Flexible, High-performance *n*- and *p*-type Thermoelectric Films

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Flexible thermoelectric generators (fTEGs) can be used to harvest body heat to power wearable electronics and could be an excellent approach to achieving energy autonomy in these devices [1]. However, their widespread use is limited due to difficulties in fabricating intrinsically flexible fTEGs and making complementary pairs of *n*- and *p*-type elements of the thermopile to maximise the power output. We present an exfoliation of $Bi_2Se_{0.3}Te_{2.7}$ (*n*-type) and $Bi_{0.5}Sb_{1.5}Te_3$ (*p*-type) via a low-temperature solution-processable liquid-phase exfoliation (LPE) process yielding intrinsically flexible laminates when the exfoliated nanosheets were restacked on a nylon substrate. The films had a Seebeck coefficient that matched the pelletised bulk powder and an optimised power factor of $(1.62\pm0.01)\times10^{-3}$ $Wm^{-1}K^{-2}$ and $(2.33\pm0.01)\times10^{-3}$ $Wm^{-1}K^{-2}$, for *n*- and *p*-type films respectively. Additionally, both laminate films demonstrated durable mechanical stability after 25,000 uniform bending cycles. We further developed an in-plane fTEG module containing two elements which we optimised by introducing metal nanoparticle decoration to improve electrical conductivity. This module, with a single pair of *n*- and *p*-type elements generated 1.98 μW across a 30 K thermal difference. Our methodology offers a novel and universal platform to design and fabricate high-performance fTEGs and thus has excellent potential for self-powered wearable devices.

References

[1] Bahk, J. H., Fang, H. Y., Yazawa, K. & Shakouri, A. J Mater Chem C 3, 10362-10374 (2015)

Figures

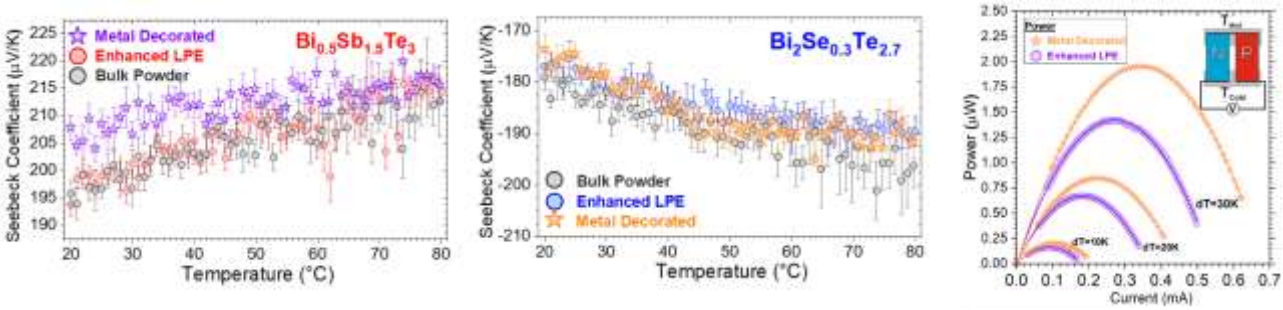

Figure 1: (Left and centre): Seebeck coefficient values against temperature for both *p*- and *n*-type films showing similar trends for flexible laminates, flexible metal decorated laminates and for brittle bulk pellets. (Right): Output power of a single two-element in-plane fTEG module against current for non-decorated and metal decorated LPE films at dT = 10, 20 and 30 K. (inset) Schematic showing module design and measurement circuitry.