Electronic Supplementary Material (ESI) for Nanoscale.
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Supporting Information

Flexible and Printable Paper–Based Strain Sensors for Wearable and Large–Area Green Electronics

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Fig. S1. The electronic waste hills around a dock (Copyright 2013, ifeng.com).

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Table S1. Comparison of the recently reported strain sensors.

Materials	Biodegradability	Cost	Method	Preparation process	Large-scale fabrication	Tailorability	GF	Response time	Strain resolution	Durability	Ref.
rGO/Au/PES	No	High	ALD, Hydrazine hydrate reduction & Electronic beam evaporation	Slow	Yes	No	~10	-	0.02%	10 000	1
Graphene/PET	No	High	UV lithography, Electronic beam evaporation & O_2-plasma etching	Slow	Yes	No	600	4 ms	-	10 000	2
CNT–Aramid nonwoven fabric	No	High	Solution casting process	Slow	Yes	-	4	-	-	-	3
Pt film/PUA/PET	No	High	UV exposure process, photolithography & Sputter deposition	slow	Yes	-	2079	-	-	-	4
Sb–doped ZnO/PS	No	Low	-	Fast	No	No	>1 000	600 ms	0.1%	-	5
CNT–AgNP/Silicone rubber	No	High	Printing	Fast	Yes	No	-	90 ms	-	10 000 (Drift 5%)	6
AuNPs/PET	No	High	Standard Turkevich method & Stop-and-go convective self-assembly	Fast	Yes	No	41	-	0.15%	-	7
CNT–AgNP/PDMS	No	High	Printing	Fast	Yes	No	95	50 ms	-	1 000	8
PDMS/AuNWs–Tissue paper/Au/PDMS	Part	High	Dip-coating Process & Electronic beam evaporation	Slow	Yes	No	7.38	17 ms	-	50 000	9
ZnO NWs/Carbon fiber/PET	Part	High	hydrothermal growth approach	Slow	NO	No	80	<500 ms	-	-	10
SWCNTs–PMMA/Buckypaper	Yes	High	Dispersion process & Vacuum drying	Slow	Yes	-	500	<40 ms	-	-	11
Graphene–Nanocellulose fibril	Yes	High	Vacuum filtration	Fast	-	-	502	-	-	-	12
Graphite–Clay/Paper	Yes	Low	Pencil–on–paper approach	Fast	No	-	536	110 ms	0.13%	10 000 (Drift 10%)	13
Graphite–MC/Paper	Yes	Low	Printing	Fast	Yes	Yes	804	19 ms	0.038%	10 000 (Drift 2%)	This work

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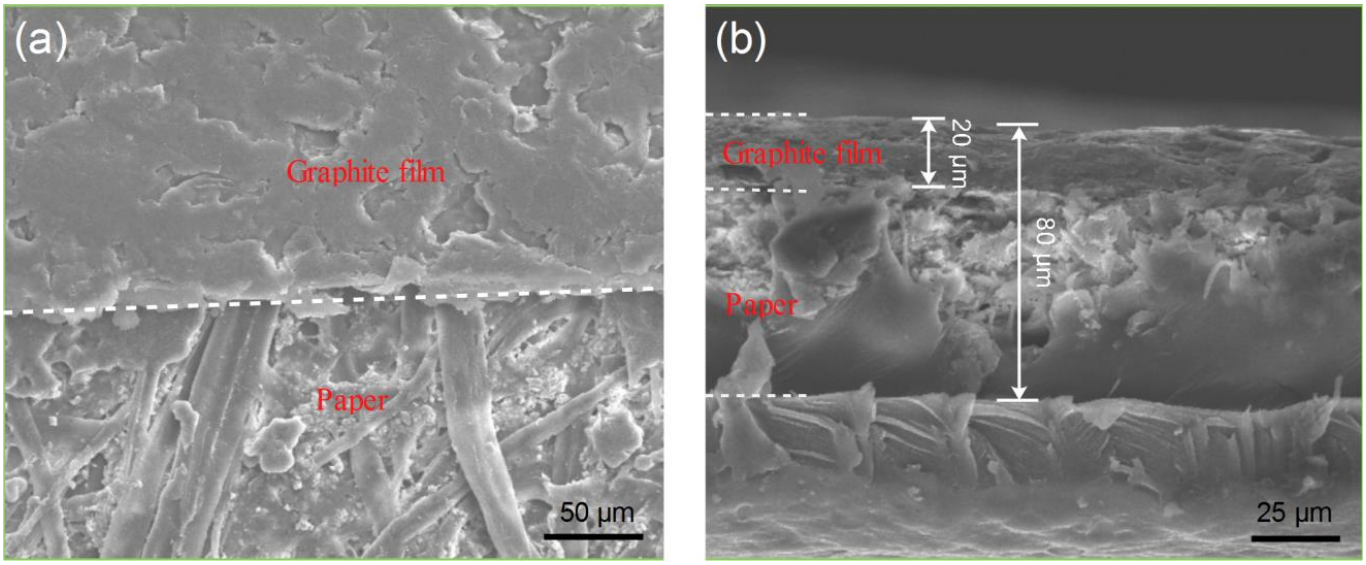

