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Extreme Low Temperature Environment Operatable Hybrid Dual-Functioning Energy Device Driven from Supercapacitor/Piezo-Tribo Electric Generator System

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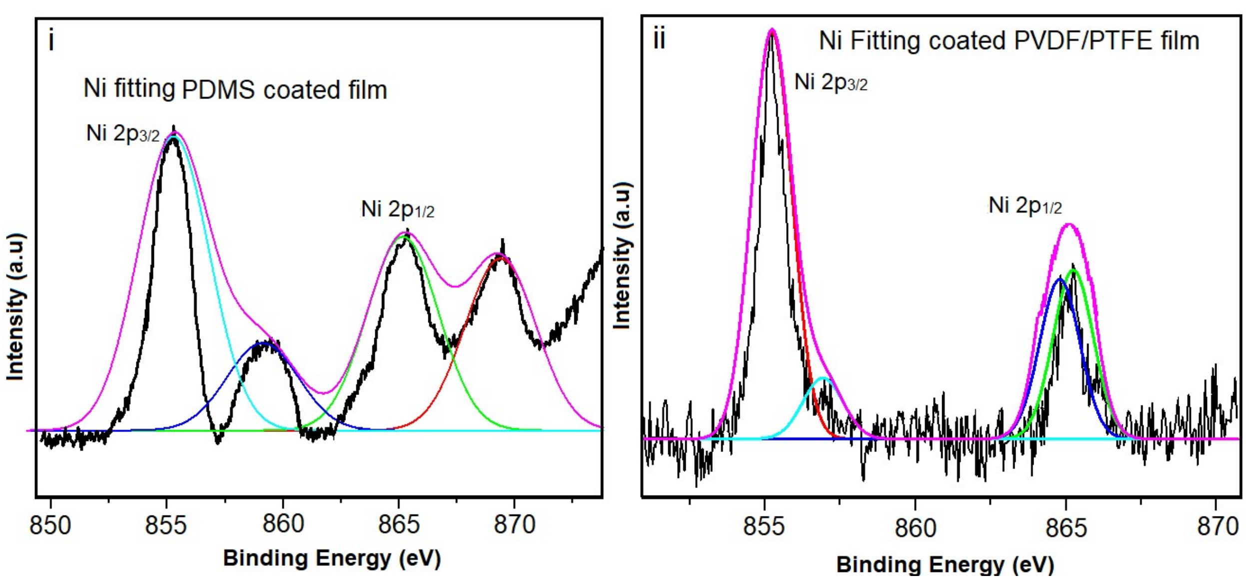
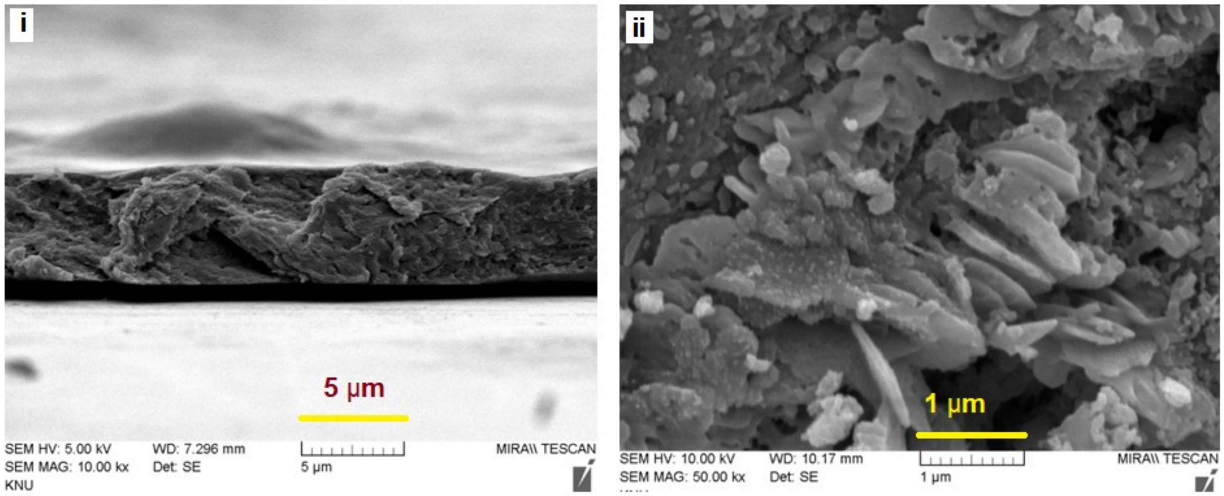
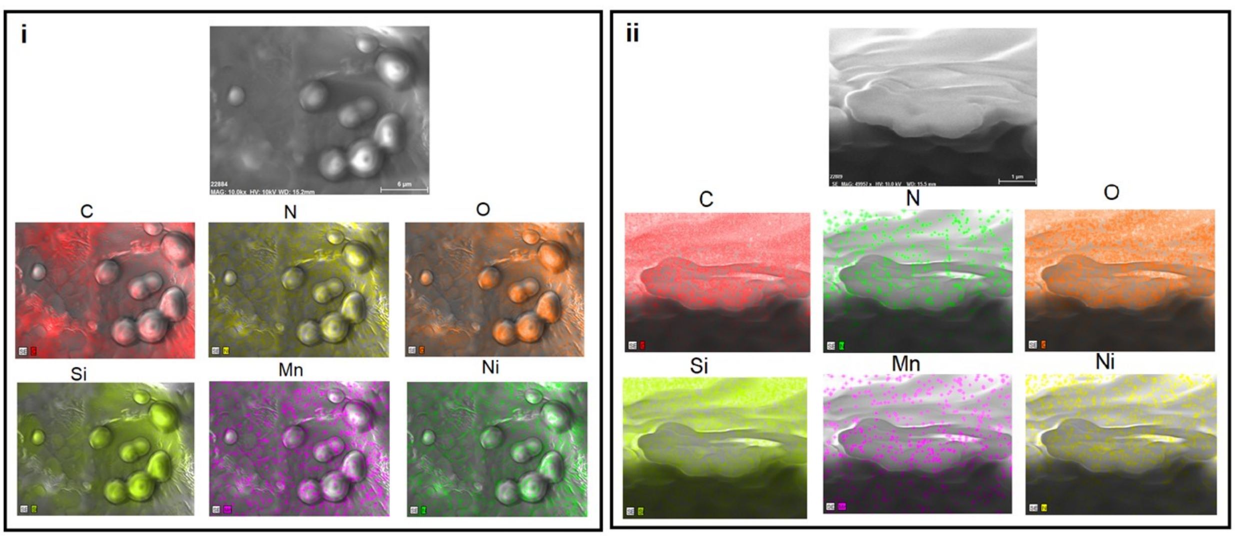


