Supplementary Information

In situ Growth of Sn Nanowires on Al Matrix using Ti_2SnC as Sn Source

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As shown in Figure S1, the EDS line-scan analysis was conducted in the nanowire-free region of sample B1. According to the elemental distribution, the left region corresponds to Al, while the right region corresponds to Ti_2SnC particles. The line-scan results indicate that the Sn content in the Ti_2SnC region is extremely low and exhibits little variation, suggesting that Sn atoms have diffused out of the Ti_2SnC matrix during heat treatment. Meanwhile, Al signals are also detected within the Ti_2SnC region, indicating the diffusion of Al atoms into the Ti_2SnC structure. Based on the EDS data, the calculated atomic ratio of Al/Ti is approximately 7-9, which supports the possible formation of $TiAl_3$.

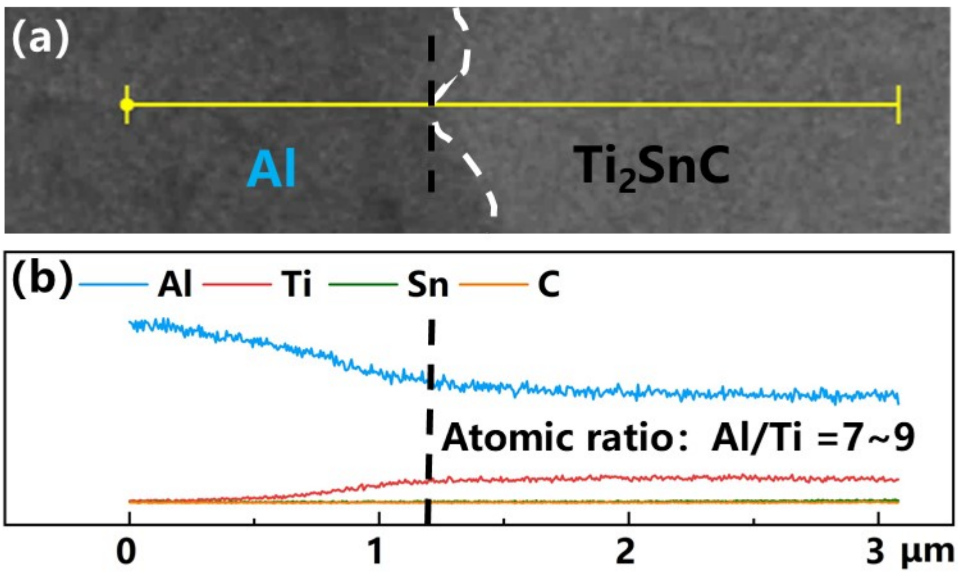

Figure S1 EDS line-scan results of the nanowire-free region in sample B1.(a) SEM image and the corresponding line-scan path; (b) Line-scan distributions of Al, Ti, Sn, and C elements. The nanowire -

free region was intentionally selected to minimize the influence of nanowires on the line-scan results.

As shown in Figure S2, the nanowires preferentially grow near the Al/Ti_2SnC interfacial regions. The EDS mapping results indicate that Sn is mainly enriched around the nanowire roots, whereas the Sn signal inside the Ti_2SnC region is significantly weakened, suggesting that Sn atoms diffuse out from the Ti_2SnC lattice during heat treatment. Meanwhile, the Ti and C elemental distributions remain highly overlapped in the matrix region, indirectly indicating the formation of TiC after the decomposition of Ti_2SnC.