Fig. S2. (a) Part of well–patterned graphite thin film prepared on the green paper. (b) Cross–sectional image of the paper coated with the well–patterned graphite thin film.

Fig. S3. The phenomenon of soil cracking exists in nature, owing to drought (Copyright 2007, xinhuanet.com).

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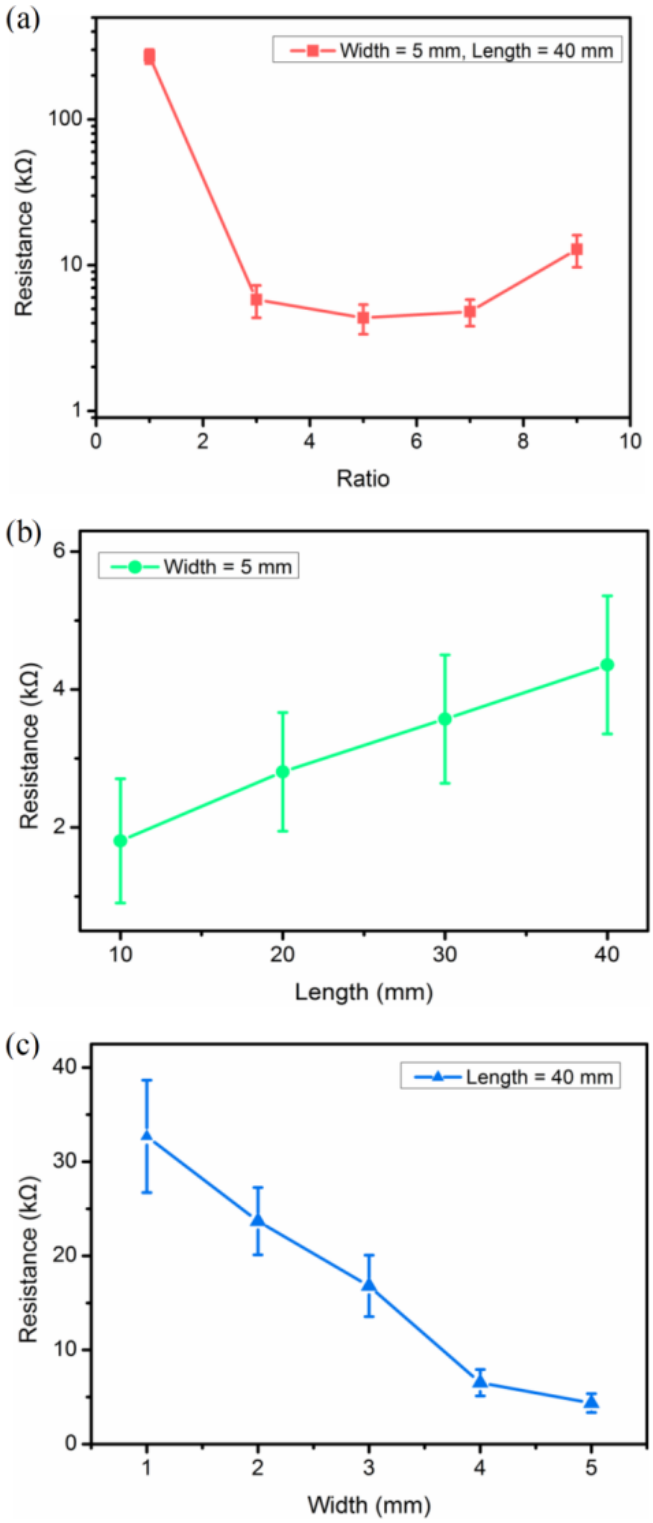

Fig. S4. (a) The electric resistance of well–patterned graphite thin film (length = 40 mm and width = 5 mm) as a function of the ratio of graphite and methylcellulose (MC). The electric resistance versus (b) length and (c) width of the well–patterned graphite thin film in a 5:1 weight ratio of graphite and MC.

