

## Electronic Supplementary Information

# All-Carbon Solid-State Yarn Supercapacitors from Activated Carbon and Carbon Fibers for Smart Textiles

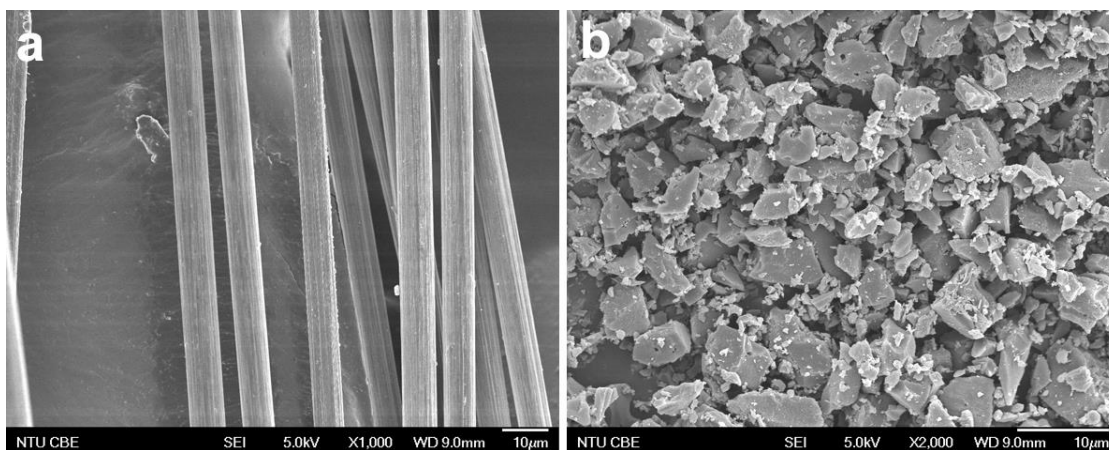
*Shengli Zhai,<sup>†</sup> Wenchao Jiang,<sup>†</sup> Li Wei,<sup>†</sup> H. Enis Karahan,<sup>†</sup> Yang Yuan,<sup>†</sup> Andrew Keong Ng,<sup>‡</sup>  
Yuan Chen<sup>\*,†</sup>*

<sup>†</sup>School of Chemical and Biomedical Engineering, Nanyang Technological University, 62  
Nanyang Drive, 637459, Singapore

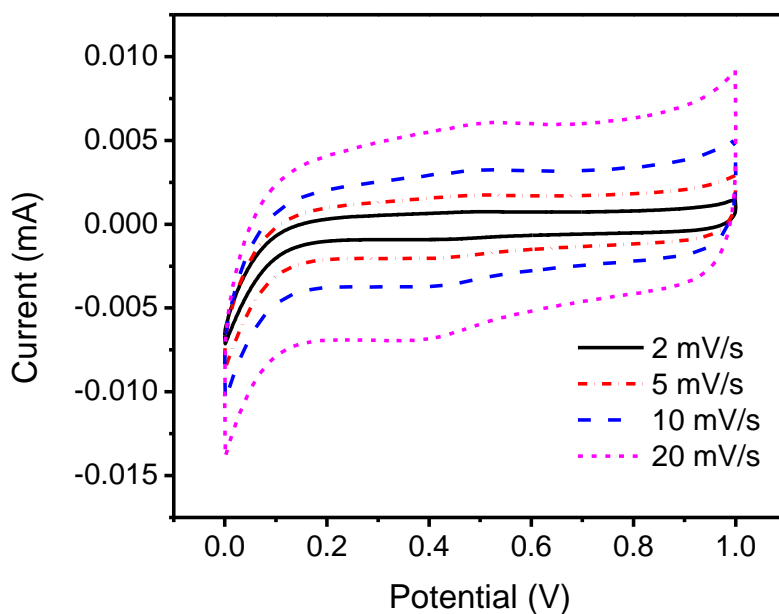
<sup>‡</sup> Singapore Institute of Technology, 10 Dover Drive, Singapore 138683, Singapore

\*To whom correspondence should be addressed.

