- Supporting Information -

Lightweight Wearable Thermoelectric Cooler with Rationally Designed Flexible Heatsink Consisting of Phase-change Material/Graphite/Silicone Elastomer

Jaeyoo Choi [a], Chaochao Dun [a], Carlos Forsythe [a], Madeleine P. Gordon [a,b], Jeffrey J. Urban [a,*]

[a] The Molecular Foundry Lawrence Berkeley National Laboratory Berkeley, CA, 94720, USA

[b] Applied Science and Technology Graduate Group, University of California, Berkeley, California, 94720, USA

Corresponding author: jjurban@lbl.gov

Thermal conductivity measurement

Thermal conductivity was measured using the 3-omega method. A 12um diameter Pt wire served as the heater for this measurement. To perform the measurement, the wire was placed between two pieces of the material in question. Thicker, Cu wire, was lain across the Pt wire to use as voltage probes, so that a 4-point voltage measurement could be performed (Fig. S1). An alternating current in the range of 30-50 mA was used to heat the wire, depending on the material's thermal conductivity, to create a temperature oscillation around a few degrees Kelvin.

The measurement itself is a voltage measurement of the heater, using a lock in amplifier, locked to 3rd harmonic of the current frequency. This 3rd harmonic voltage ($V_{3\omega}$) gives a direct measurement of the amplitude of the temperature oscillations in the wire. Under specific frequency conditions, these oscillations have a linear relationship to the log of the current frequency (Fig. S1). The slope can be extracted to give the thermal conductivity of the material, under the assumption that the thermal conductivity is isometric. The thermal conductivity was extracted for frequencies between 0.3 – 7 Hz (the grey shaded region), where we calculate and observe the temperature to conform to a simple linear model.

The error of our measurements is dominated by error in the determination of the wire's temperature coefficient of resistance. The temperature coefficient of resistance is a material property which states how much the wire resistance changes with temperature. We calculate the error in our determination of the temperature coefficient to be 5 %, which directly imparts a 5 % error onto our measurement of thermal conductivity for each material.