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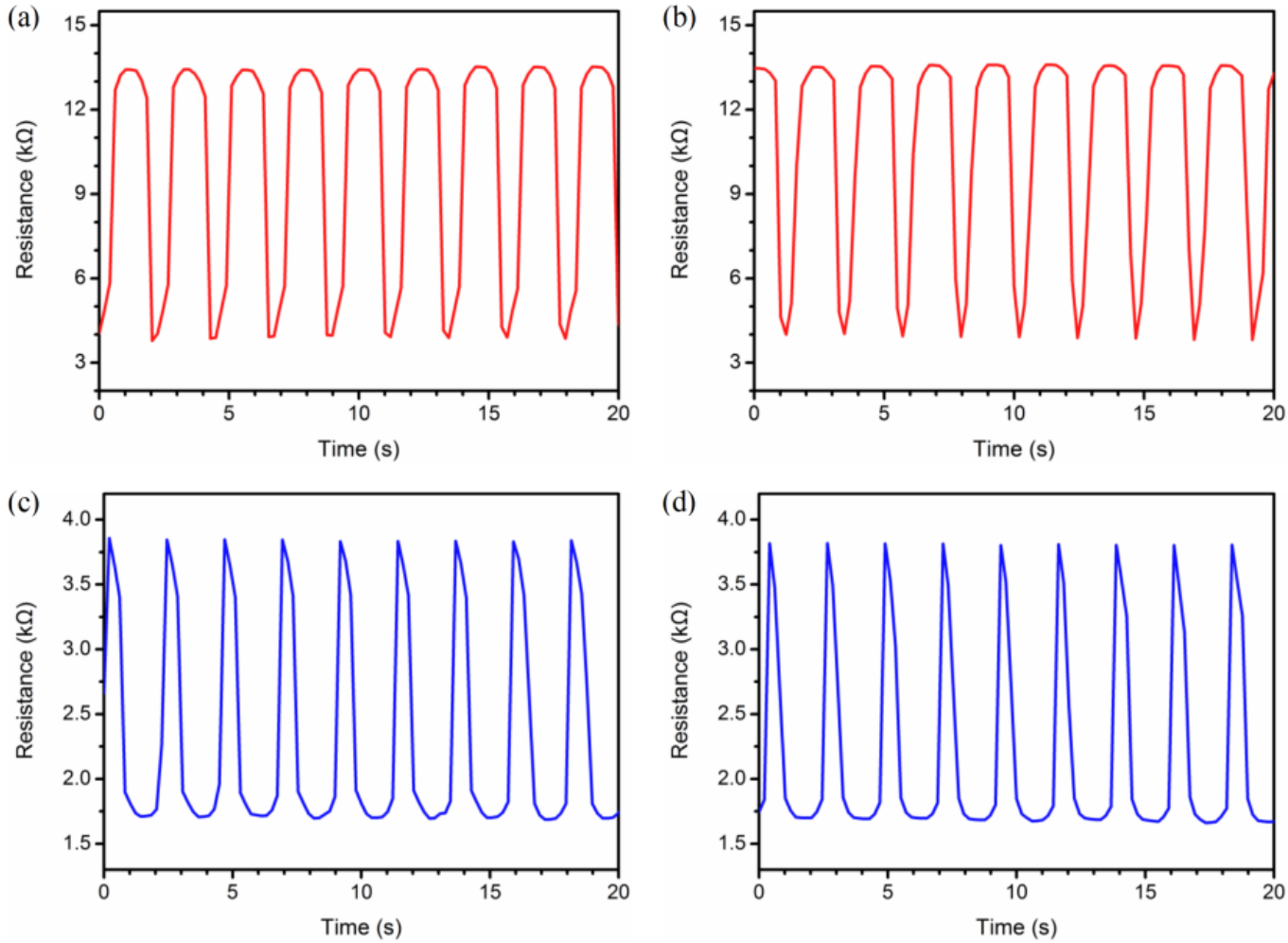

Fig. S5. The resistance changes versus multi-bending strain under both tensile (up, red) and compressive (down, blue) modes. (a, c) The response curves of PPBSSs during initial period for the tensile and compressive strain (~0.44%). (b, d) The response curves of PPBSSs after >5 000 bending cycles.

