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Electronic Supporting Information (ESI)

Flexible-Wire Shaped All-Solid-State Supercapacitors Based on Facile Electropolymerization of Polythiophene with Ultra-High Energy Density

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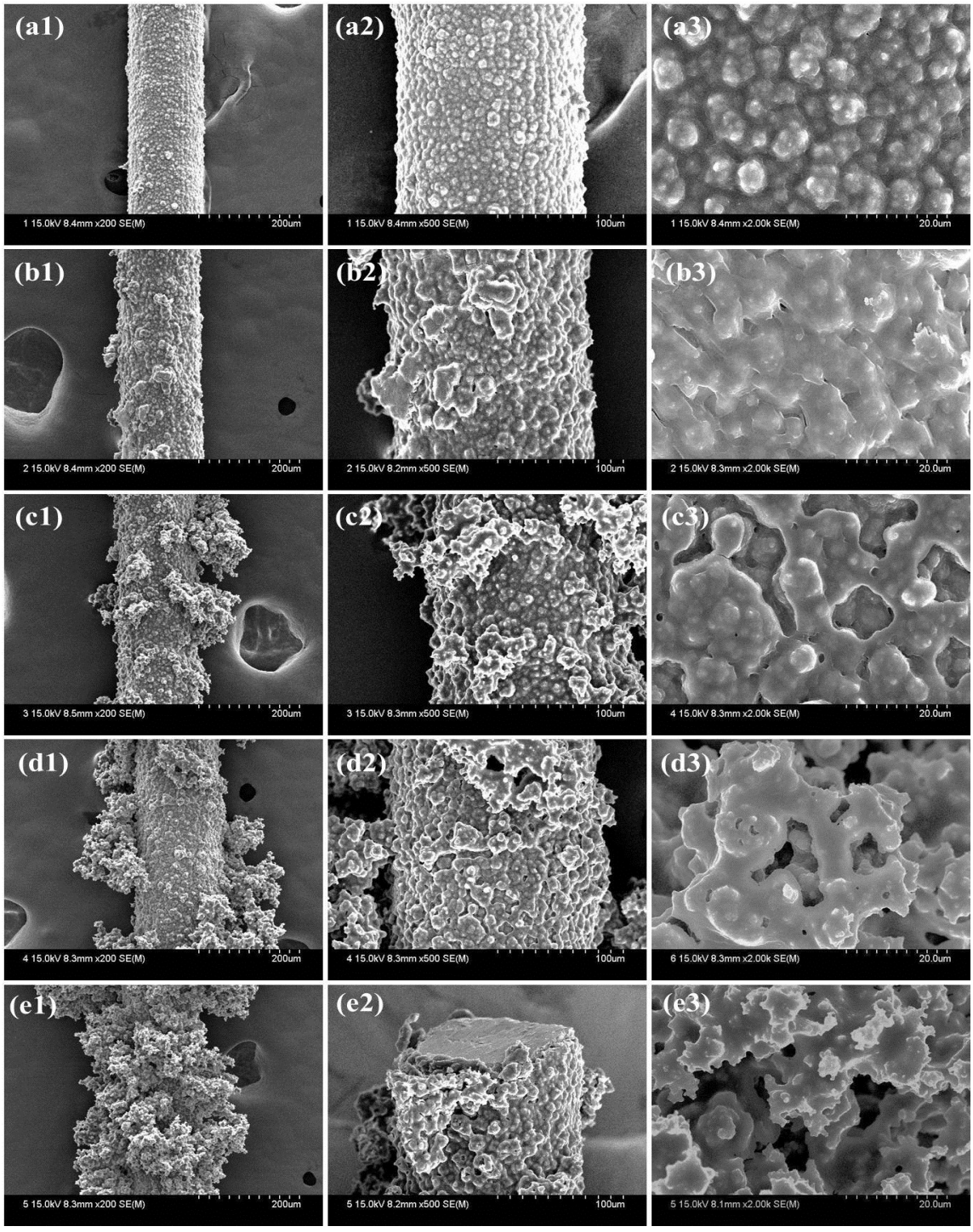


Figure S1. FE-SEM images of *e*-PTh/Ti wire (a1-a3) 1 cycle, (b1-b3) 2 cycles, (c1-c3) 3 cycles, (d1-d3) 4 cycles and (e1-e3) 5 cycles at different magnification.

