**Supplementary Information**

**Table 1** Zero temperature phase diagram of the optimized potential for the diamond target structure. We show the stable phase (column 1), its lattice parameters (column 2), the corresponding stable pressure range (column 3) and the stable density range (column 4). The parameter nomenclature is the same as described in Ref\(^1\).

*Lattice acronyms:* face-centered cubic (FCC), body-centered cubic (BCC), diamond (DIA), simple cubic (SC), wurtzite (WUR), hexagonal (SH), body centred orthorhombic (BCO), rhombohedral (hR).

<table>
<thead>
<tr>
<th>Lattice</th>
<th>Parameters</th>
<th>Pressure (Pσ^3/ε)</th>
<th>Density (ρσ^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>hR</td>
<td>1.417</td>
<td>0.1 - 2.0</td>
<td>0.27547 - 0.59252</td>
</tr>
<tr>
<td>BCC</td>
<td>2.1 - 3.6</td>
<td>0.60570 - 0.73819</td>
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</tr>
<tr>
<td>hR</td>
<td>0.2162</td>
<td>3.7 - 3.9</td>
<td>0.84149 - 0.85735</td>
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<tr>
<td>BCO</td>
<td>0.6234, 1.7403</td>
<td>4.0 - 4.4</td>
<td>0.87317 - 0.90280</td>
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<tr>
<td>SH</td>
<td>0.61</td>
<td>4.5 - 6.4</td>
<td>0.91409 - 1.03991</td>
</tr>
<tr>
<td>A7</td>
<td>3.8874, 0.3172</td>
<td>6.5 - 7.9</td>
<td>1.08248 - 1.16240</td>
</tr>
<tr>
<td>DIA</td>
<td>8.0 - 14.5</td>
<td>1.21318 - 1.52094</td>
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</tr>
<tr>
<td>hR</td>
<td>1.4124</td>
<td>14.6 - 15.3</td>
<td>1.62509 - 1.65489</td>
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<tr>
<td>SH</td>
<td>1.4148</td>
<td>15.4 - 15.9</td>
<td>1.65918 - 1.67987</td>
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<tr>
<td>SH</td>
<td>1.4157</td>
<td>16.0 - 16.4</td>
<td>1.68398 - 1.70019</td>
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<tr>
<td>SH</td>
<td>1.4171</td>
<td>16.5 - 17.9</td>
<td>1.70425 - 1.75908</td>
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<tr>
<td>A20</td>
<td>1.6658, 0.5892, 0.1745</td>
<td>18.0 - 18.3</td>
<td>1.82194 - 1.83304</td>
</tr>
<tr>
<td>A20</td>
<td>1.7447, 0.6455, 0.3331</td>
<td>18.4 - 26.9</td>
<td>1.83805 - 2.13483</td>
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</table>

**Table 2** Zero temperature phase diagram of the optimized potential for the simple cubic target structure. We show the stable phase (column 1), its lattice parameters (column 2), the corresponding stable pressure range (column 3) and the stable density range (column 4). The parameter nomenclature is the same as described in Ref\(^1\).

<table>
<thead>
<tr>
<th>Lattice</th>
<th>Parameters</th>
<th>Pressure (Pσ^3/ε)</th>
<th>Density (ρσ^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>hR</td>
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<td>1.1 - 3.4</td>
<td>0.54192 - 0.74723</td>
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<td>BCC</td>
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<tr>
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<td>1.03577</td>
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<tr>
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<td>7.6 - 7.9</td>
<td>1.05841 - 1.07616</td>
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<tr>
<td>BCO</td>
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<td>8.0 - 8.2</td>
<td>1.08617 - 1.09760</td>
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<tr>
<td>βSn</td>
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<td>8.3 - 11.1</td>
<td>1.12945 - 1.26788</td>
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<tr>
<td>SC</td>
<td>11.2 - 16.9</td>
<td>1.30781 - 1.53378</td>
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<tr>
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<td>3.5155</td>
<td>17.0 - 17.3</td>
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<tr>
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<td>18.3 - 19.2</td>
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<tr>
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**References**