Tel.: +65 63168939. E-mail: chenyan@ntu.edu.sg (Yuan Chen)

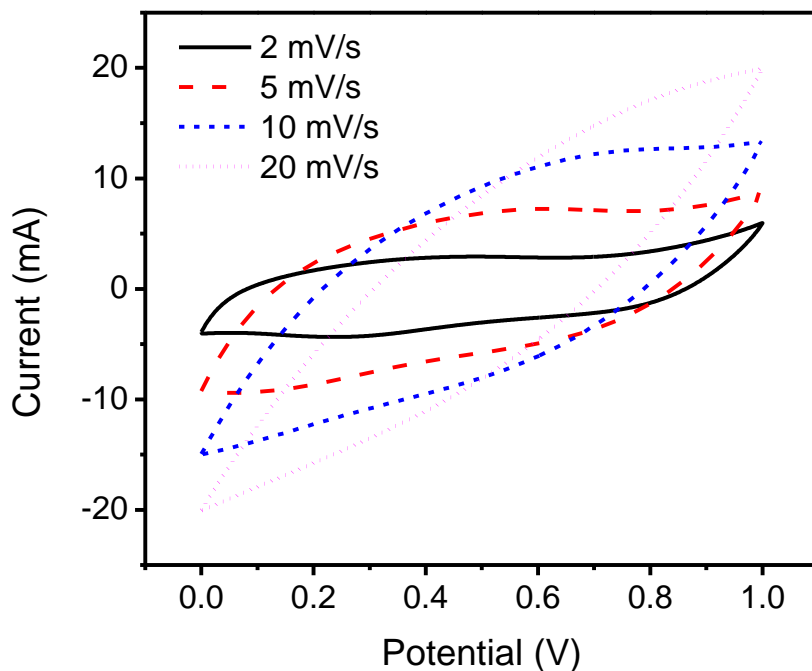


**Fig. S1** Scanning electron microscope images of carbon fiber (a) and activated carbon (b) used in this study. Carbon fibers are from Zoltek (Panex 35). Activated carbon is from Kuraray, Japan (YP-50F: pore volume: 0.7 mL/g, packing density:  $\sim 0.4$  g/cm<sup>3</sup>, total surface area:  $\sim 1600$  m<sup>2</sup>/g,)