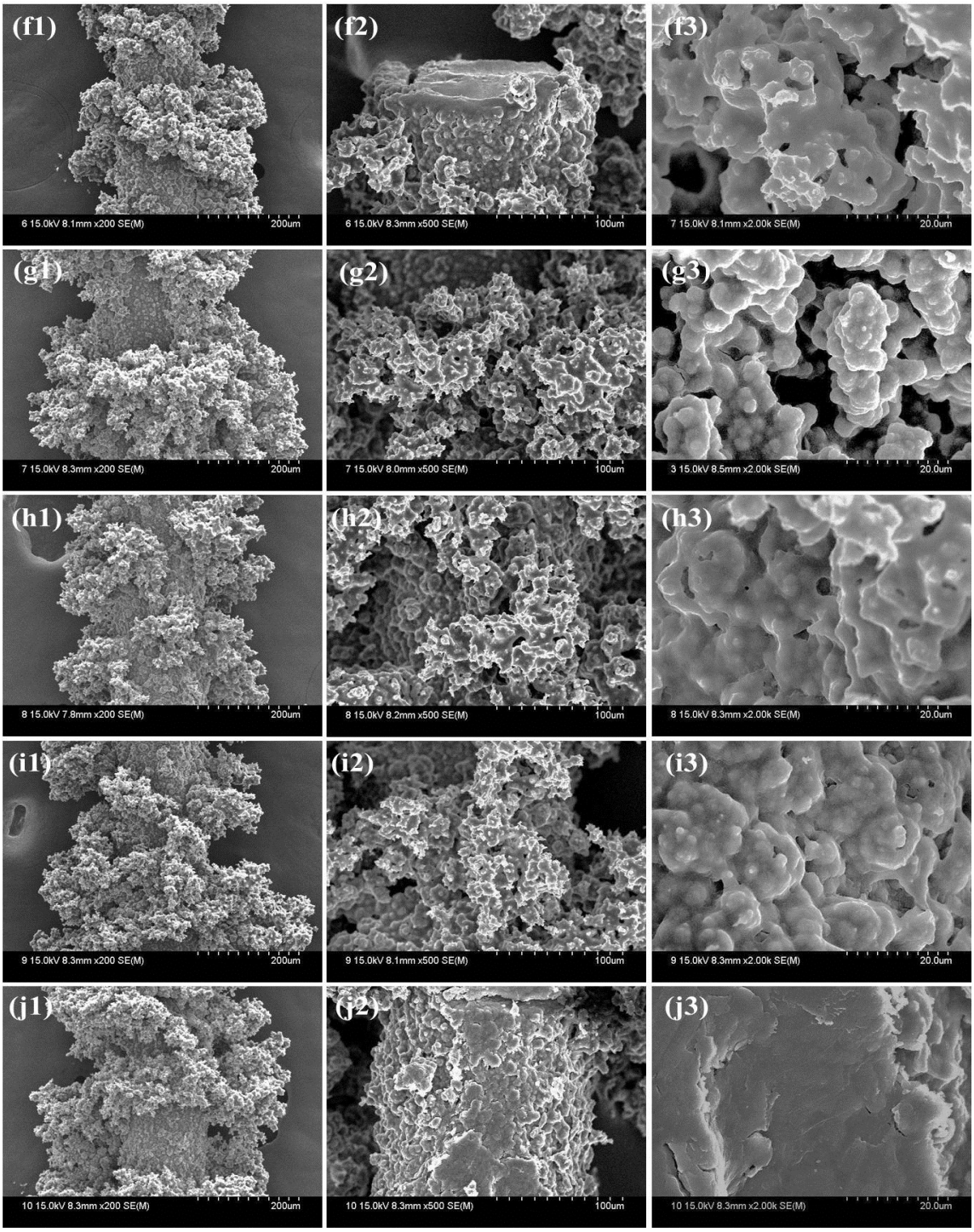
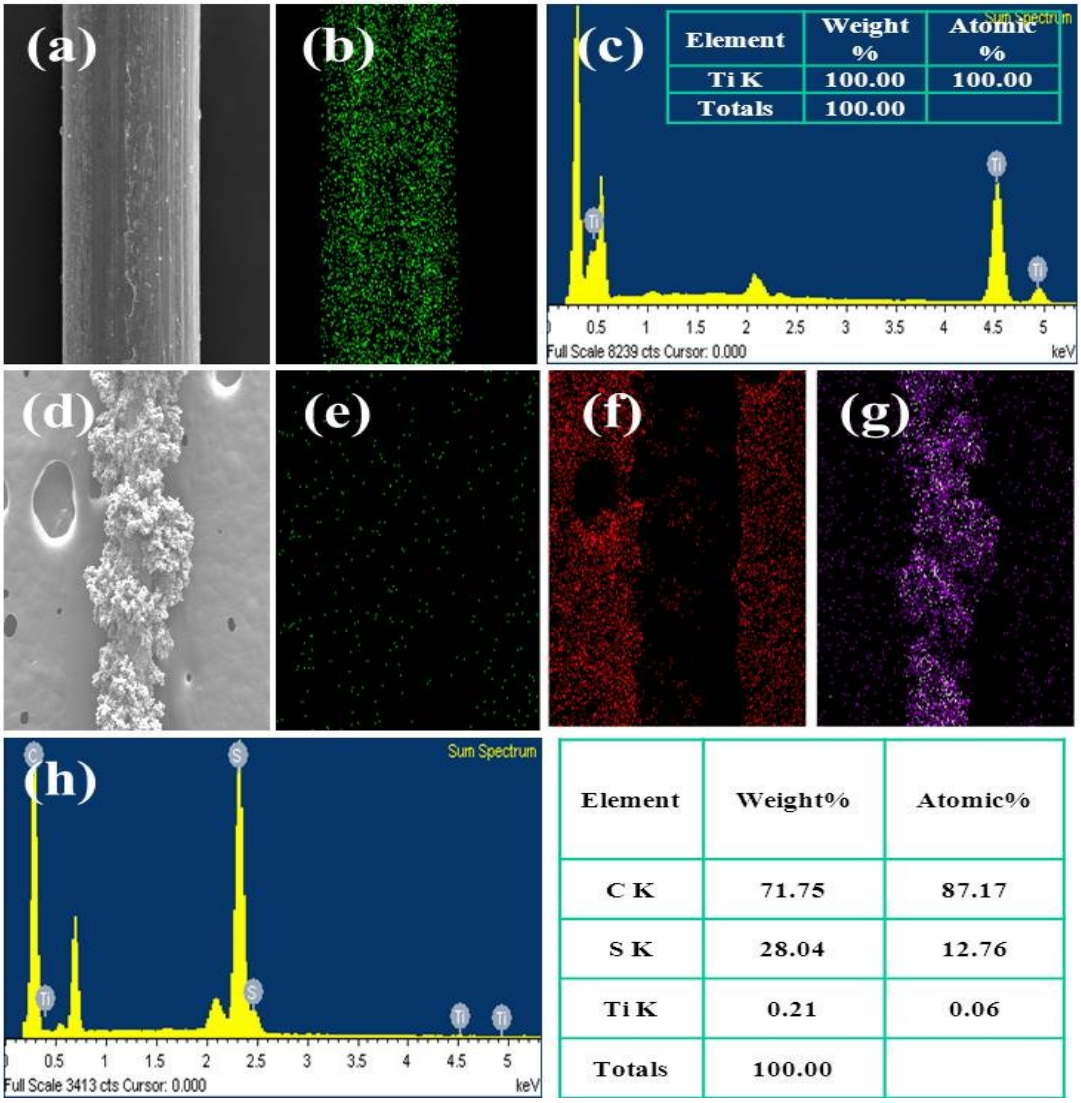
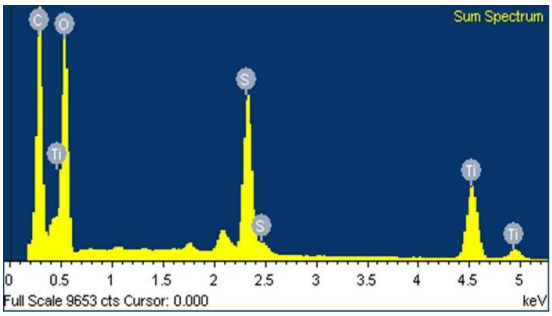


