ADVANCED HEALTHCARE MATERIALS

Supporting Information

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Ultracompliant Carbon Nanotube Direct Bladder Device

*Dongxiao Yan, Tim M. Bruns, Yuting Wu, Lauren L. Zimmerman, Chris Stephan, Anne P. Cameron, Euisik Yoon, and John P. Seymour**

Supporting Information:

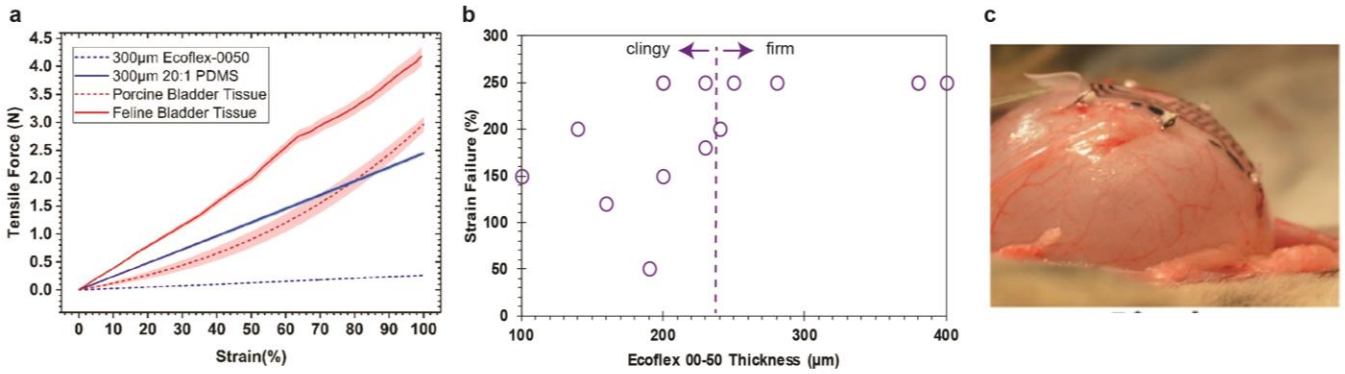

Figure S1. | Substrate selection for a direct bladder interface. a, Characterization of the elasticity of porcine bladder (N=3), and feline bladder (N=2), Ecoflex (N=2), and PDMS (N=2). All sections were 1.2cm x 2cm. Shaded region is one standard deviation. **b,** Strain failure in a manual, uniaxial pull test for different thickness values. Thin substrates tended to be clingy when handled and had large variance in robustness. **c,** A full cat bladder was not visibly deformed when 300-μm thick substrate was attached.

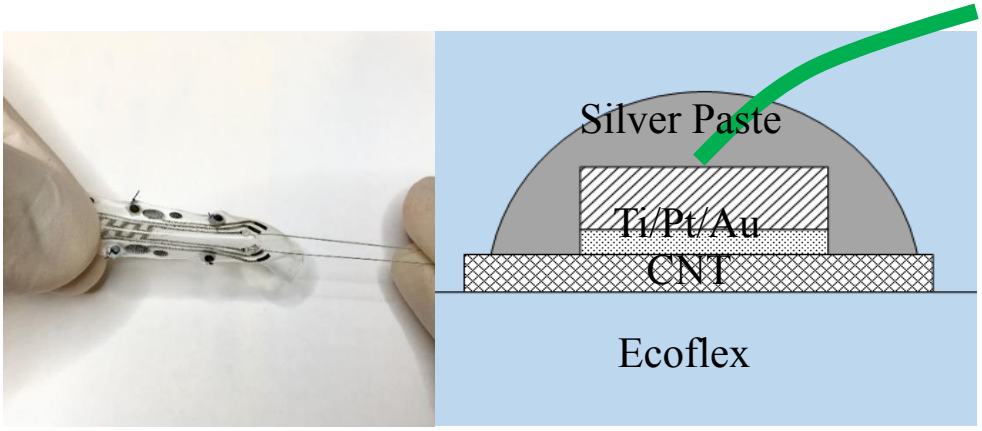

Figure S2. | Bond pad interface and mechanical robustness. Left: The wire was pulled directly until the whole device was extended by 50% while no electrical or mechanical failure was observed. Right: The wire bonding interface was made out of a 50nm/100nm/300nm thick Ti/Pt/Au layer and Ag paste. The wire was a medical grade super-alloy MP35N.

