Supporting Information

High-Performance Flexible Thermoelectric Devices with Foam Copper Heatsink for Personal Thermal Management

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Synthesis of materials

The sample synthesis of p-type $Bi_{0.4}Sb_{1.6}Te_3$: high purity (<99.999%) Bi, Sb, Se and Te blocks, and synthesized AgGeTe are weighed according to the stoichiometric ratio of $Bi_{0.4}Sb_{1.6}Te_{2.95}Se_{0.05}$ + 0.10 wt% Ag_8GeTe_6.The raw materials are loaded into quartz tubes and sealed with an oxyacetylene flame under a vacuum of 5 Pa. The mixture is then melted at 750°C for 1.0 h, oscillated for half an hour, and air quenched. Finally, the obtained material is ground into fine powder through high-speed ball-milled that is loaded in a Φ40 mm graphite mold and densified by discharge plasma sintering at 703 K and 50 MPa for 8 min.(1)

Similarly, for n-materials, Bi, Te, and Se blocks (5 N), BiI_3 powders (4 N) and the prepared $SnSb_2Te_4$ powders were weighed according to the stoichio-metric ratio of $Bi_2Te_{2.7}Se_{0.3}$ +0.15 wt% BiI_3 +0.15 wt.% $SnSb_2Te_4$. The mixtures were sealed in a Φ12.7 mm quartz tube at a high vacuum and melted in a rocking furnace at 1023 K for 1 h, followed by air quenching. Subsequently, the obtained ingots were zone-melting at 1013 K with a growth rate of 25 mm h^{-1} in a vertical growth furnace.(2)

Error analysis of material's transport coefficients

The electronic and thermal transport measurements for the materials were conducted along the same direction of the same ingot. The systematic errors of Seebeck coefficient α and electrical conductivity σ measurements were about 3% and 5%, respectively. Based on the uncertainties of 1% for the density ρ, 5% for the specific heat C_p, and 5% for the thermal diffusion D, the combined uncertainty for the total thermal conductivity κ_{tot} is about 7%. Ultimately, the uncertainty in the ZT value is estimated to be about 10%.

Test method for cooling temperature difference

The cooling performance of the device was evaluated according to Fig. S4, the DC power supply inputs distinct currents for F-TED, and the cooling system kept the hot side (T_h) at a stable temperature of 27 °C. The temperature of the cold side (T_c) was monitored by an infrared thermal imaging device (Fluke, Ti400, USA). The maximum cooling temperature difference of the F-TED was calculated by following formulae, $\Delta T_{\max} = T_h - T_c$.

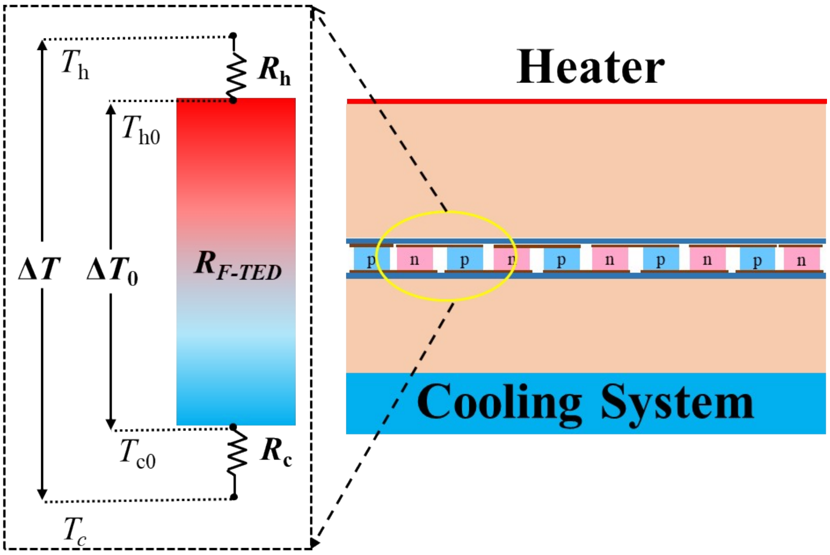

Figure S1. Schematic diagram of thermal resistance network in thermoelectric device testing