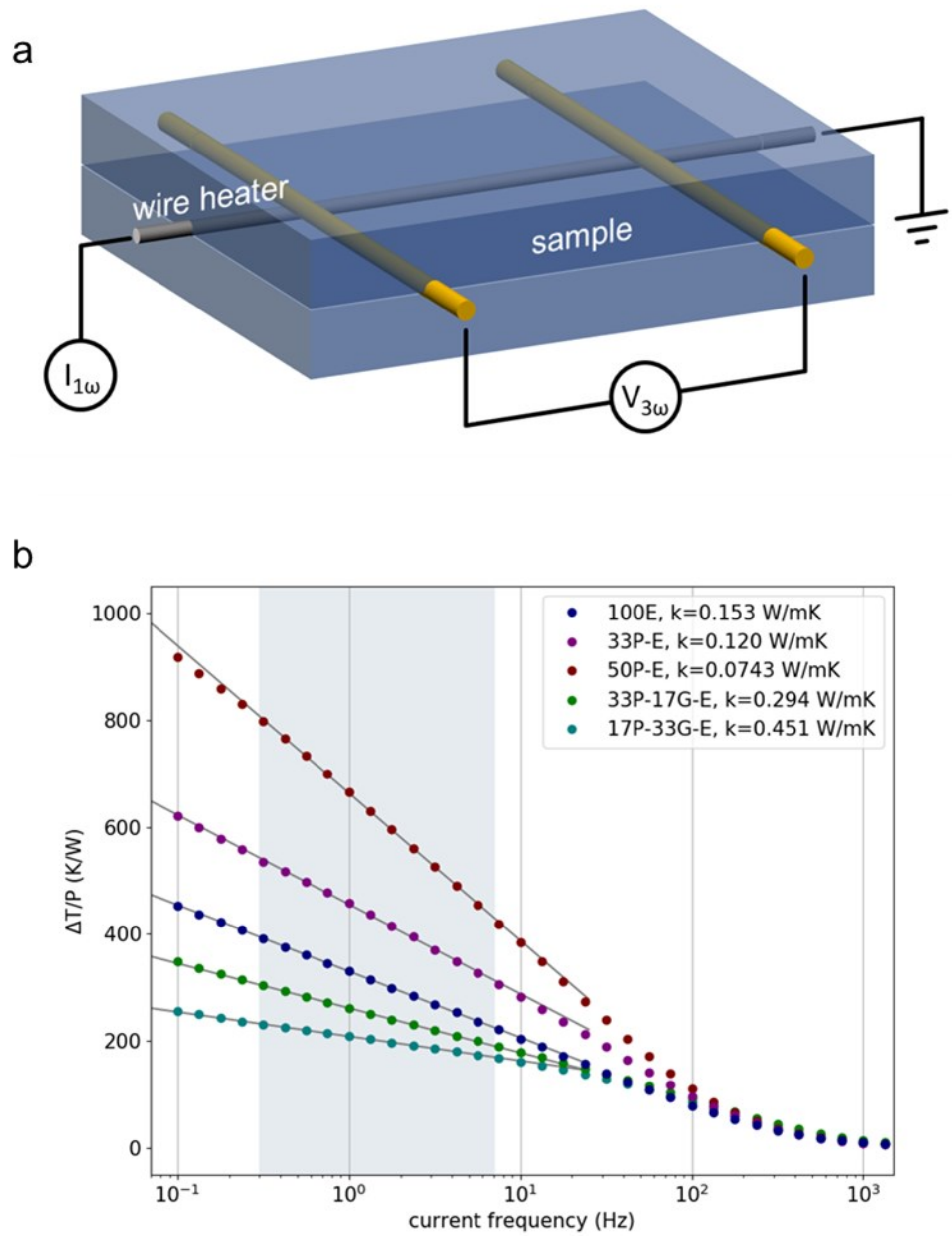

Figure S1. (a) Schematic image of thermal conductivity measurement setup based on 3 omega method (b) Measured results of the heatsink samples with different compositions. Graphed, is the in-phase temperature oscillation of wire, ΔT, normalized by the Joule heating power oscillation, P, as a function of the frequency of the heat-inducing current through the wire.