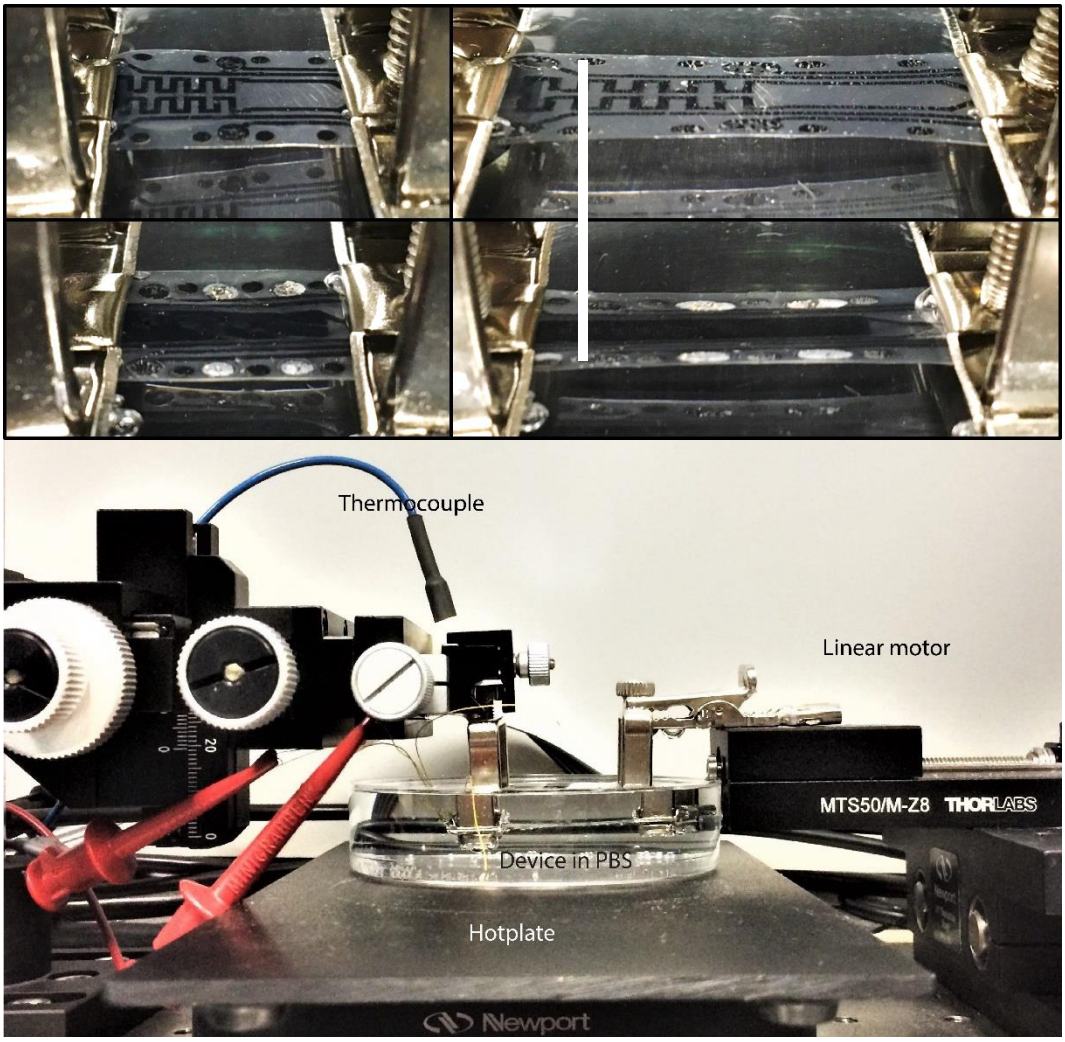

Figure S3. |Uniaxial test setup. a, Snapshots of a single device at free state and being stretched to 100% strain. **b,** Photo of the bench-top testing of a device submerged in a

phosphate-buffered saline (PBS) bath. The hot plate maintained the bath temperature at 37°C.