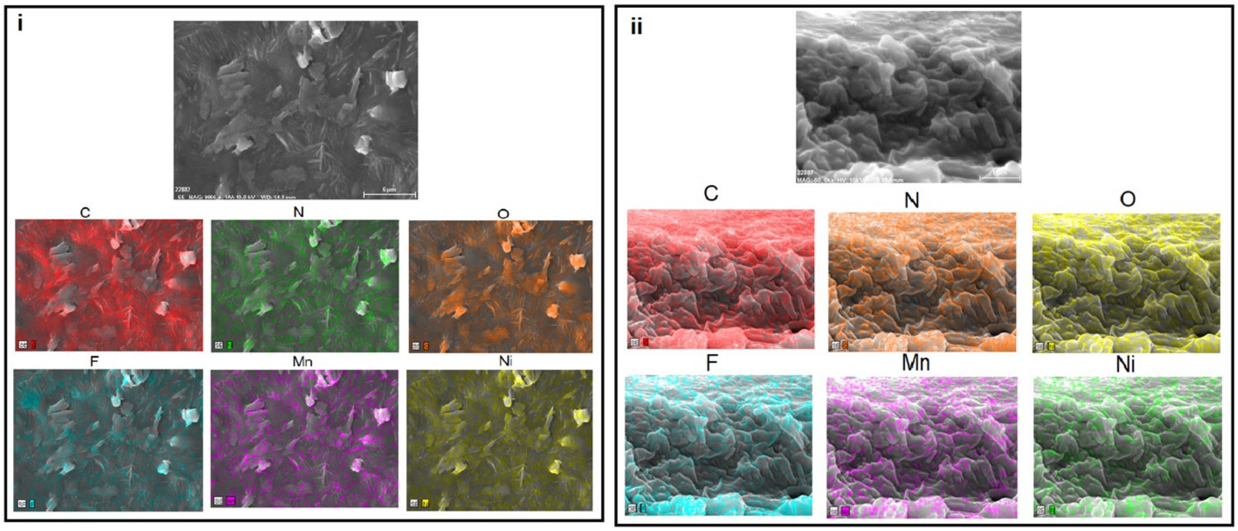
ESI. Fig. 1. (i and ii) Ni XPS fitting details of PDMS and PVDF-PTFE coated composite