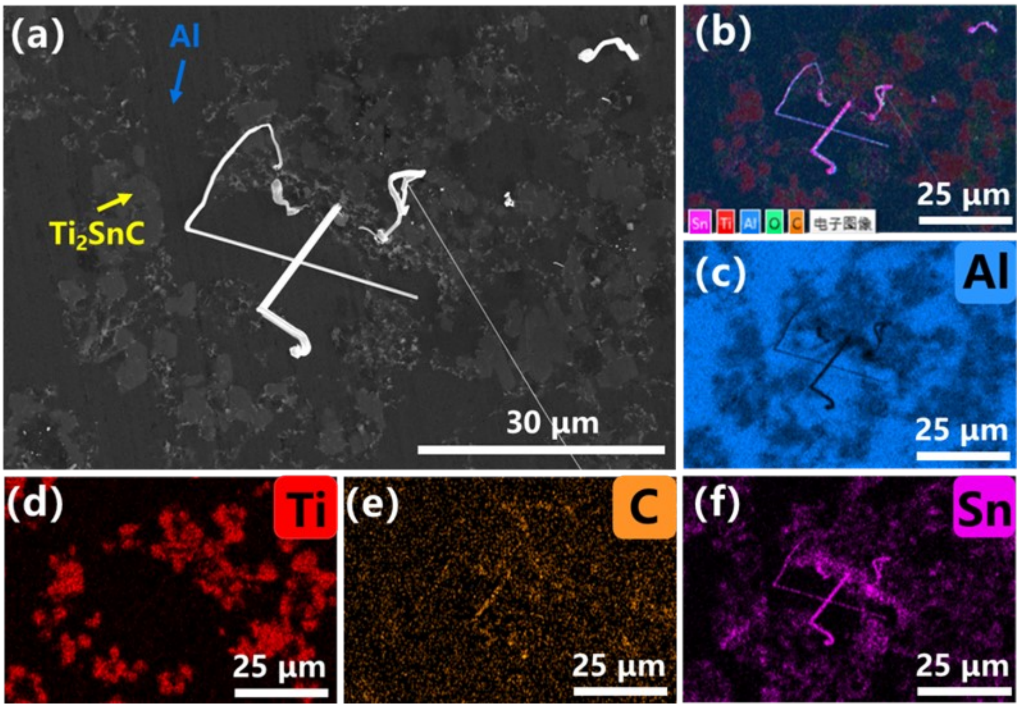

Figure S2 EDS elemental mapping results of the region with a small amount of nanowires growth in sample B1. (a) SEM image; (b) overall elemental mapping image; (c-f) corresponding EDS elemental mapping results of Al, Ti, C and Sn, respectively. The region with limited nanowire growth was intentionally selected to better reveal the elemental distribution in the matrix as well as at the nanowire roots.

To select appropriate conditions for releasing Sn from the Al/Ti_2SnC matrix, a series of specimens was prepared following the same process while varying the heat-treatment temperature and dwell time. Sample identifiers are listed in Table S1.

Table S1. Samples Designation, Composition, and Processing Conditions

Sample name	Metal: Ti_2SnC (by mole)	Temperature/°C Pressure/MPa	Temperature/°C Time/h
B4	Al:Ti_2SnC=1:0.1	210 °C/400 MPa	500 °C/2 h
B5	Al:Ti_2SnC=1:0.1	210 °C/400 MPa	550 °C/2 h
B6	Al:Ti_2SnC=1:0.1	210 °C/400 MPa	600 °C/2 h
B7	Al:Ti_2SnC=1:0.1	210 °C/400 MPa	650 °C/2 h

B8	Al:Ti_2SnC=1:0.1	210 °C/400 MPa	650 °C/1 h

Figure S1. XRD results show that after heat treatment at 550 °C for 2 hours, the phase constitution remained Al and Ti_2SnC. When the temperature was increased to 600 °C, diffraction peaks of $TiAl_3$ and Sn appeared, while reflections from Al and Ti_2SnC persisted, indicating that Sn release from Ti_2SnC was incomplete at 600 °C. Upon raising the temperature to 650 °C, the main phases became Sn and $TiAl_3$, with only minor Al and residual Ti_2SnC. Since 650 °C is close to the melting point of Al, the temperature did not increase further. So, 650 °C was identified as the optimal heat-treatment temperature.

Figure S2 Surface morphologies of samples B4-B7. No nanowire growth was observed after heat treatment at 500 °C. After 550 °C, a few small mounds appeared on the surface of B5, implying that Ti_2SnC began to release atomized Sn at this temperature, though the amount was limited. At 600 °C and 650 °C, thermal activation of Ti_2SnC released large amounts of Sn, leading to the growth of abundant metal nanowires on the surface.