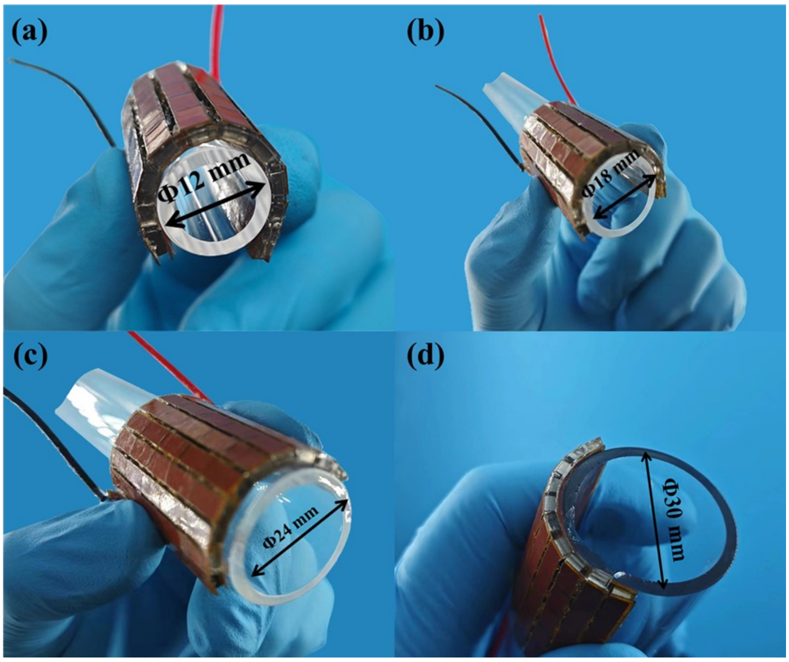

Figure S2. Schematic diagram of bending of flexible devices at different diameters.

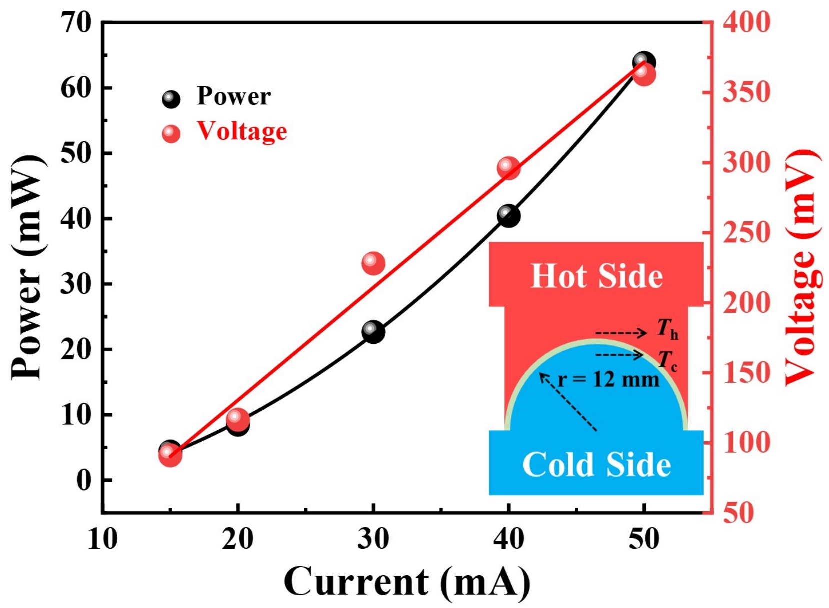

Figure S3. Schematic diagram of F-TED's power generation performance and testing system under bending conditions