Experiment	Max Strain, Longitudinal ($\Delta L/L$)	Max Strain, Transverse ($\Delta W/W$)	Max Strain, Biaxial Measured ($\Delta S/S$)
Animal 1	44.0%	31.9%	82.9%
Animal 2	27.8%	22.2%	48.8%
Animal 3	49.6%	30.2%	90.5%
Animal 4	41.6%	28.0%	71.1%

Table S1. | Maximum strain on the device during *in vivo* test. The biaxial strain was estimated in two ways: calculated from the strain of two orthogonal directions; or measured from device area change by pixel counting.

During bench top testing the transverse dimension was allowed to remain relaxed, therefore based on area change alone, the equivalent biaxial strain range in table above (49 to 90%) was approximately equivalent to a uniaxial strain of 56% to 109%. This was calculated from images of device during bench testing. In an over-filling case, we observed electrical failure at a biaxial strain above 133%, which is approximately equivalent to a uniaxial strain of 160% but that degree of strain was not attempted on the bench.

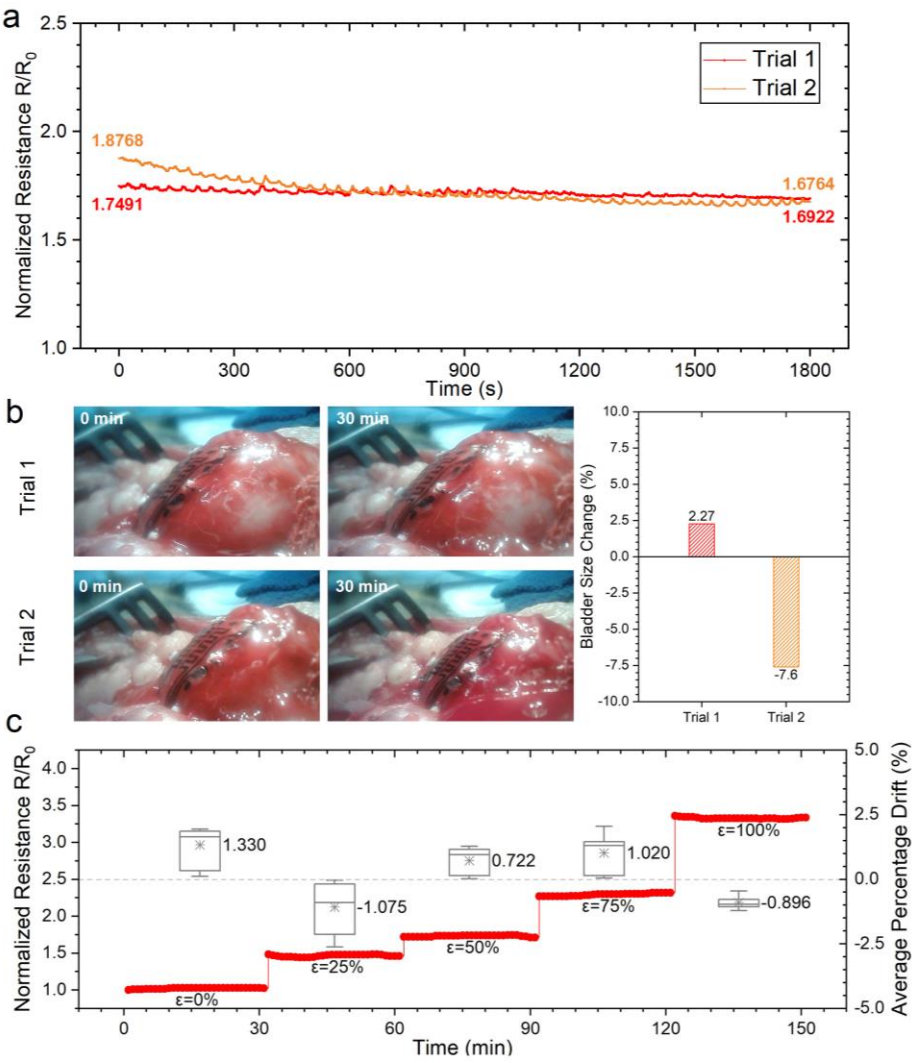

Figure S4. | Resistive device output stability with time for different test conditions. **a,** ***In vivo*** sensor output vs. time while the bladder was held at maximum volume for 30 mins for 2 trials. **b,** The percent changes in the bladder size across each 30-min test. At left, *in vivo* images used for volume estimation are shown. **c,** 1 device tested on bench top at several uniaxial strains and held for 30 mins each. Normalized resistance is plotted in red, for each strain. The box plot shows the mean (*), median, min and max, and 10% to 90% range of the drift value. The mean value is also given for each strain hold.