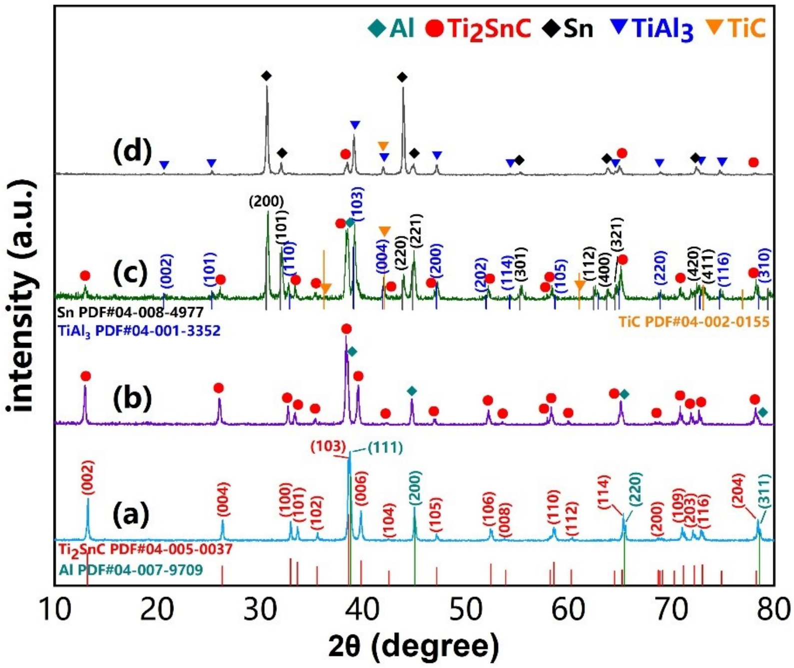

Figure S3. XRD patterns of bulk Al/Ti_2SnC sample (Al: Ti_2SnC = 1:0.1, molar) after 2 h heat treatment at different temperatures: (a) as-prepared, (b) 550 °C, (c) 600 °C, (d) 650 °C.

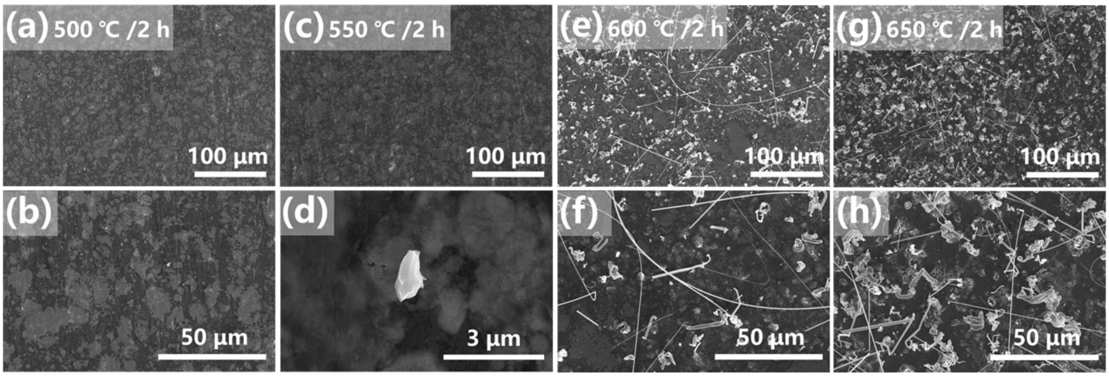

Figure S4. Surface nanowire growth on samples B4–B7. (a-b) B4-500 ℃/2h, (c-d) B5-550 ℃/2h, (e-f) B6-600 ℃/2h, (g-h) B7-650 ℃/2h。

As evidenced by the XRD (Figure S3) and SEM (Figure S4) results obtained at 650 °C, extending the dwell time from 0.5 h to 1 h and 2 h led to an increased number of surface nanowires and hillock-like features, suggesting more extensive outward diffusion of atomized Sn and more pronounced decomposition of Ti_2SnC. Considering that a sufficient nanowire population can already be achieved at 0.5 h. Therefore, the heat-treatment time was set to 0.5 h.