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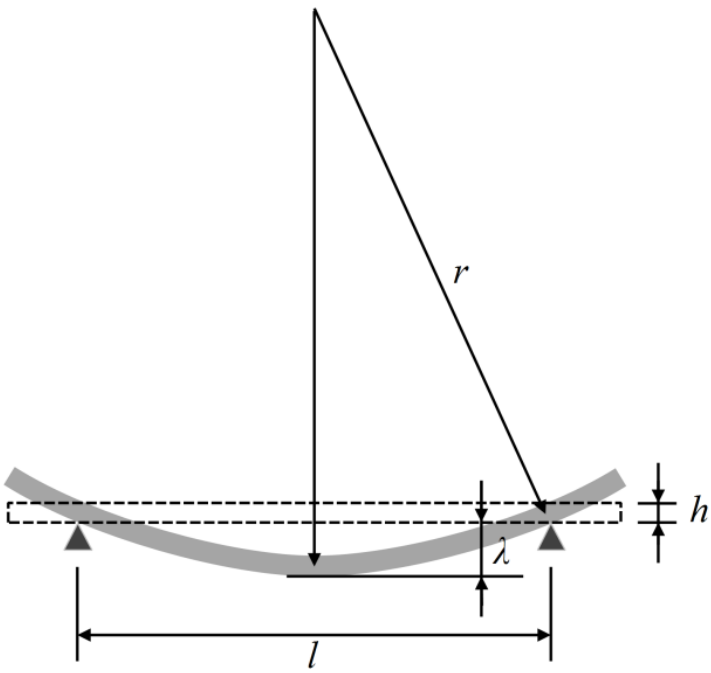

Fig. S6. Schematic model image of a bending microstrain deformation for physical parameters. A flexible substrate is adopt and bent with radius r, sagitta λ, thickness h, and the distance between two supporting points is length l. Their relationships can be expressed as:

$$\left(r + {}^{h}/_{2}\right)^2 = \left({}^{l}/_{2}\right)^2 + \left[\left(r + {}^{h}/_{2}\right) - \lambda\right]^2 \quad \text{(S1)}$$

Then, we can obtain the radius as expressed in Equation S2:

$$r = \left({}^{l^2}/_{4} - \lambda \cdot h + \lambda^2\right)/2\lambda \quad \text{(S2)}$$

Table S2. Summary data of the bending microstrain deformation for physical parameters.

Length (mm)	Sagitta (mm)	Thickness (mm)	Radius (mm)	Strain (ε=h/2r)	Ref.
250	10	2	785.25	0.13%	13
250	2	3	3905.75	0.038%	This work

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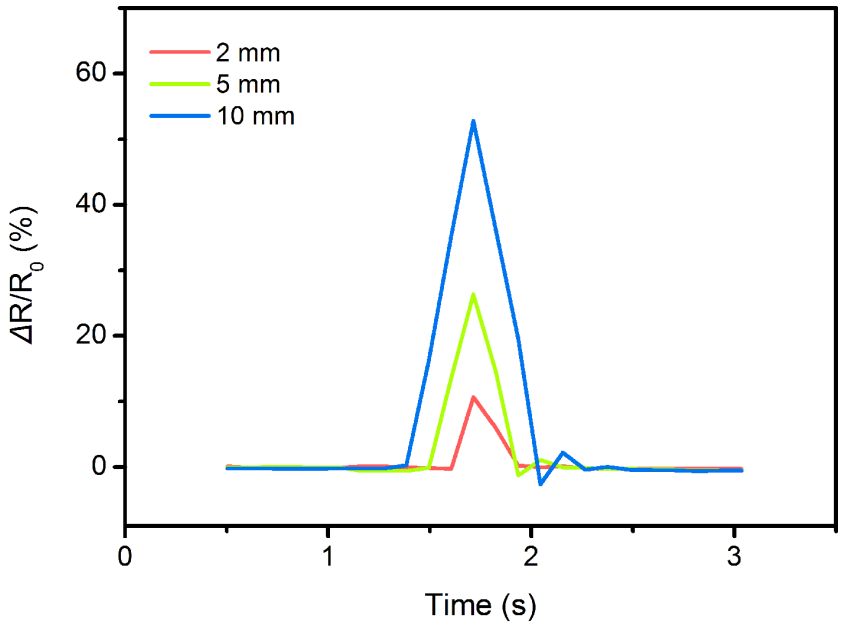

Fig. S7. The normalized resistance changes of the PPBSS versus different deformations.