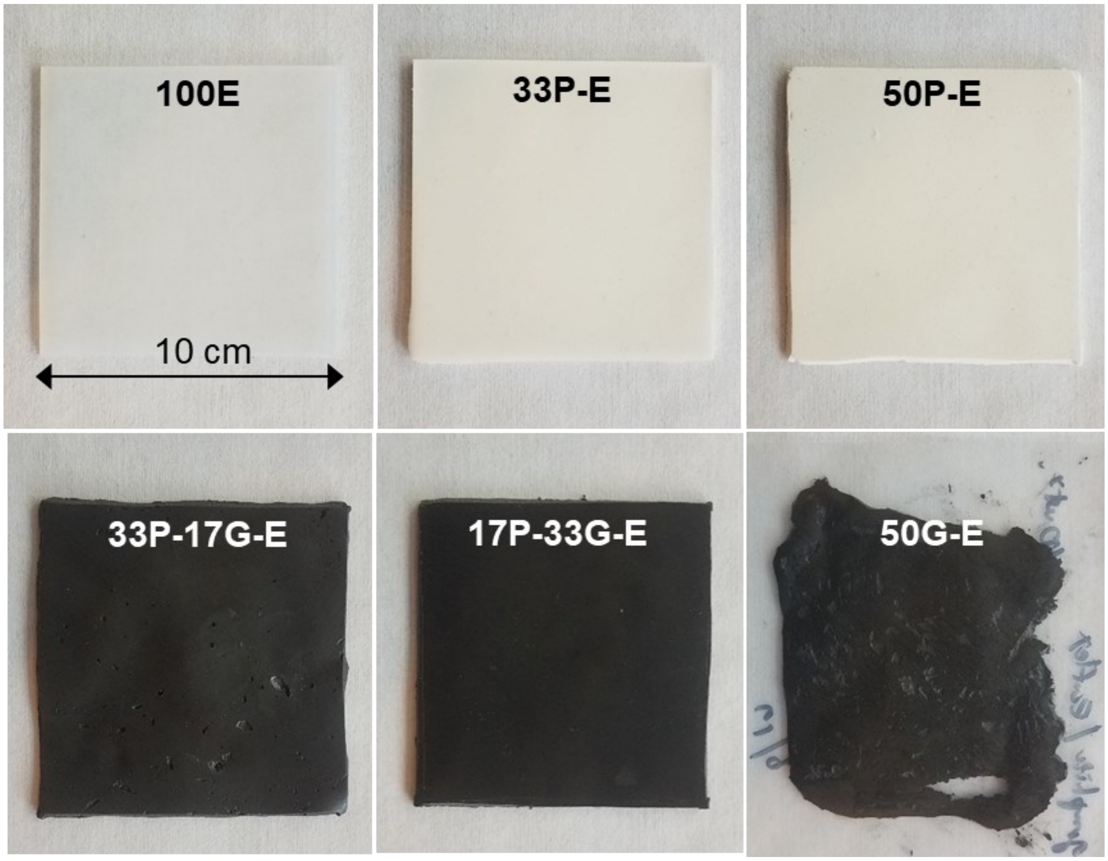

Figure S2. Optical images of flexible heatsinks with various compositional ratios.

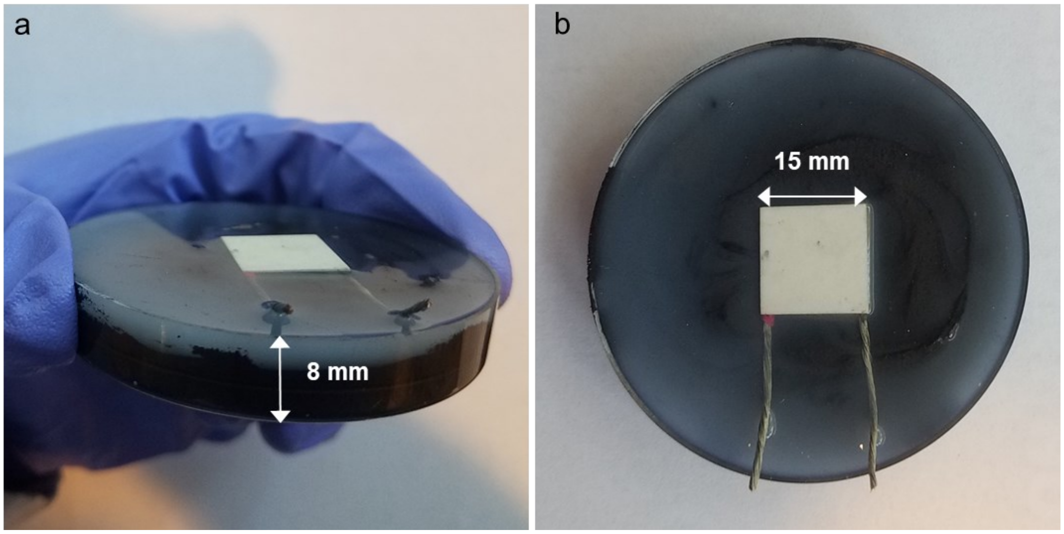

Figure S3. Optical images of the prototype TE cooler with flexible heat sink (a) side view (b) top view.