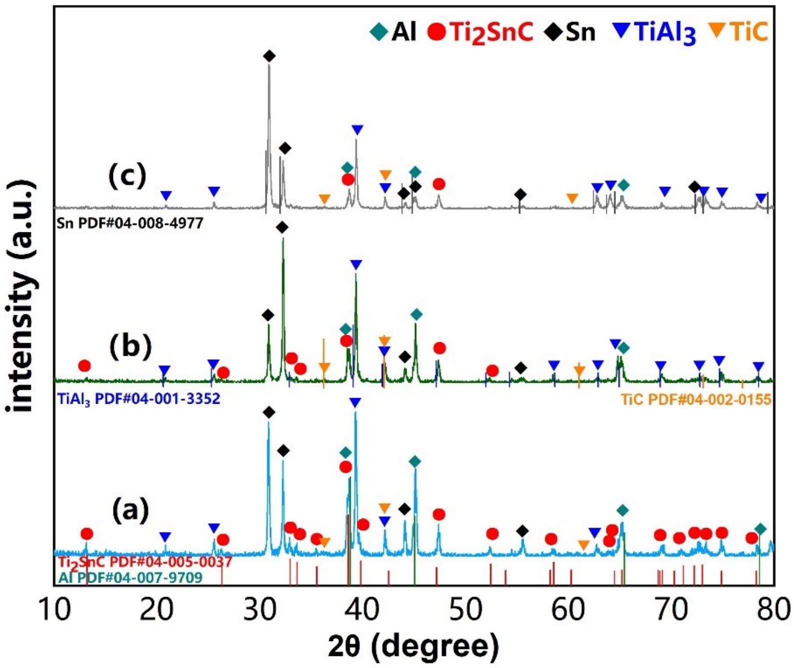

Figure S5 XRD patterns of bulk Al/Ti_2SnC sample (Al: Ti_2SnC = 1:0.1, molar) after heat treatment at 650 °C for different dwell times(a) 0.5 h, (b) 1 h, (c) 2 h.

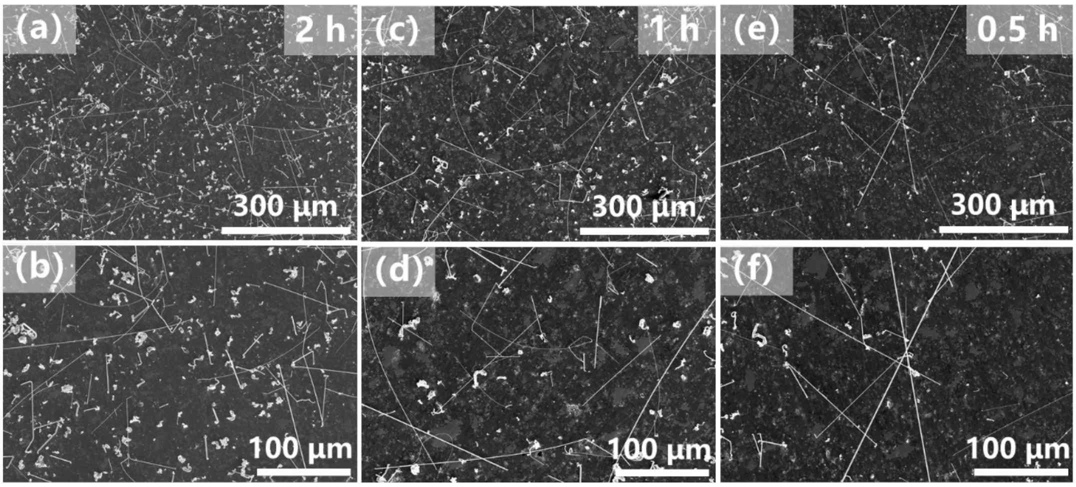

Figure S6 Surface nanowire growth on samples B7-B9, B1. (a-b) B7-650 °C/2 h, (c-d) B8-650 °C/1h, (e-f) B1-650 °C/0.5h.