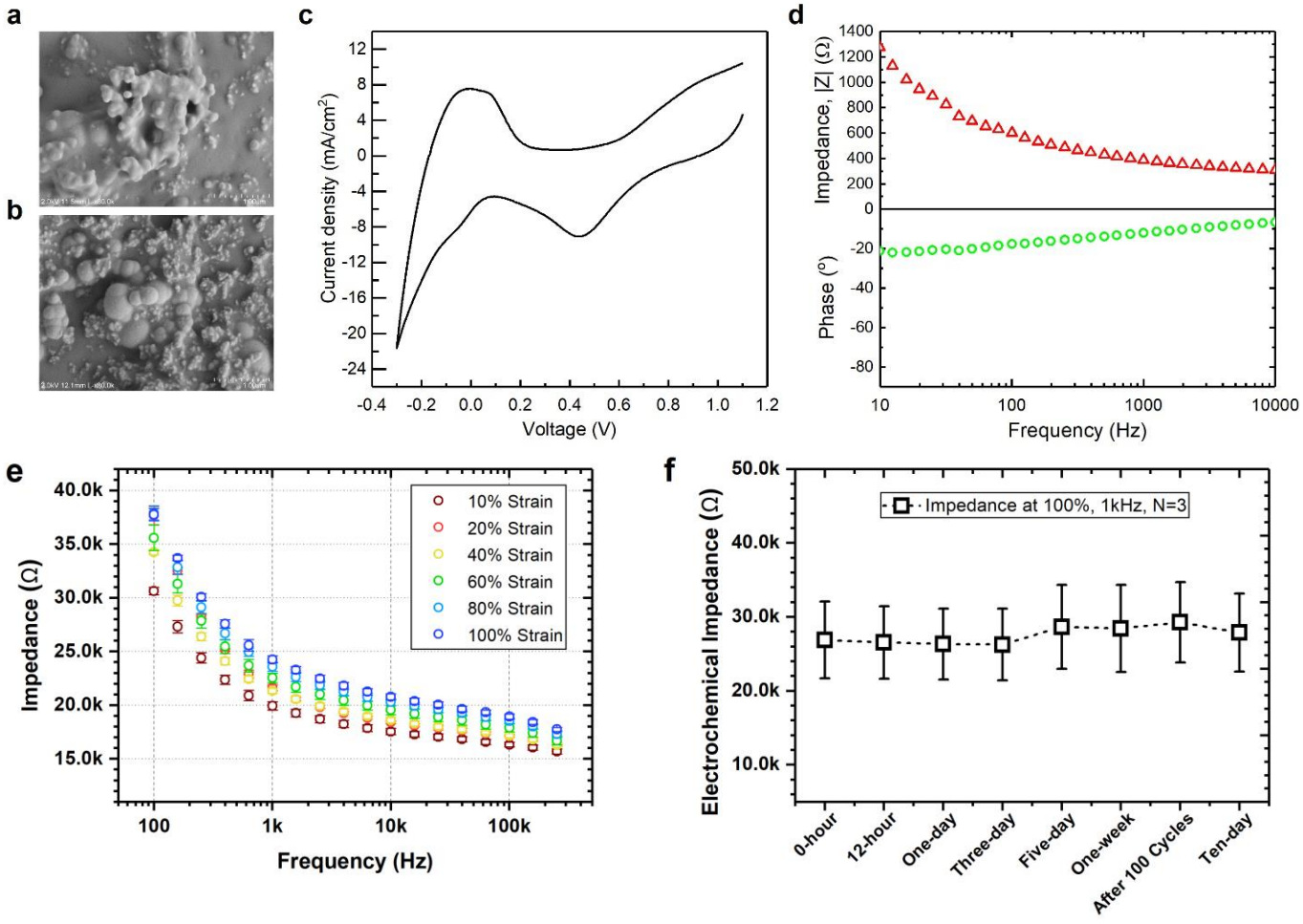

Figure S5. | Pt/PDMS micro-composite flexible electrode properties. a, Surface of the Pt/PDMS micro-composite electrode as printed and **b,** after 20μm plasma etching of PDMS. **c,** Cyclic voltammetry and **d,** impedance spectroscopy of one electrode after screen-printing and plasma-surface-etching and **e,** after pre-strain cycles at various substrate strain from 0% to 100% but electrode strain was much smaller as predicted by