Figure S2. FE-SEM images of *e*-PTh/Ti wire (f1-f3) 6 cycles, (g1-g3) 7 cycles, (h1-h3) 8 cycles, (i1-i3) 9 cycles and (j1-j3) 10 cycles at different magnification.



Element	Weight%	Atomic%
C K	71.75	87.17
S K	28.04	12.76
Ti K	0.21	0.06
Totals	100.00	

Figure S3. EDAX and mapping images of (a-c) bare Ti wire and (d) *e*-PTh/Ti wire 7 cycles.



Element	Weight%	Atomic%
C K	31.19	47.13
O K	32.35	36.69
S K	12.65	7.16
Ti K	23.81	9.02
Totals	100.00	

Figure S4. EDAX of *e*-PTh/Ti wires 7 cycles intertwined wires coated with the gel electrolyte.

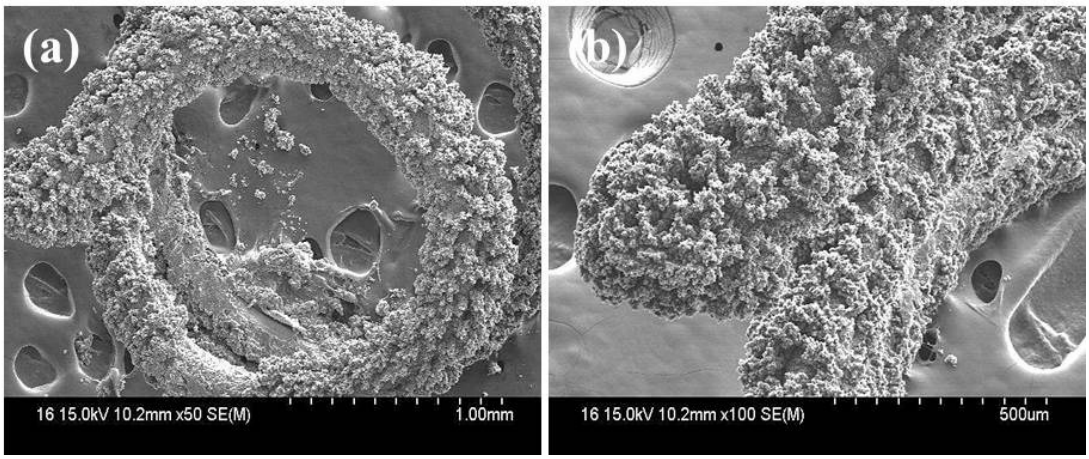


Figure S5. FE-SEM images of (a-b) *e*-PTh/Ti wire after 7 cycles with spiral flexibility.

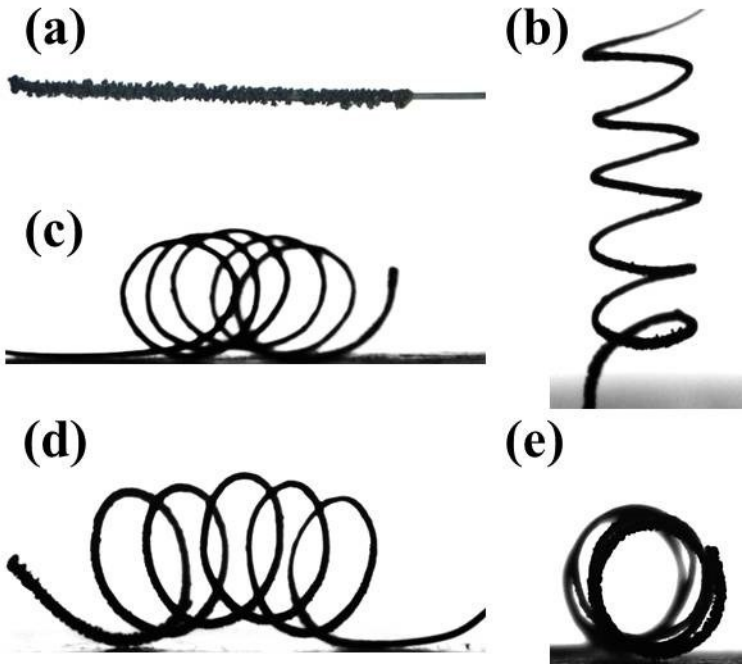


Figure S6. Digital photo images of *e*-PTh/Ti wire after 7 cycles (a) straight (b-e) spiral flexibility.

