Supplementary Information (SI) for

‘From synthesis to device: comparative study of Bi_2Te_3 alloys prepared by direct melt and ball milling for printed thermoelectrics’

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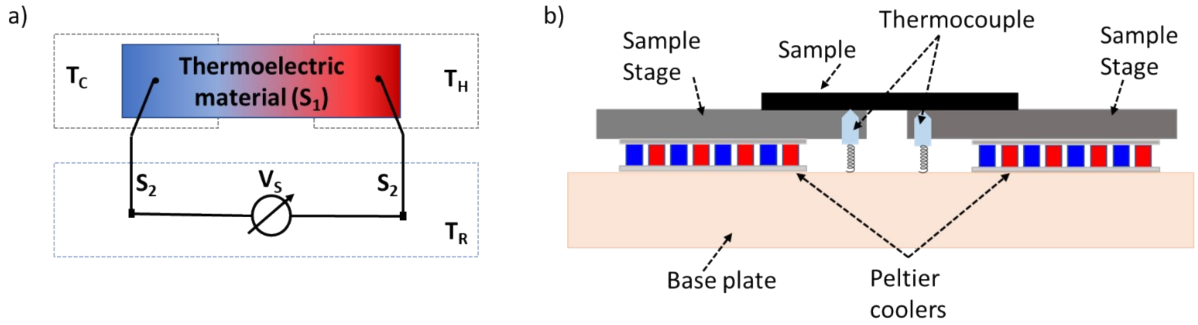


Figure S1: Seebeck measurement a) Schematic representation of the measurement concept b) Schematic representation of the measurement setup.

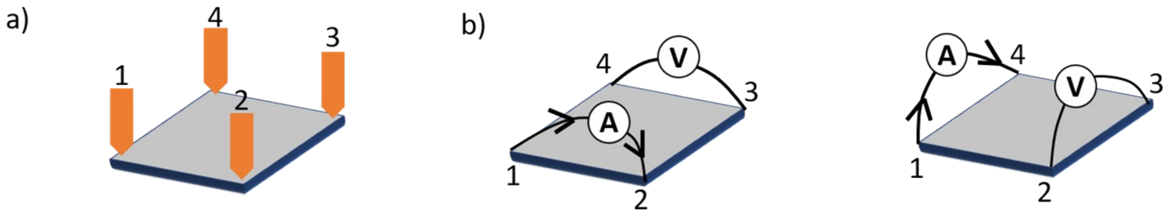
The basic setup for the measurement of Seebeck coefficient used in this work is illustrated in Figure S1 (a). The test samples (thermoelectric material on a FR4 substrate), having a Seebeck coefficient of S_1, is connected to a voltmeter using two identical wires made of material with known Seebeck coefficient of S_2. The sample is placed on two plates, where the temperature of one plate is (T_C) and the other is (T_H), and thus the sample is subjected to a temperature difference of (T_H-T_C). The region enclosed as the blue dashed line is isothermal, where both the voltmeter ad the wire connections are maintained at a constant temperature of T_R (reference temperature). Consequently, the two connecting wires experience respective temperature gradients of (T_R-T_C) and (T_H-T_R).

Assuming small-enough temperature gradients for the Seebeck coefficient to be constant, the voltage between the terminals of the voltmeter VS can be calculated as:
$$V_s = S_2 * (T_H - TR) + S_1 * (T_H - T_C) + S_2 * (T_R - T_C)$$
Above equation can be simplified to:
$$V_s = (S_1 - S_2) * (T_H - Tc)$$
Since the S2 is a known value, the Seebeck coefficient of thermoelectric material was then calculated according to:
$$S_1 = \frac{V_S}{(T_H - T_C)} + S_2$$

The schematic of the custom-built Seebeck measurement setup is shown in Figure S1(b). The setup consists of a base plate and two aluminum sample stages, each equipped with a commercial Peltier cooler for precise temperature control. Type K thermocouples are embedded within the stages to monitor and regulate the temperature, with their tips left exposed to ensure direct thermal and electrical contact with the sample surface.

During measurement, the sample is placed face-down onto the stages to ensure intimate contact with the thermocouple probes. The thermocouples are used both to determine the actual sample temperatures and to measure the thermoelectric voltage via copper and constantan leads. The Seebeck coefficient of the sample is obtained by correcting the measured voltage for the known Seebeck coefficients of the leads (+1.8 μV K^{-1} for copper and −38 μV K^{-1} for constantan).

The entire measurement process is largely automated using a LabVIEW program, which controls the temperature setpoints and records temperature and voltage data during measurement.



Van-der-Pauw method

Geometry 1

Geometry 2

Figure S2: Electrical resistivity measurement a) Experimental setup for Van-der-Pauw measurement b) Measurement geometries of a square conductivity sample

During the four probe/ Van-der-Pauw method, the horizontal (R_A) and vertical (R_B) resistances are measured using the formulae:

$$R_A = \frac{V_{43}}{I_{12}};\ R_B = \frac{V_{23}}{I_{14}}$$

Th two resistance measurements are combined with the thickness of the sample to get the conductivity of the sample.