To verify the scalability of this approach for producing large quantities of nanowires, Ti_2InC was synthesized following the reference[1] and uniformly mixed with Al at a molar ratio of 1:0.1. After heat pressing at 210 °C/400 MPa, the compacts were heat-treated at 650 °C for 2 hours. Numerous In nanowires were observed on the surface of the aluminum matrix (Figure S5).

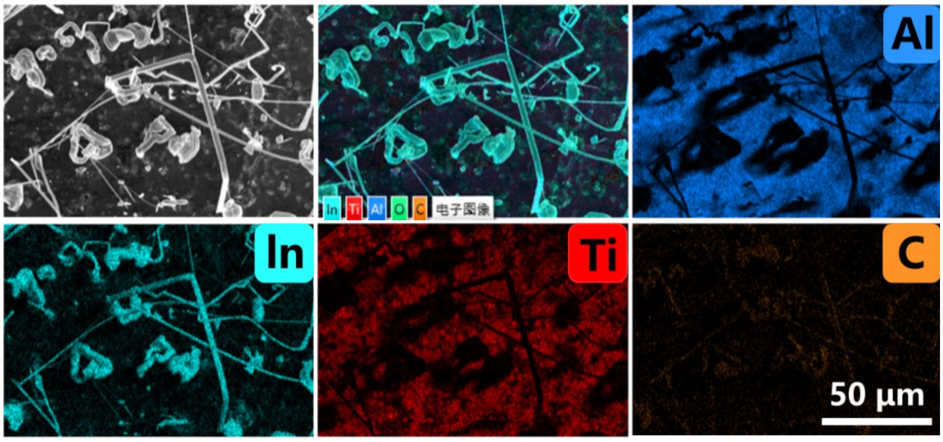

Figure S7. In nanowires grown on the surface of the Al/Ti_2InC sample.

In addition, Al, Ti_2InC, and Ti_2SnC were weighed at a molar ratio of 1:0.05:0.05, uniformly mixed, thermal-pressed at 210 °C/400 MPa, and heat-treated at 650 °C for 0.5 h; the surface of the aluminum matrix exhibited numerous InSn nanowires (Figure S6).

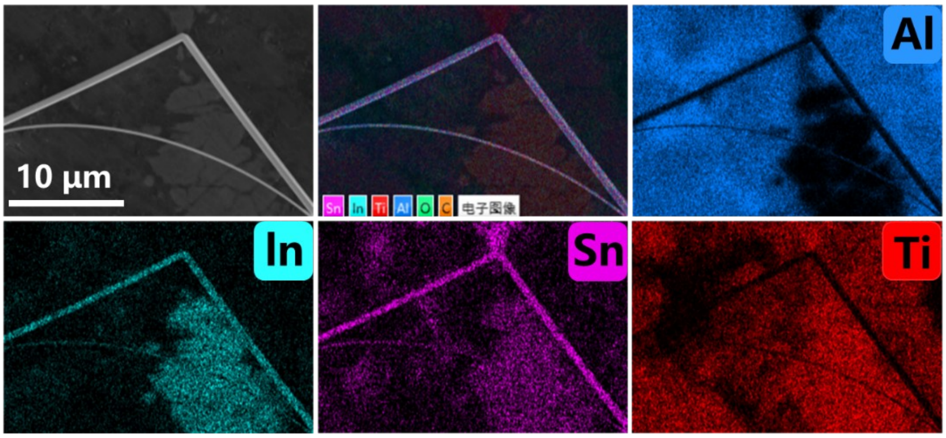

Figure S8. InSn nanowires grown on the surface of the Al/Ti_2InC/ Ti_2SnC sample.

Reference

[1] S. Li, Y. Liu, P. Zhang, Y. Zhang, C. Lu, L. Pan, J. Ding, Z. Sun, Interface energy-driven indium whisker growth on ceramic substrates, Journal of Materials Science: Materials in Electronics, 32 (2021) 16881-16888. https://doi.org/10.1007/s10854-021-06250-5.