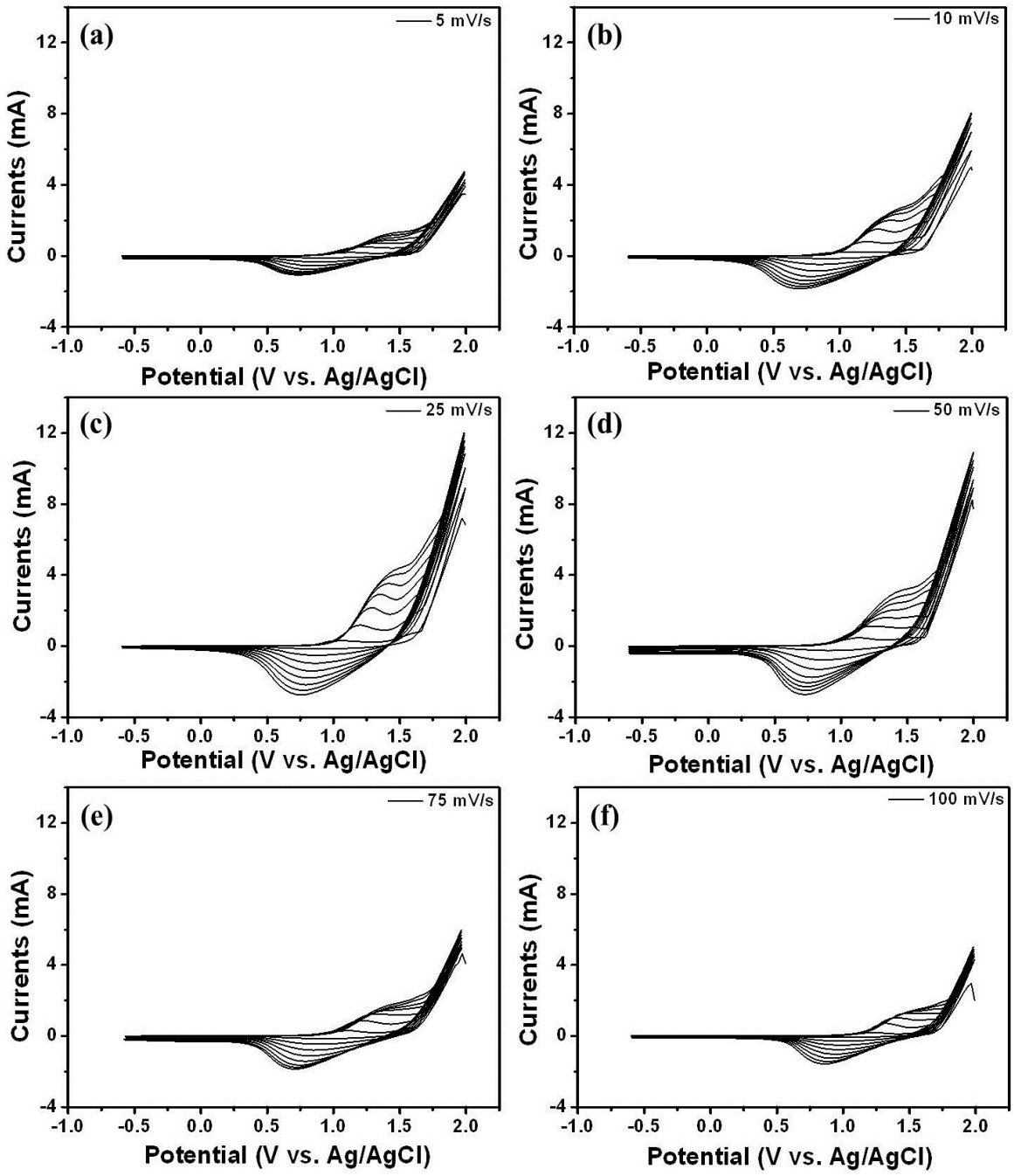


Figure S7. Cyclic voltammograms of electropolymerization of thiophene on Ti wire for 7 cycles at different scan rates: (a) 5 mV/s, (b) 10 mV/s, (c) 25 mV/s, (d) 50 mV/s, (e) 75 mV/s and (f) 100 mV/s.

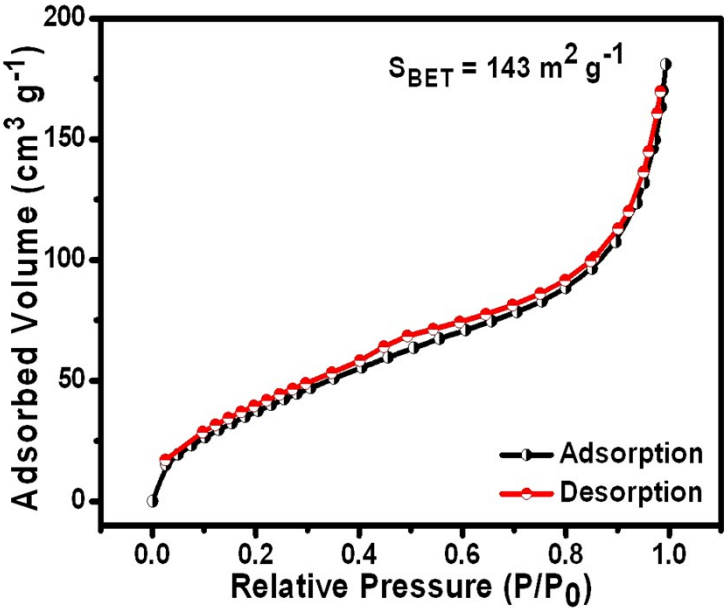


Figure S8. Nitrogen adsorption–desorption isotherm.