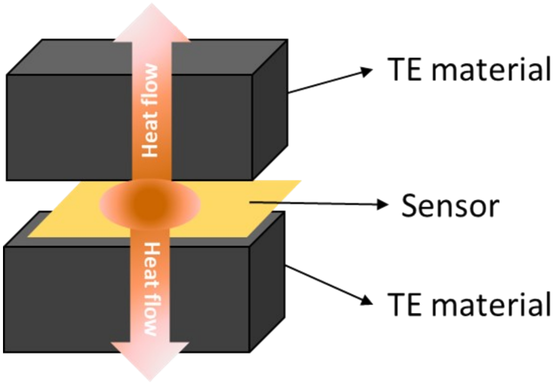


Figure S3: Schematic illustration of the thermal conductivity measurement setup using the transient hot bridge method, in which a combined hot-wire heater and thermometer sensor is sandwiched between two identical thermoelectric material blocks.

The thermal conductivity was measured using the transient hot bridge (THB) method based on the hot-wire principle. In this method a metallic sensor act simultaneously as localized heat source and a temperature probe. When a constant electric current is applied, joule heating induces a transient temperature rise around the sensor that depends on the thermal conductivity of surrounding material. In this study a hot pint sensor is used due to the smaller volume of the sample (5×5 mm^2). The sensor is heated by an applied electrical current, and the resulting temperature rise is recorded as a function of time. The thermal conductivity is determined from the transient temperature response using an analytical heat diffusion model, with an estimated measurement uncertainty of approximately 5–10%.

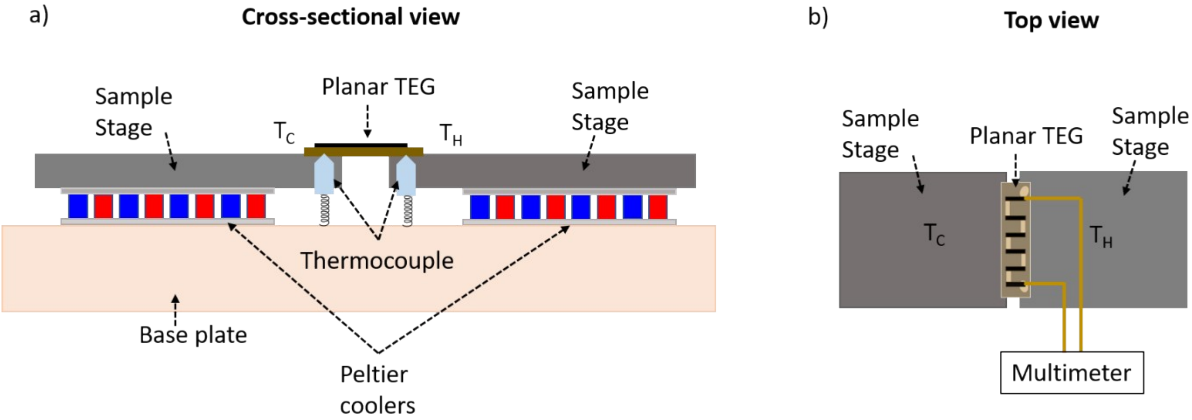


Figure S4: Planar TEG performance measurement setup a) Cross-sectional schematic of the custom-built Seebeck measurement platform used for planar thermoelectric generator (TEG) characterization. The TEG is positioned on the sample stages such that one side rests on the cold stage (T_C) and the opposite side on the hot stage (T_H), both temperature-controlled by Peltier elements. B) Top view of the placement of TEG and voltage measurement.

Resistance and voltage measurement of the planar TEGs

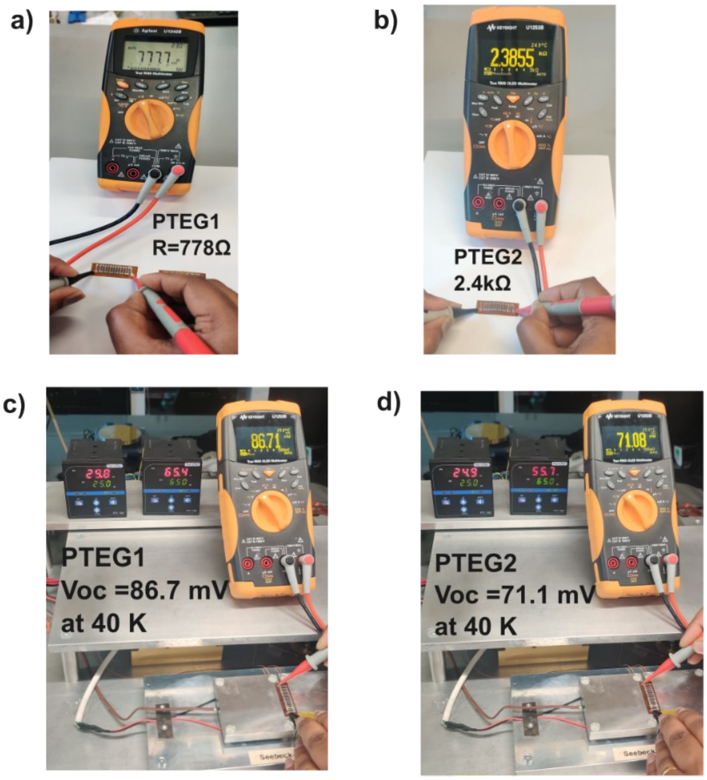


Figure S5: a) Photographs of the resistance measured TEG for PTEG1 (milled materials) after fabrication b) Photograph of the measured TEG for PTEG2 (melt materials) after fabrication c) Photograph of open circuit voltage measured using a multimeter for PTEG1 at ΔT = 40K d) Photograph of open circuit voltage measured using a multimeter for PTEG2 at ΔT = 40K