COMSOL. **f,** Impedance at 100% strain after soaking up to 10 days at 37℃.

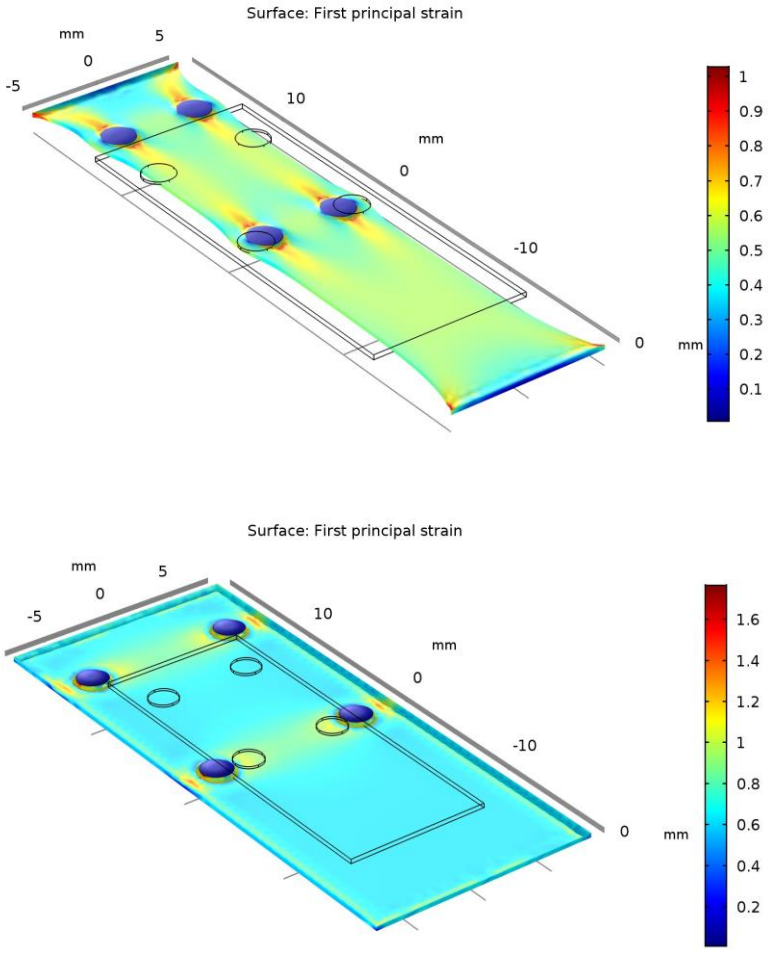

Figure S6. | Simulated strain distribution around the electrodes. (top) A 4-electrode device with Pt/PDMS composite had an average strain of only 14% when under uniaxial, 50% longitudinal strain and (bottom) biaxial, 50% longitudinal and 30% transverse strain.

Supplemental Video 1. | Demonstration of stimulation effects on the abdomen of an anesthetized feline.