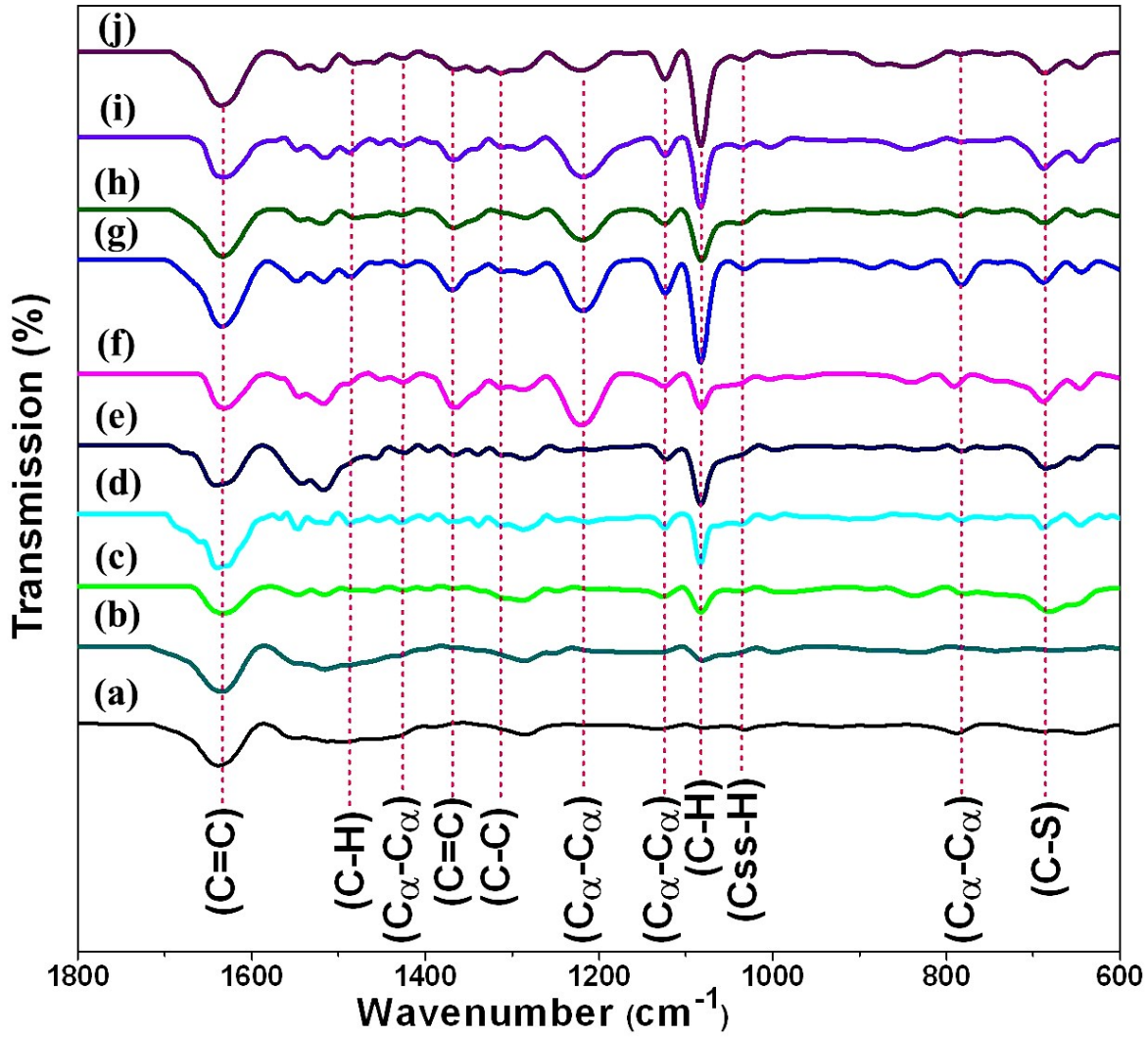


Figure S9. FTIR spectra of *e*-PTh/Ti wire after (a) 1 cycle, (b) 2 cycles, (c) 3 cycles, (d) 4 cycles, (e) 5 cycles, (f) 6 cycles, (g) 7 cycles, (h) 8 cycles, (i) 9 cycles and (j) 10 cycles.

Table S1. FT-IR peak assignments of the *e*-PTh/Ti wire.