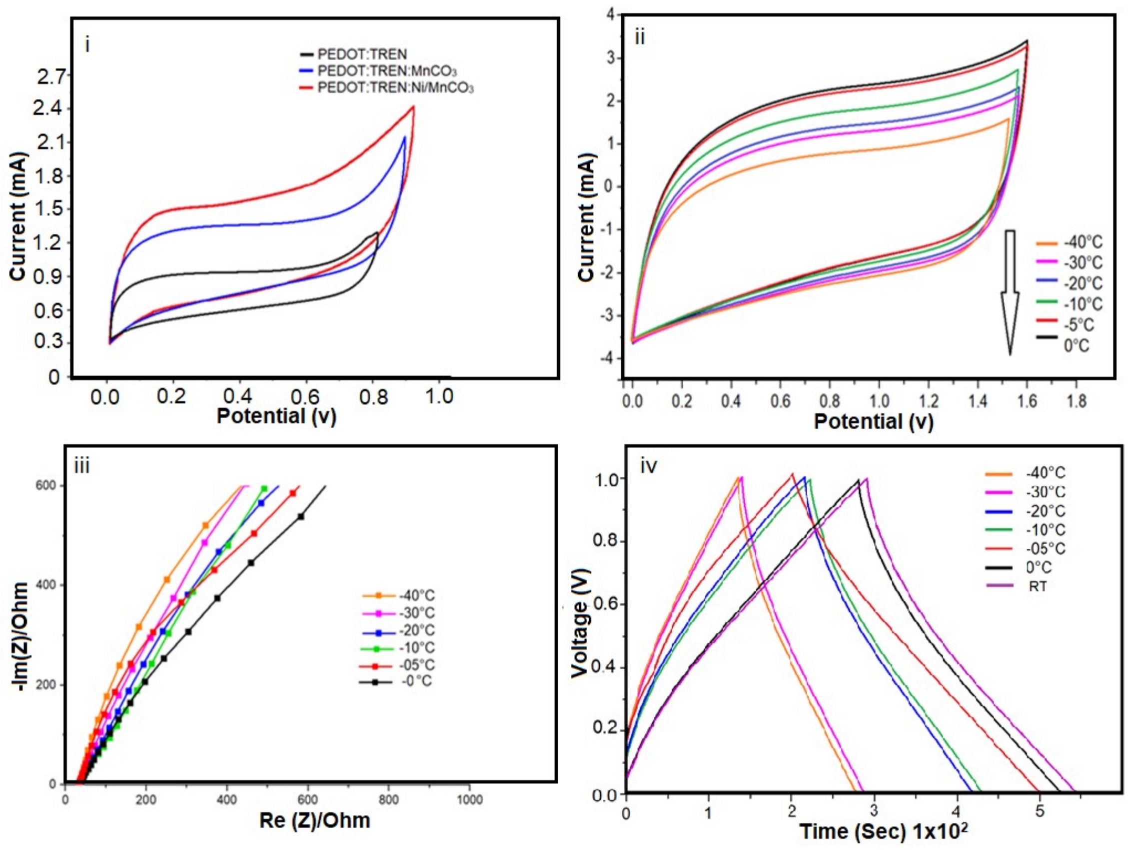
ESI. Fig. 2. (i and ii) SEM images of Cross section images of PEDOT:TREN:Ni@$MnCO_3$ composite



ESI Fig. 3. EDS mapping of PEDOT:TREN:Ni@$MnCO_3$/PDMS Composite Surface (i) and Cross section (ii)



ESI Fig. 4 EDS mapping of PEDOT:TREN:Ni@$MnCO_3$/PVDF-PTFE Surface (i) and Cross section (ii)



ESI Fig. 5 CV profile of PEDOT:TREN, PEDOT:TREN:$MnCO_3$ and PEDOT:TREN, PEDOT:TREN:Ni/$MnCO_3$ composite without GO (i), CV details at various current rate (ii) and EIS studies (iii) and (iv) Charge-discharge curves.