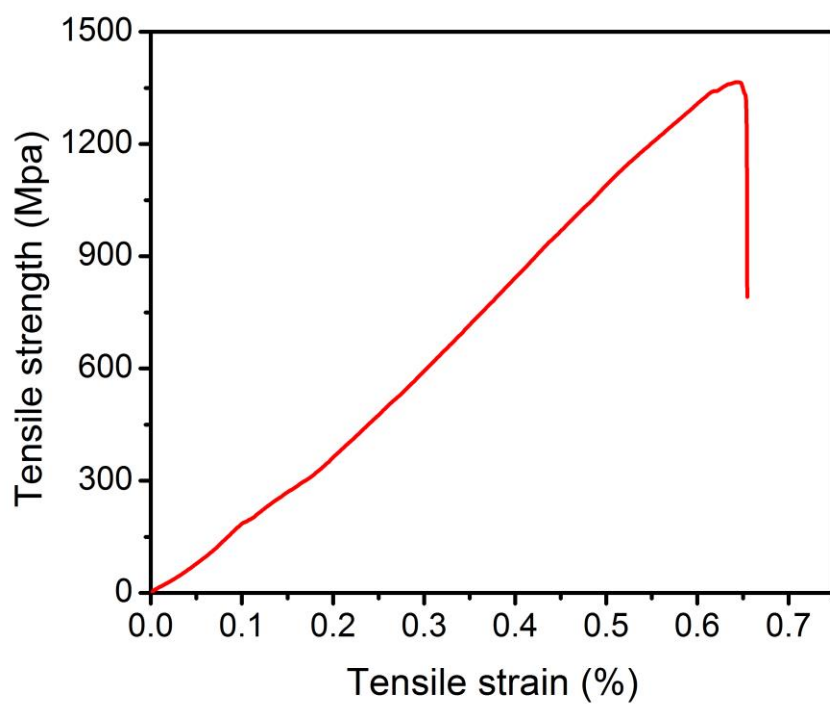


**Fig. S2** CV curves of pristine carbon fiber yarn. The CV test was performed in a three-electrode configuration in 1 M H<sub>2</sub>SO<sub>4</sub> electrolyte with a platinum wire as counter electrode, an Ag/AgCl electrode as reference electrode, and a 3.5 cm-long pristine carbon fiber yarn (1 mg/cm) as

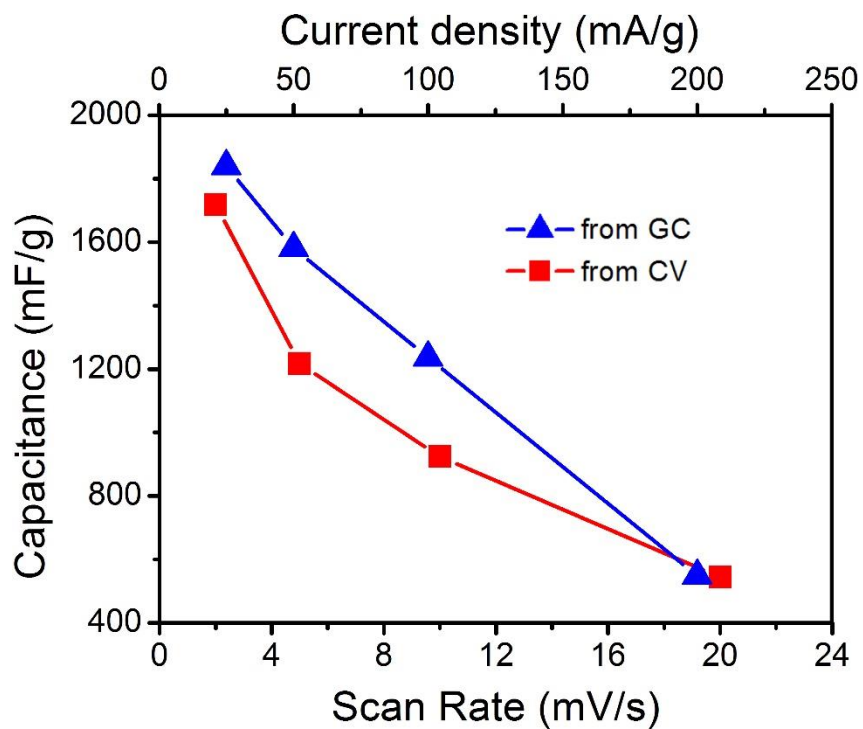
working electrode. The capacitance of the carbon fiber yarn determined from its CV curves is 0.141 mF/cm at the scan rate of 2 mV/s, 0.105 mF/cm at 5 mV/s, 0.090 mF/cm at 10 mV/s, and 0.080 mF/cm at 20 mV/s.



**Fig. S3** CV curves of activated carbon. Activated carbon (2 mg) and polyvinylidene fluoride (PVDF) (binder) were mixed at a mass ratio of 9:1 in N-methyl pyrrolidone (NMP) by sonication. The mixture was then coated on a  $1 \times 1$  cm area at one end of a rectangle carbon cloth ( $1 \times 3$  cm), followed by drying at  $100^\circ\text{C}$  overnight. The CV test was performed in a three-electrode configuration in 1 M  $\text{H}_2\text{SO}_4$  electrolyte with a platinum wire as counter electrode, an Ag/AgCl electrode as reference electrode, and the carbon cloth coated with activated carbon as working electrode. The capacitance of activated carbon determined from its CV curves is 126.30 F/g at the scan rate of 2 mV/s, 100.87 F/cm at 5 mV/s, 74.91 F/cm at 10 mV/s, and 47.86 F/cm at 20 mV/s.