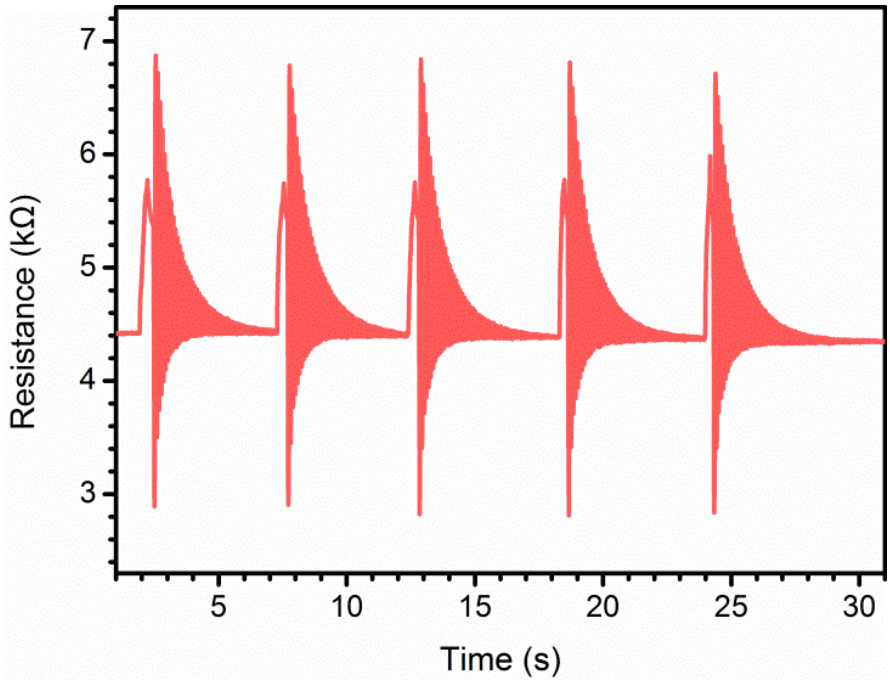

Fig. S8. Multiple tests of damped motion of plastic ruler cantilever model.

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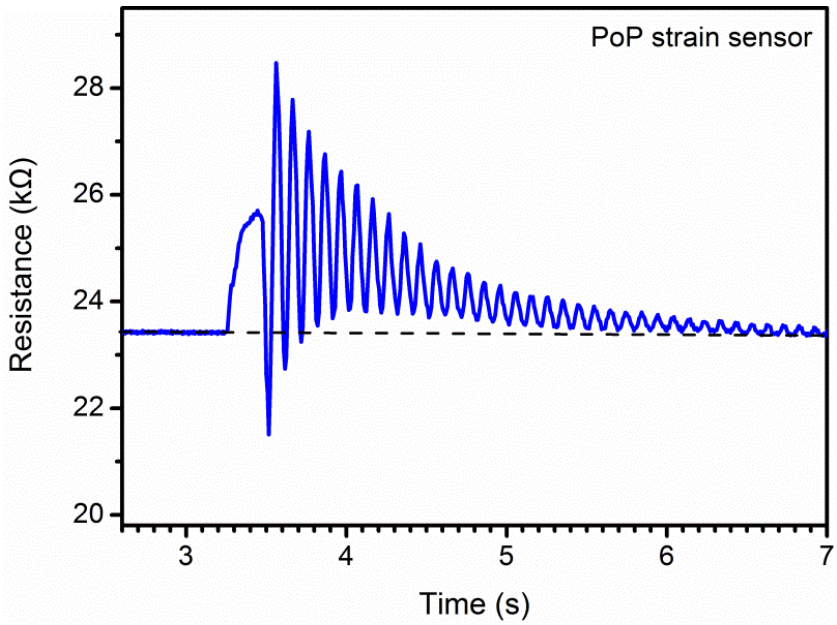

Fig. S9. The resistance of the pencil–on–paper (PoP) strain sensor versus damped motion of plastic ruler cantilever model.

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