Calculations

The Gravimetric specific capacitance was calculated from the galvanostatic discharge curves, using the following equation 1.

$$C = \frac{I\Delta t}{m\Delta V} \quad .....1$$

Also, the aerial capacitance was calculated from equation 2

$$C = \frac{I\Delta t}{A\Delta V} ....2$$

Where (I) is charge or discharge current, Δ*t* (s) is the time for a full charge or discharge, *m* (g) designates the mass of the active material, A is the area of the active materials and Δ*V* signifies the voltage change after a full charge or discharge.

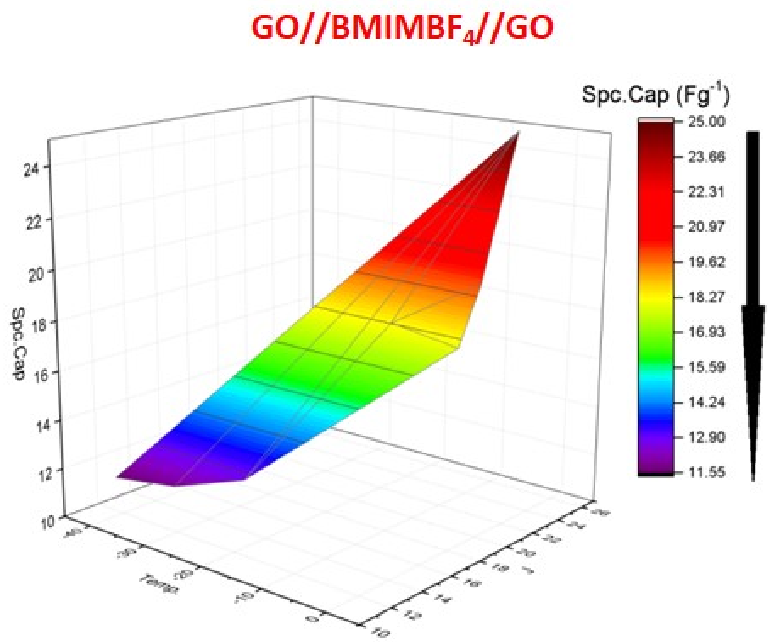
The energy density (E) considered by equation 3 .

$$E = \frac{C(\Delta V)^2}{2} \quad \text{WhKg}^{-1}......3$$

Where C is the specific capacitance of the active materials, and ΔV is the potential window of discharge.[1-5]