**Fig. S4** Stress-strain curve of pristine single carbon fiber yarn used in this work. It has a Young's modulus of 255.7 GPa.



**Fig. S5** Gravimetric capacitance at different CV scans rates and discharging current densities. The weight of yarn supercapacitors per centimetre is about 26.3 mg/cm (including activated carbon, carbon fibers and gel electrolyte).

**Table S1** Specific length capacitance at different CV scan rates

Scan rate (mV/s)	2	5	10	20	50	100	200	500
Capacitance per length (mF/cm)	45.2	28.0	24.3	14.3	9.8	6.5	3.2	1.5

**Table S2** Specific length capacitance at different current densities

Current density (mA/g)	25	50	100	200	500	1000
Capacitance per length (mF/cm)	46.8	39.7	34.9	21.3	11.2	2.6

**Table S3** Comparison of yarn/fiber supercapacitors reported in the literature

Ref.*	Electrode Materials	Electrolyte	Measurement methods	Length (cm)	Specific length capacitance (mF/cm)	Total capacitance (mF)
<b>This work</b>	<b>Activated carbon/carbon fibers</b>	<b>PVA/H<sub>3</sub>PO<sub>4</sub></b>	<b>2-electrode CV, 2 mV/s</b>	<b>5</b>	<b>51.2</b>	<b>256</b>
				<b>10</b>	<b>45.2</b>	<b>452</b>
				<b>20</b>	<b>31.65</b>	<b>633</b>
				<b>50</b>	<b>23.28</b>	<b>1164</b>
20	Graphene framework/graphene fiber	PVA/H <sub>2</sub> SO <sub>4</sub>	2-electrode	4.5	0.018	0.081
22	MWCNTs/CMF bundles/CNT film	PVA/H <sub>3</sub> PO <sub>4</sub>	2-electrode GC, 2 mV/s	5	6.3	31.5
24	rGO/CNT	PVA/H <sub>2</sub> SO <sub>4</sub>	2-electrode GC, 0.1 mA/cm <sup>2</sup>	40	5.3	
26	CNT/carbon fiber	PVA/H <sub>2</sub> SO <sub>4</sub>	2-electrode	17	0.5	8.5
28	CNT/OMC	PVA/H <sub>3</sub> PO <sub>4</sub>	2-electrode GC, 0.5 $\mu$ A		1.91	
39	CNT/MnO <sub>2</sub>	PVA/H <sub>3</sub> PO <sub>4</sub>	2-electrode		0.015	

40	PEDOT/MWCNT	PVA/H <sub>2</sub> SO <sub>4</sub>	GC, 2 $\mu$ A 2-electrode CV, 1 V/s	5	0.46	2.3
41	Activated carbon/stainless steel/natural fiber	SiWA	2-electrode CV, 2 mV/s	6	37.2	223.2
44	CNT/rGO fiber	PVA/H <sub>2</sub> SO <sub>4</sub>	2-electrode GC, 50 mA/cm <sup>3</sup>	3 6	0.351 0.288	1.053 1.73
45	PPy/MnO <sub>2</sub> /rGO	PVA/H <sub>3</sub> PO <sub>4</sub>	2-electrode GC	10	15.5	155
46	PANI/functionalized carbon fiber	PVA/H <sub>3</sub> PO <sub>4</sub>	2-electrode GC	10	3.9	39
54	Coiled carbon nanotubes/MnO <sub>2</sub> /polymer fiber	PVA/LiCl	2-electrode	1	5.4	5.4
56	PANI/CNT/Pt	PVA/H <sub>3</sub> PO <sub>4</sub>	2-electrode CV, 5 mV/s		0.2413	
57	CNT/Ti fiber	PVA/H <sub>3</sub> PO <sub>4</sub>	2-electrode GC, 0.25 $\mu$ A		0.024	
58	ZnO nanowires/graphene	PVA/H <sub>3</sub> PO <sub>4</sub>	2-electrode CV, 100 mV/s		0.025	

\* Reference number is the same as that in the main text