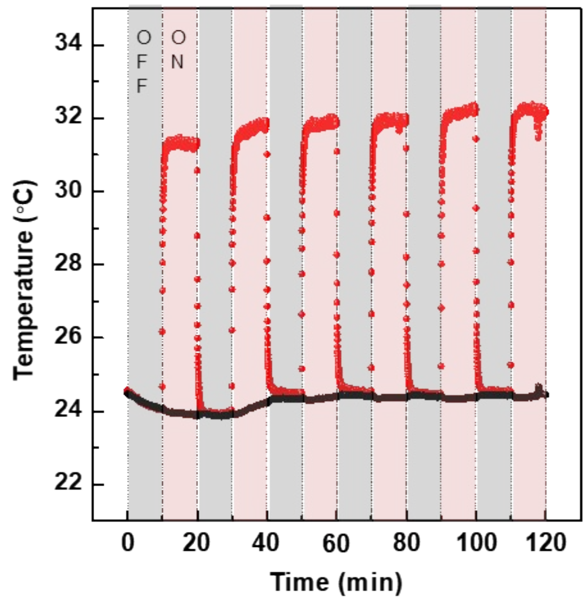

Figure S4. Heating demonstration of the prototype TE device with switching on/off every 10 min.

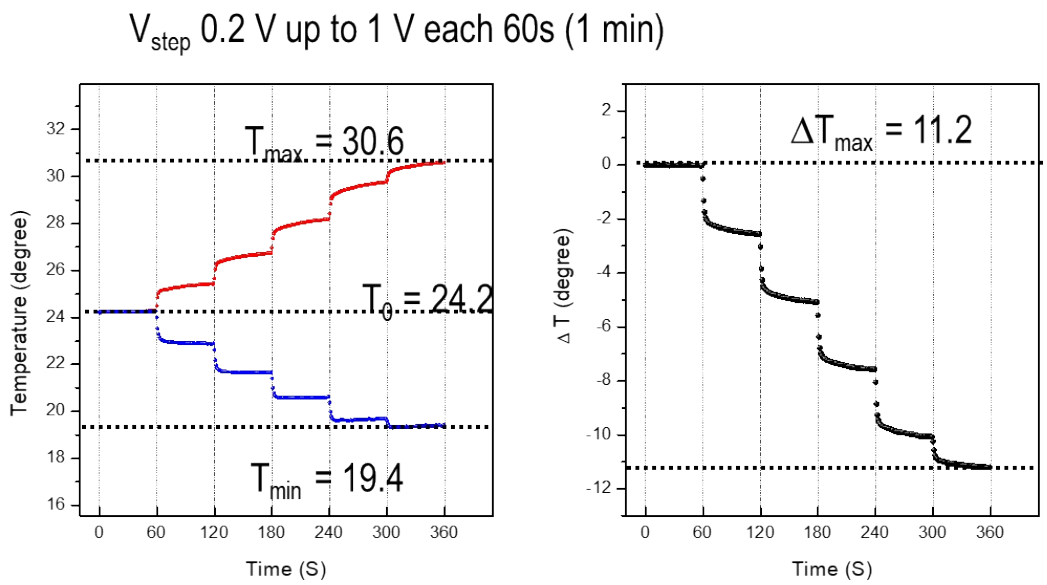

Figure S5. Adjustable cooling and heating temperature of prototype TE device as a function of applied voltage.

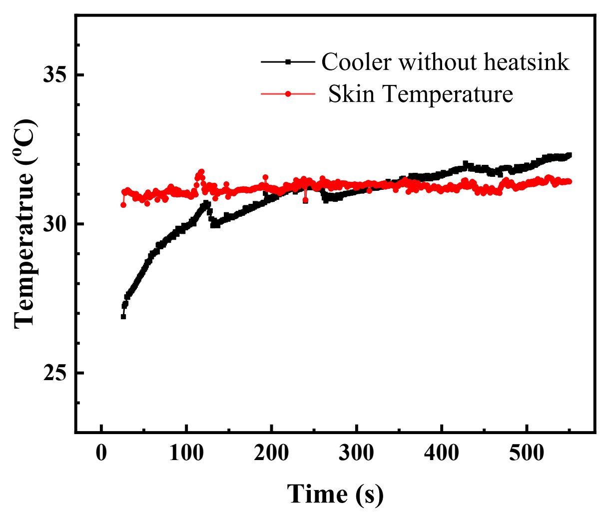

Figure S6. The on-body cooling performance of a device without a heatsink. As can be seen, without the heatsink, the device cannot maintain as a functional cooler as compared with the one with the proposed heatsink.