EIS. Table 1. Specific capacitance calculation details of PEDOT:TREN:Ni@$MnCO_3$

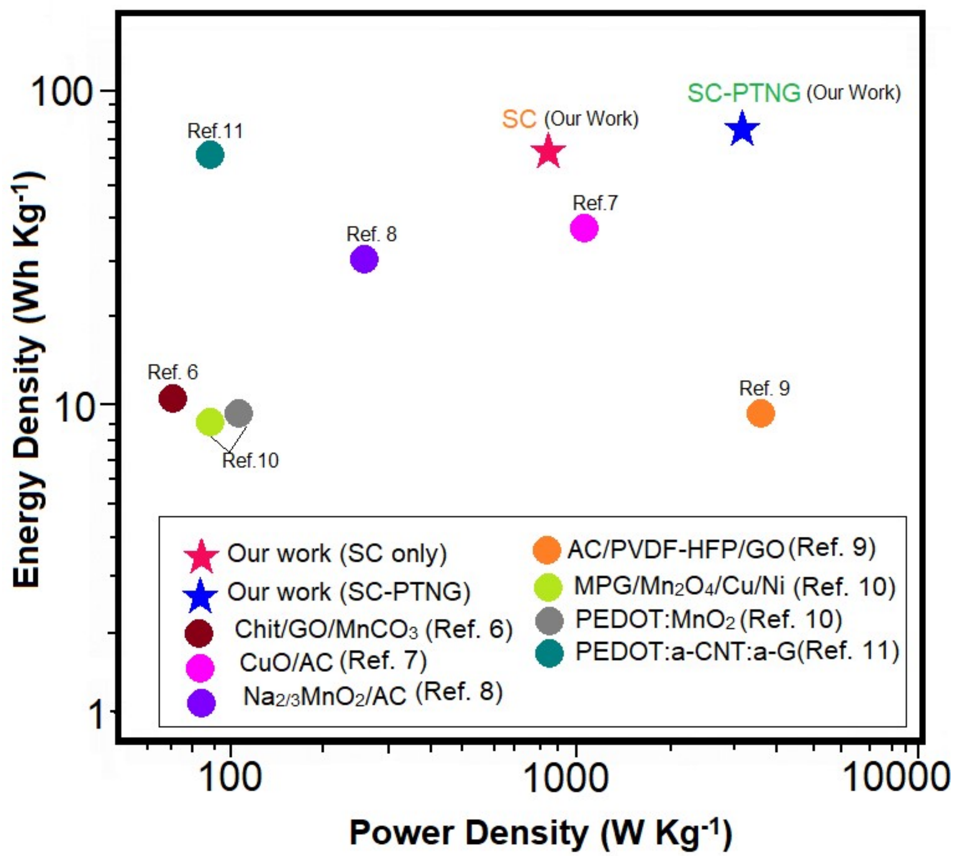
Temp.	**Gravimetric Cap. Fg^{-1}**
-40°C	275
-30°C	283
-20°C	350
-10°C	426
-05°C	504
0°C	491
RT	475



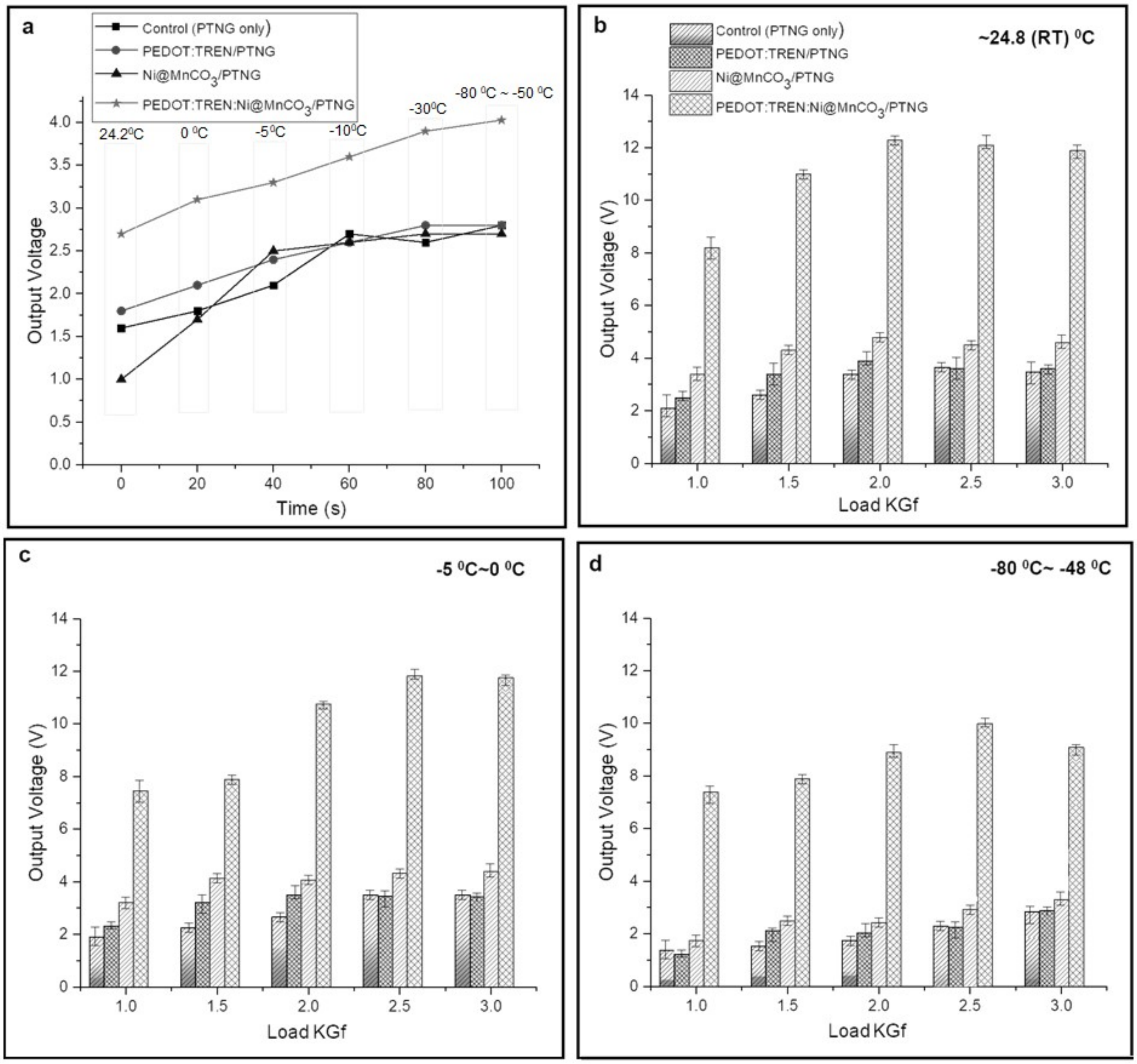
ESI. Fig 6 Electrolyte performance at low temperature conditions in terms of Specific capacitance and calculation details