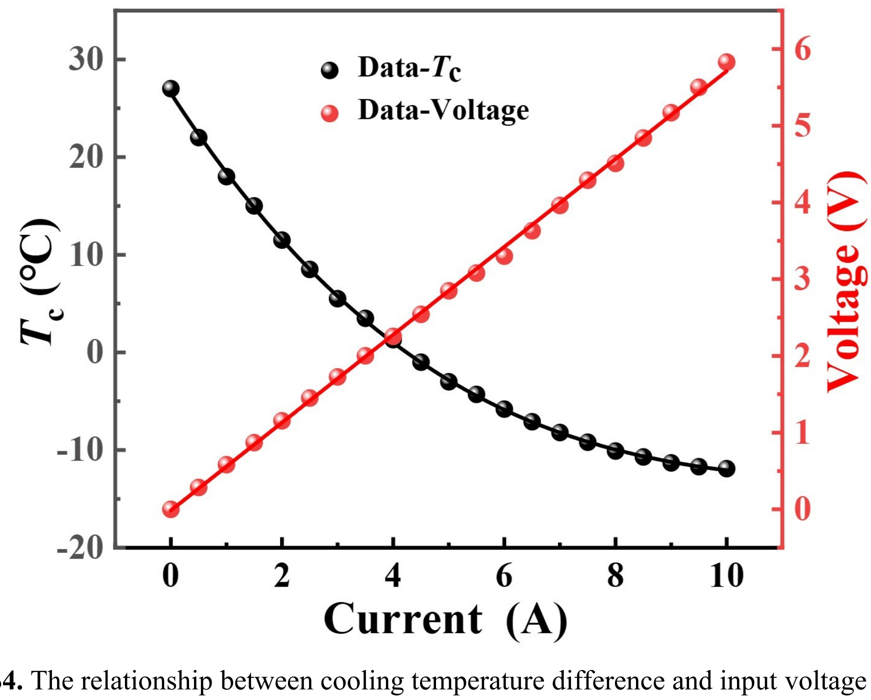

Figure S4. The relationship between cooling temperature difference and input voltage and input current of devices in a bent state

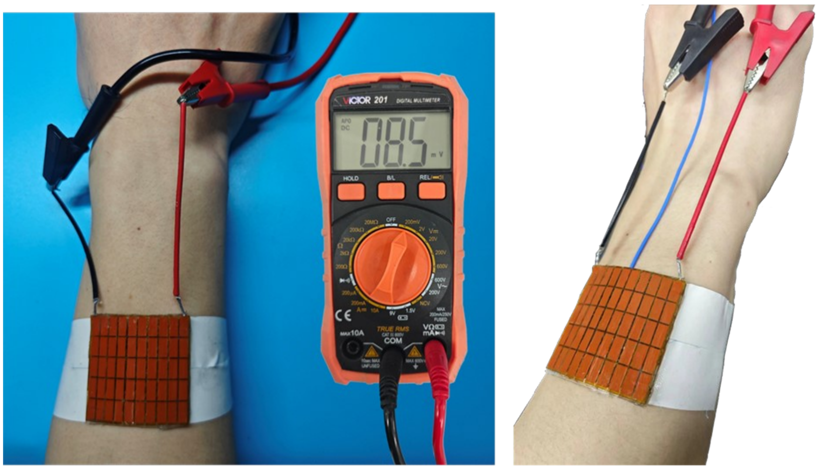

Figure S5. Experimental diagram of flexible components without foam copper heatsink in PTM