ν (cm^{-1})	**Assignment**
3500~3100	-OH stretching vibration
3100~2800	C-H stretching vibration
2957	C-H bonds
1622	C=C aromatic stretching bond
1082, 1488	C-H stretching of thiophene ring
3500~3100	-OH stretching vibration
1384, 1422	C=C symmetric stretching vibrations
1310	C-C stretching vibration mode of thiophene ring
1033,785	Css-H out of phase and in phase bending vibration
1428,1112,1033,785	C_α-C_α linkage
997,724	C-S bending mode

Calculations:

1. *Specific Capacitance:*
   a. The specific capacitance (C_{sp}) derived from CV curves was calculated from equation (S1) given below [1]
      i. C_{sp} p by mass (F g^{-1}):

$$C_{sp} = 2\,(\int i\,dV)/\,(s.\,m.\Delta V) \tag{S1}$$

      ii. C_{sp} p by Area (F cm^{-2}):

$$C_{sp} = 2\,(\int i\,dV)/\,(s.\,A.\Delta V) \tag{S2}$$

where,
i is the voltammetric current,
m is the mass of one electrode in grams,
s is the potential scan rate in volt/s,
ΔV is the potential window,
A is the surface area of the electrode calculated by

$$A = L\,.\,(\pi\,.\,d) \tag{S3}$$

where L and d are the length (cm) and diameter (cm) of the electrode, respectively.

   b. The specific capacitance (C_{sp}) derived from galvanometric charge-discharge (GCD) was calculated from equation (S4) given below [2]

$$C_{cell} = i/(dV/dt) \tag{S4}$$

$$C_{sp} = \frac{2\,C_{cell}}{B_i} \tag{S5}$$

where,

C_{cell} is the total capacitance of the SC,
i is the discharge current,
dV is the potential window,
dt is the discharge time.
B_i is the mass (C_{sp} by mass, F g^{-1}) or area (C_{sp} by area, F cm^{-2})

2. *Energy Density (E):*
The energy density of *f*-WS all solid-state symmetric SCs depicted in Ragone plot was calculated by using the equation is given below [3]

$$E = i \cdot \int_{V_1}^{V_2} t \cdot V dV \approx \left(\frac{1}{3600}\right) \cdot \left(\frac{1}{2}\right) \cdot C_{sp} \cdot (V_2^2 - V_1^2) \quad \text{(S6)}$$

where,
i is the discharge current,
t is the total discharge time,
V_2 *and* V_1 correspond to initial and final voltage of the capacitance,
C_{sp} is the capacitance obtained from galvanometric charge-discharge (GCD).

3. *Power Density (P):*
The power density was calculated by:

$$P = E/\Delta t \quad \text{(S7)}$$

where,
E is the energy density,
Δt is the total discharge time.