EIS. Table 2. Specific capacitance calculation details of Electrolyte performance

Temp.	**Gravimetric Cap.** $\mathbf{Fg^{-1}}$
-40°C	11.6
-30°C	11.9
-20°C	12.7
-10°C	18.3
-05°C	25
0°C	20
RT	18



ESI. Fig 7. Energy density and Power density comparison from Ragone plot from reports on $MnCO_3$, Ni, PEDOT related Asymmetric supercapacitors (ASC)



ESI. Fig 8. Control experiment PTNG performance test under bending and twist conditions at after 1000 cycles workout; (a); output voltage error bar diagram of PTNG performance test under various load condition and temperature ranges (b-d) respectively.

ESI. Table 3. Comparative analysis of similar SC-PTNG from the literature.

Self-powered supercapacitor (SC-PTNG)	System	Electrolyte	Temp. (°C)	Specific capacitance	Charging Volt/ Output Volt)	Ref
PEDOT:TREN:PDMS:Ni@$MnCO_3$/ PEDOT:TREN:PVDF-PTFE:Ni@$MnCO_3$	SC- Piezo-Tribo hybrid	[BMIM][BF_4]	RT	542 Fg^{-1}	22 V	Our work
PEDOT:TREN:PDMS:Ni@$MnCO_3$/ PEDOT:TREN:PVDF-PTFE:Ni@$MnCO_3$	SC- Piezo-Tribo hybrid	[BMIM][BF_4]	-80	317 Fg^{-1}	11.9 V	Our work
AgNWS/NiOH/ P(VDF-TrFE)	SC- Piezo-Tribo hybrid	(PVA/KOH	RT	3.47 $mFcm^{-2}$	150 V	ESI. Ref. 12
Siloxene–PVDF piezofiber	SC- Piezo- separately	$TEABF_4$	RT	27.58 $mFcm^{-2}$	207 mV	ESI. Ref. 13
Co-Fe_2O_3@ACC	SC- Piezo- separately	PVA-KCl-$BaTiO_3$	RT	2.8 $mFcm^{-2}$	120 mV	ESI. Ref. 14
3D AG/PTFE/PDMS	SC-Tribo separately	NA	RT	550 Fg^{-1}	3.2V	ESI. Ref. 15
Silicone-CF fiber	SC-Tribo separately	H_3PO_4/ PVA gel	RT	31.25Fg^{-1}	42.9 V	ESI. Ref. 16

ESI. References

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