Panoscopically optimized thermoelectric performance of half-Heusler/full-Heusler based in-situ bulk composite Zr\textsubscript{0.7}Hf\textsubscript{0.3}Ni\textsubscript{1+x}Sn: Energy and Time efficient way

A. Bhardwaj\textsuperscript{1,2}, N. S. Chauhan\textsuperscript{1,2} Bhagyashree Sancheti\textsuperscript{1}, T. D. Senguttuvan\textsuperscript{1,2} and D. K. Misra*\textsuperscript{1,2},

\textsuperscript{1}Physics of Energy Harvesting Division, National Physical Laboratory, Council of Scientific and Industrial Research, New Delhi 110012, India.

\textsuperscript{2}Academy of Scientific & Innovative Research (AcSIR), CSIR-National Physical Laboratory (CSIR-NPL) campus, New Delhi-110012, India.

Supplementary Information:

The SEM morphology taken corresponding to HH Zr\textsubscript{0.7}Hf\textsubscript{0.3}NiSn clearly reveals a single phase contrasts as shown in Fig. S1(a). Fig S1(b) shows energy dispersive X-ray analysis (EDAX) spectrum recorded from the sample of HH Zr\textsubscript{0.7}Hf\textsubscript{0.3}NiSn indicating almost nominal composition of HH Zr\textsubscript{0.7}Hf\textsubscript{0.3}NiSn. However, the SEM morphology obtained from composite of HH(1-x)/FH(x) with compositions Zr\textsubscript{0.7}Hf\textsubscript{0.3}Ni\textsubscript{1+x}Sn (0.03, 0.05 & 0.10) with increasing FH fractions display two phase contrasts which are presented in supporting information S1(c, e & f). One can clearly see that with increasing FH fractions, the size of FH grains also increases and these grains were noted to be of varying length scales S1(c, e & f). The compositional analysis of these phases was performed employing EDAX to verify the homogeneities of the samples. The compositions of HH and FH in all the compositions Zr\textsubscript{0.7}Hf\textsubscript{0.3}Ni\textsubscript{1+x}Sn have been quantified and averaged from values taken at 8 positions and no obvious impurities phase were observed other than HH and FH in any of the composite samples. A representative EDS spectrum and quantification of elements for the best performing sample Zr\textsubscript{0.7}Hf\textsubscript{0.3}Ni\textsubscript{1+x}Sn with x=0.03, have been presented in fig. S1(d).
EDAX analysis confirms the minor phase to be full-Heusler, while matrixes phase to be HH, which are consistent with the XRD results.

**Figure S1:** (a) The back scattered SEM micrograph of $\text{Zr}_{0.7}\text{Hf}_{0.3}\text{NiSn}$ representing a single phase contrast which corresponds to half heusler phase confirmed by the EDAX pattern shown in Fig (b); (c) SEM of $\text{Zr}_{0.7}\text{Hf}_{0.3}\text{Ni}_{1.03}\text{Sn}$ representing dominantly two phase contrasts; (d) the EDAX pattern
of dark contrast and overall phase; (e & f) SEM micrograph of HH (1-x)/FH(x) Zr$_{0.7}$Hf$_{0.3}$Ni$_{1+x}$Sn (0.05 & 0.10) composites showing dominantly two phase contrasts with varying FH grain sizes.

Figure S2: Temperature dependence of thermal diffusivity of composite of HH(1-x)/FH(x) with compositions Zr$_{0.7}$Hf$_{0.3}$Ni$_{1+x}$Sn (0, 0.03, 0.05 & 0.10).

Figure S3: Temperature dependence value of specific heat ($c_p$) of composite of HH(1-x)/FH(x) with compositions Zr$_{0.7}$Hf$_{0.3}$Ni$_{1+x}$Sn (0, 0.03, 0.05 & 0.10).
**Table ST1:** Crystal density data along with geometrical pellet density of HH (1-x)/FH(x) composites derived from the compositions Zr$_{0.7}$Hf$_{0.3}$Ni$_{1+x}$Sn ($0.0 \leq x \leq 0.10$).

<table>
<thead>
<tr>
<th>Composition:</th>
<th>Zr$<em>{0.7}$Hf$</em>{0.3}$NiSn</th>
<th>Zr$<em>{0.7}$Hf$</em>{0.3}$Ni$_{1.03}$Sn</th>
<th>Zr$<em>{0.7}$Hf$</em>{0.3}$Ni$_{1.05}$Sn</th>
<th>Zr$<em>{0.7}$Hf$</em>{0.3}$Ni$_{1.1}$Sn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crystal Density (kg/m$^3$)</strong></td>
<td>8724.27</td>
<td>8766.52</td>
<td>8805.21</td>
<td>8873.65</td>
</tr>
<tr>
<td><strong>Geometrical pellet density (kg/m$^3$)</strong></td>
<td>8584.68</td>
<td>8677.10</td>
<td>8678.41</td>
<td>8717.47</td>
</tr>
<tr>
<td><strong>Relative %</strong></td>
<td>98.4%</td>
<td>98.98%</td>
<td>98.56%</td>
<td>98.24%</td>
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