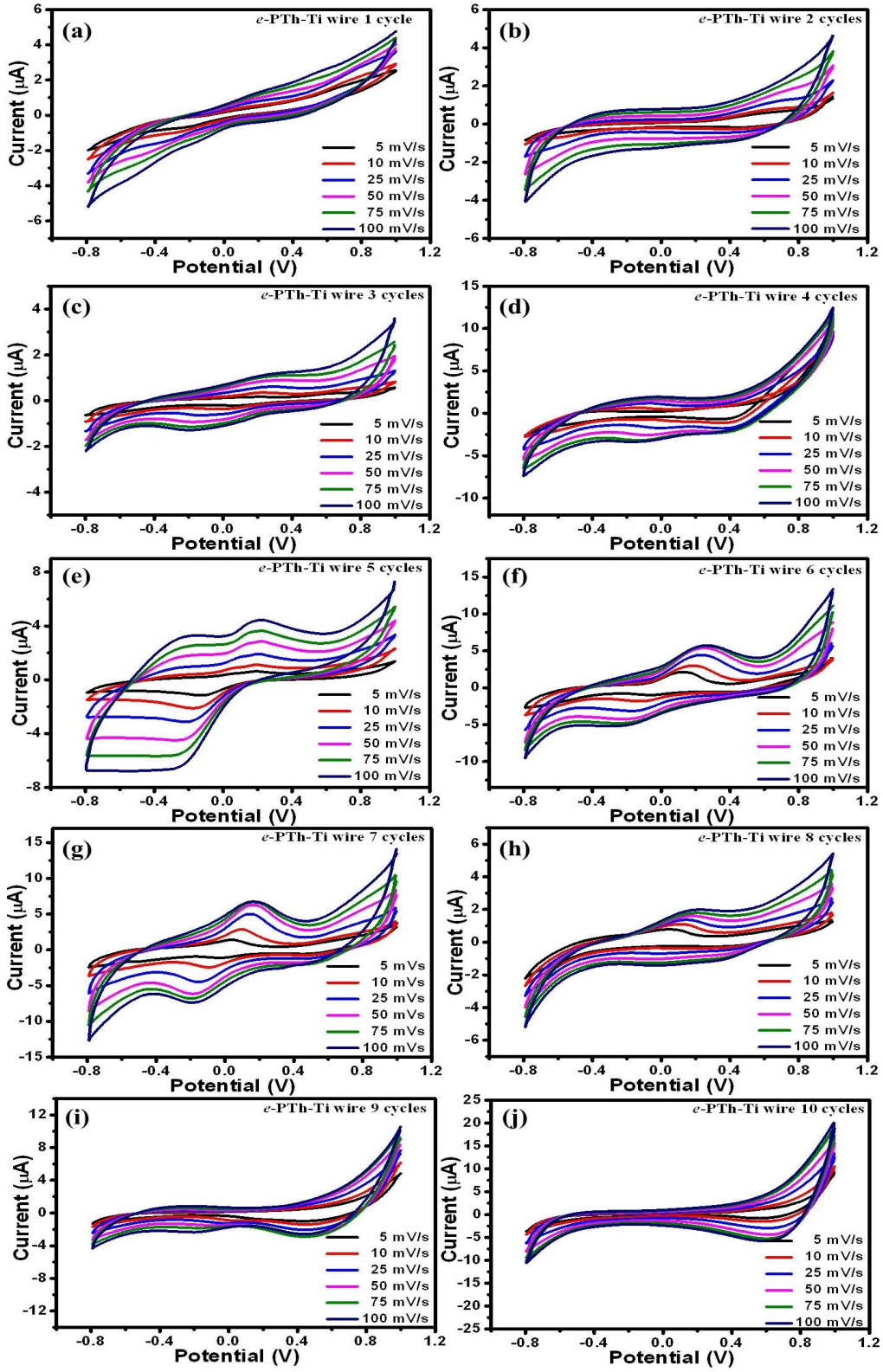

(a)
e-PTh-Ti wire 1 cycle
(b)
e-PTh-Ti wire 2 cycles
(c)
e-PTh-Ti wire 3 cycles
(d)
e-PTh-Ti wire 4 cycles
(e)
e-PTh-Ti wire 5 cycles
(f)
e-PTh-Ti wire 6 cycles
(g)
e-PTh-Ti wire 7 cycles
(h)
e-PTh-Ti wire 8 cycles
(i)
e-PTh-Ti wire 9 cycles
(j)
e-PTh-Ti wire 10 cycles
Current (μA)
Potential (V)
5 mV/s
10 mV/s
25 mV/s
50 mV/s
75 mV/s
100 mV/s
5 mVs
10 mVs
25 mVs
50 mVs
75 mVs
100 mVs

Figure S10. (a to j) CV curves of *e*-PTh/Ti wire at different in sweep rates for various numbers of polymerization cycles (1 to 10 cycles, respectively).

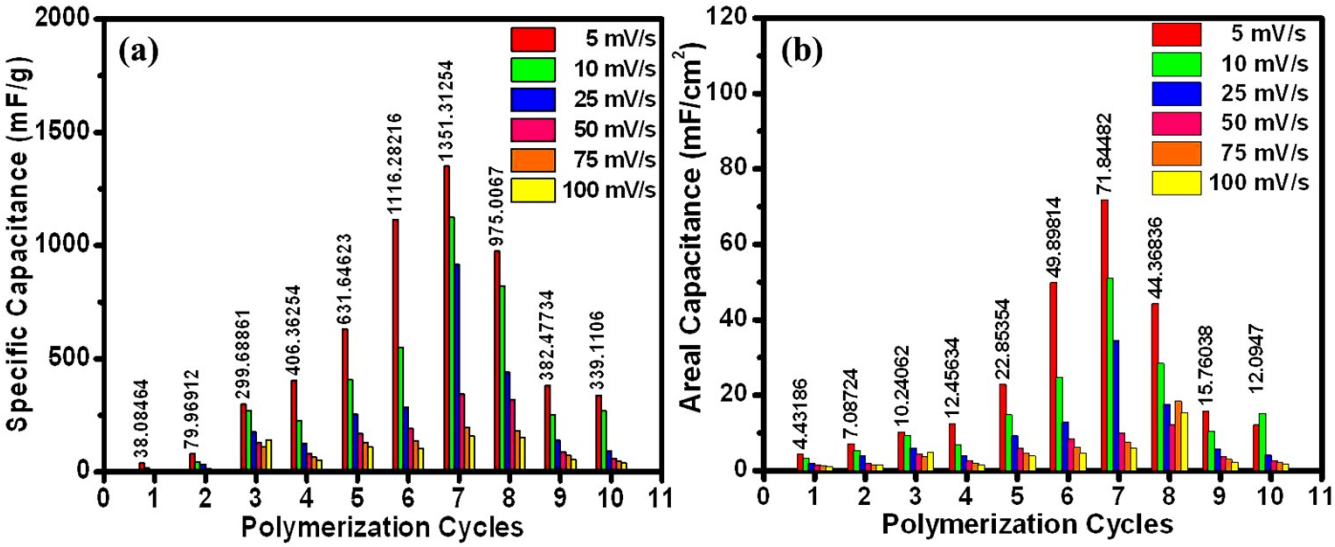


Figure S11. Effect of scan rate on (a) specific capacitance and (b) areal capacitance for the various polymerization conditions of *e*-PTh/Ti wire.