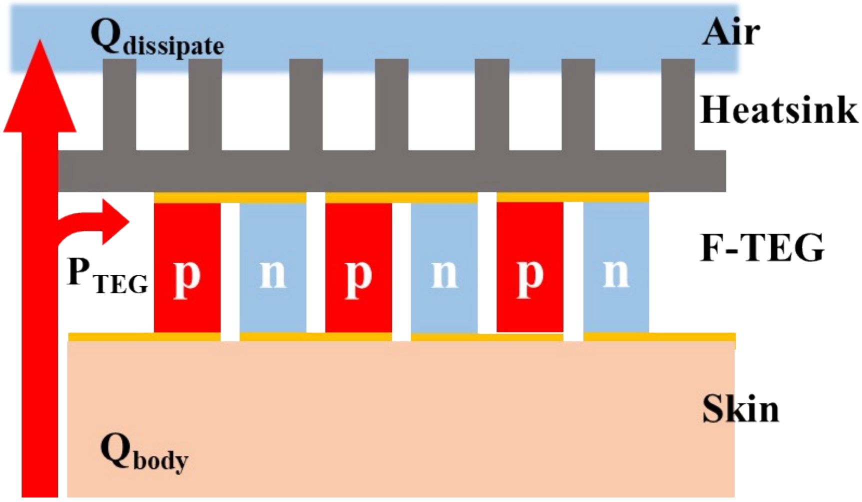

Figure S6. Schematic diagram of human body waste heat power generation

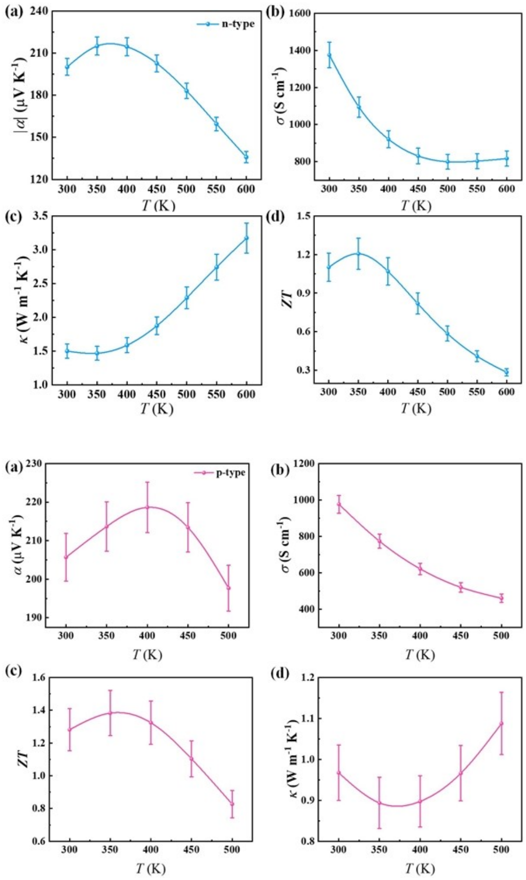

Figure S7. Temperature-dependent TE transport coefficients of n-type and p-type Bi_2Te_3-based materials: (a) Seebeck coefficient, (b) electrical conductivity, (c) thermal conductivity, and (d) *ZT* value

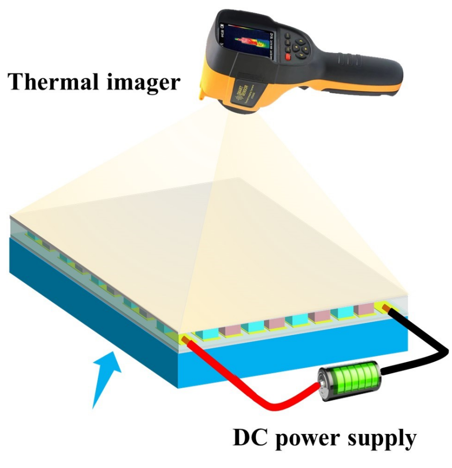

Figure S8. Schematic diagram of cooling performance measurement.

Table S1 V_{oc} of a single pair of TE leg in literature under various ΔT

ΔT (K)	Total voltage (mV)	pairs	reference
50	37.2	52	(3)
10	121	31	(4)
20	600	200	(5)
30	500	128	(6)
30	246	60	(7)
50	236	18	(8)
40	2120	220	(9)
20	3	1	(10)
10	59.96		
30	130	32	(11)
60	278.3		
45	381	32	(12)
52	1300	204	(13)
20	88	50	(14)
10	93	70	(15)
15	101		
20	129		
30	253	49	This work
40	329		
50	404		

Table S2 A comparison of our f-TED with recently typical f-TEDs in TE output performances.

Materials	Seebeck coefficient per unit area ($\mu V\ K^{-1}\ cm^{-2}$)	Normalized power density ($\mu W\ cm^{-2}\ K^{-2}$)	Ref.
Ag-Ni/PDMS-Bi_2Te_3	3160	0.26	(16)
Ecoflex-Bi_2Te_3/Sb_2Te_3	1058	0.416	(17)
Polyimine-Bi_2Te_3/Sb_2Te_3	1302	1.08	(5)
Bi/Sb chalcogenides	10526	0.0022	(18)
Yarn-Bi_2Te_3/Sb_2Te_3	4024	0.095	(19)
p/n type MWCNT film	333	0.75	(20)
PEDOT:PSS film	427	0.045	(21)
Sb_2Te_3/Te_x film	334	0.7	(22)
LMEC-Bi_2Te_3	396	0.163	(23)
PI-p/n type CNT films	3390	0.0931	(24)
p/n type CNT fiber	125	0.0035	(25)
PI/BN- Bi_2Te_3/Sb_2Te_3	1340	1.54	(4)
BiTe-based TE leg /LM electrodes	74.4	0.1	(10)
BiTe-based TE film /Cu electrodes	600	1.52	(26)
BiTe-based TE leg /Cu electrodes	1250	7.648	(27)
BiTe-based TE leg /Cu electrodes	1000	0.576	(28)

Table S3 National standard of Air Velocity Rating issued by China Meteorological Newspaper

Level	Air velocity(m s-1)	wind
0	0~0.2	Ash breeze
1	0.3~1.5	Soft breeze
2	1.6~3.3	Light breeze
3	3.4~5.4	Breeze
4	5.4~7.9	Gentle breeze
5	8.0~10.7	Strong breeze
6	10.8~13.8	Strong wind
7	13.9~17.1	Moderate gale
8	17.2~20.7	gale
9	20.8~24.4	Strong gale
10	24.5~28.4	Wild wind
11	28.5~32.6	Storm wind
12	32.7~36.9	hurricane
13	>36.9	---

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