 ms
This work	**Ag/AuNPs /PDMS**	**Solution process (Ag enhancement on AuNPs) /Spin coating**	**Grid metal /Elastomer**	**4685.9**	**5**	**18.6 ms**

a) When the response time is not given in the report, response time is estimated by the highest frequency.

References

1 D. Kang, P. V. Pikhitsa, Y. W. Choi, C. Lee, S. S. Shin, L. Piao, B. Park, K-Y. Suh, T.-I Kim and M. Choi, *Nature*, 2014, **516**, 222–226.

2 B. Park, J. Kim, D. Kang, C. Jeong, K. S. Kim, J. U. Kim, P. J. Yoo and T.-I. Kim, *Adv. Mater.*, 2016, **28**, 8130–8137.

3 H. Jeon, S. K. Hong, M. S. Kim, S. J. Cho and G. Lim, *ACS Appl. Mater. Interfaces*, 2017, **9**, 41712–41721.

4 C. Pang, G.-Y. Lee, T.-I. Kim, S.-M. Kim, H. N. Kim, S. H. Ahn and K.-Y. Suh, *Nat. Mater.*, 2012, **11**, 795–801.

5 T. Yang, X. Li, X. Jiang, S. Lin, J. Lao, J. Shi, Z. Zhen, Z. Li and H. Zhu, *Mater. Horizons*, 2016, **3**, 248–255.

6 L. Yi, W. Jiao, K. Wu, L. Qian, X. Yu, Q. Xia, K. Mao, S. Yuan, S. Wang and Y. Jiang, *Nano Res.*, 2015, **8**, 2978–2987.

7 M. Zheng, W. Li, M. Xu, N. Xu, P. Chen, M. Han and B. Xie, *Nanoscale*, 2014, **6**, 3930–3933.

8 J. Lee, S. Kim, J. Lee, D. Yang, B. C. Park, S. Ryu and I. Park, *Nanoscale*, 2014, **6**, 11932–11939.

9 M. Amjadi, A. Pichitpajongkit, S. Lee, S. Ryu and I. Park, *ACS Nano*, 2014, **8**, 5154–5163.

10 S. Gong, W. Schwalb, Y. Wang, Y. Chen, Y. Tang, J. Si, B. Shirinzadeh and W. Cheng, *Nat. Commun.*, 2014, **5**, 3132.

11 M. Amjadi, M. Turan, C. P. Clementson and M. Sitti, *ACS Appl. Mater. Interfaces*, 2016, **8**, 5618–5626.

12 H. Song, J. Zhang, D. Chen, K. Wang, S. Niu, Z. Han and L. Ren, *Nanoscale*, 2017, **9**, 1166–1173.

13 X. Ye, Z. Yuan, H. Tai, W. Li, X. Du and Y. Jiang, *J. Mater. Chem. C*, 2017, **5**, 7746–7752.

14 J. Zhou, H. Yu, X. Xu, F. Han and G. Lubineau, *ACS Appl. Mater. Interfaces*, 2017, **9**, 4835–4842.