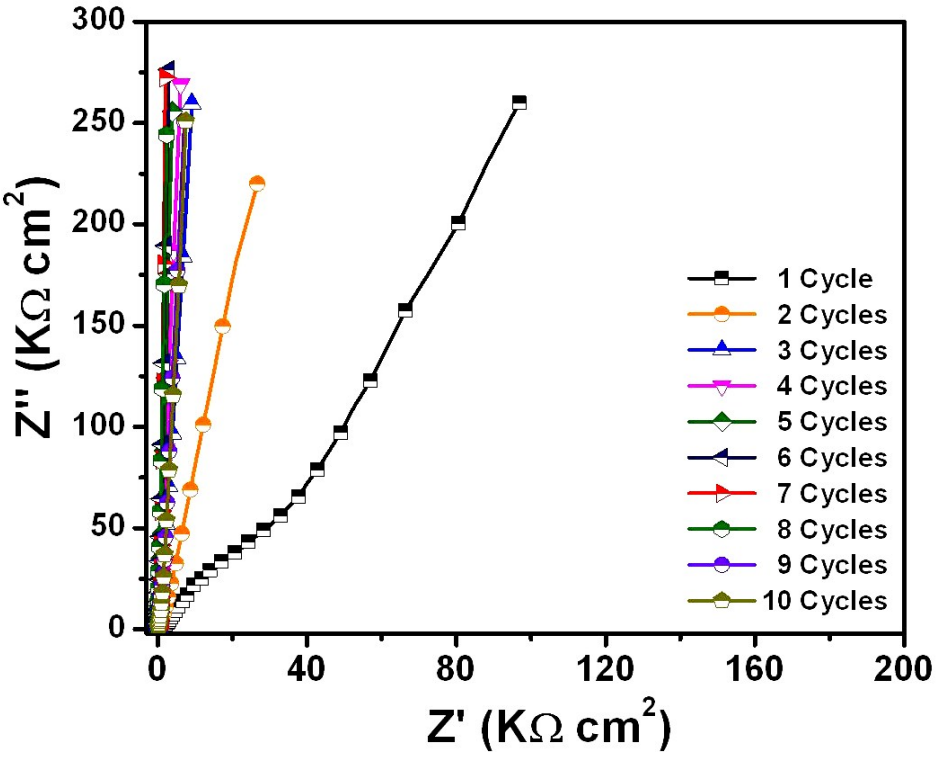


Figure **S12.** Nyquist plots of *e*-PTh/Ti wire electrodes at different polymerization cycles.

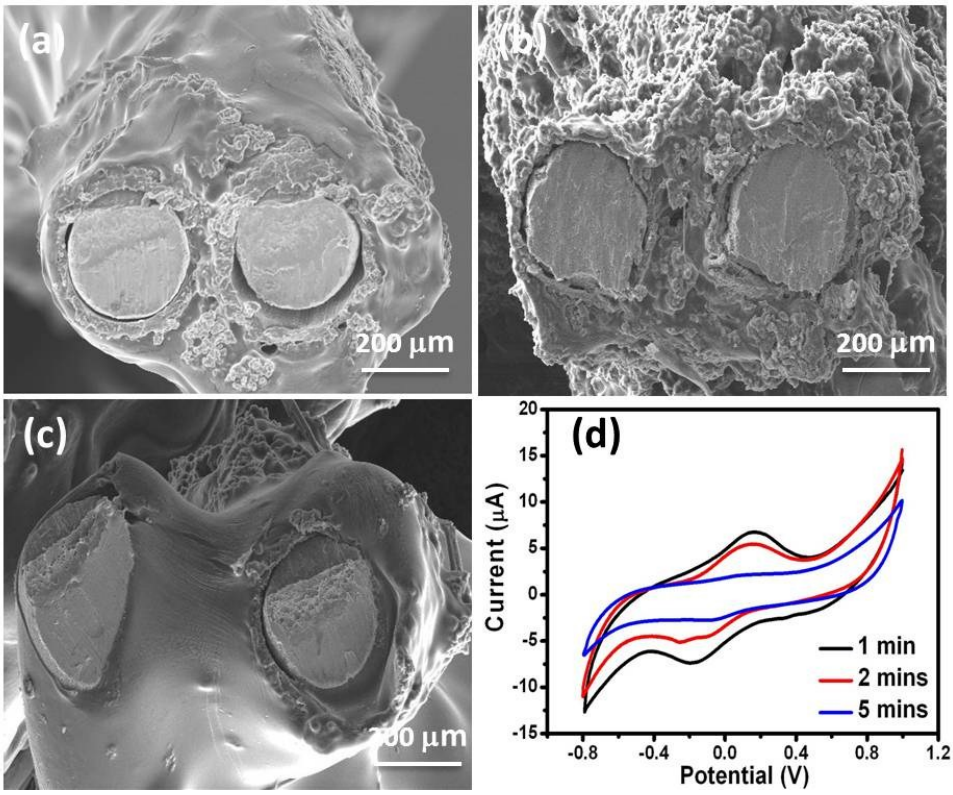


Figure S13. The *e*-PTh/Ti wire at 7 cycles with different PVA-H_2SO_4 gel electrolyte coating time (a) 1 min, (b) 2 mins, (c) 5 mins and (d) CV curves at different PVA-H_2SO_4 gel electrolyte coating time.

Table S2. Comparison of our *f*-WS all-solid-state SCs with the reported data.

Electrode Materials	Electrolyte	Potential Window	Specific Capacitance (mF cm^{-2})	Energy Density E (μWh cm^{-2})	Power Density P (μW cm^{-2})	Reference
***e*-PTh/Ti wire**	**PVA-H_2SO_4**	**-0.8 to 1 V**	**71.84**	**23.26**	**90.44**	**This work**
Pen ink	PVA-H_2SO_4	0 to 1 V	26.4	2.7	42	[4]
RGO+CNT	PVA-H_3PO_4	0 to 0.8 V	177	3.84	20	[5]
CNT and Ti fibers	PVA-H_3PO_4	0 to 0.8 V	0.6	0.15	-	[6]
PANI-CNT Yarn	PVA-H_2SO_4	0 to 0.8 V	38	-	-	[7]
CVD – Graphene Fiber/MnO_2	PVA-H_3PO_4	0 to 1 V	42.02	1.46	-	[8]
ZnO nanowires-/MnO_2	PVA-H_2SO_4	0 to 0.8 V	2.4	0.027	14	[9]
PANI-Graphene Fiber	PVA-H_3PO_4	0 to 1 V	66.6	-	-	[10]
PANI-Stainless steel	PVA-H_2SO_4	0 to 0.6 V	41	0.95	-	[11]
OMC/CNT	PVA-H_3PO_4	0 to 0.8 V	39.7	1.77	43	[12]

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