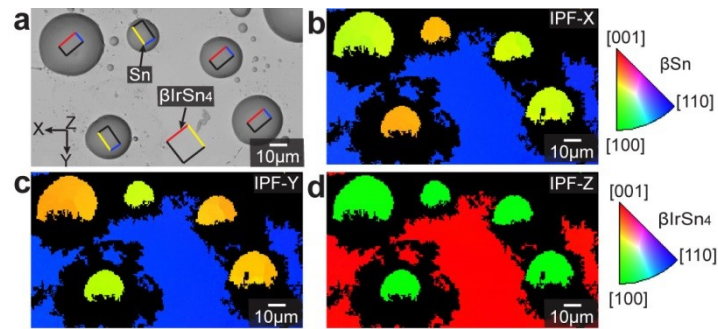
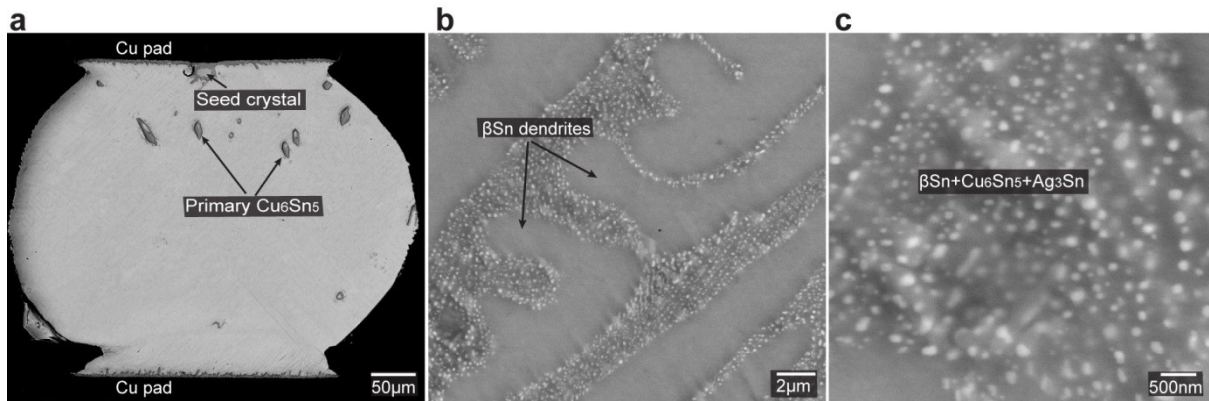


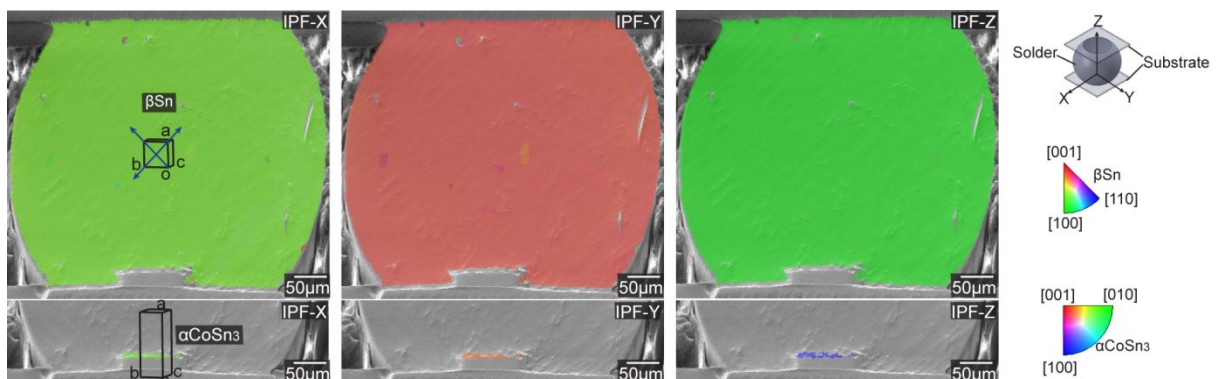
## Supplementary Information



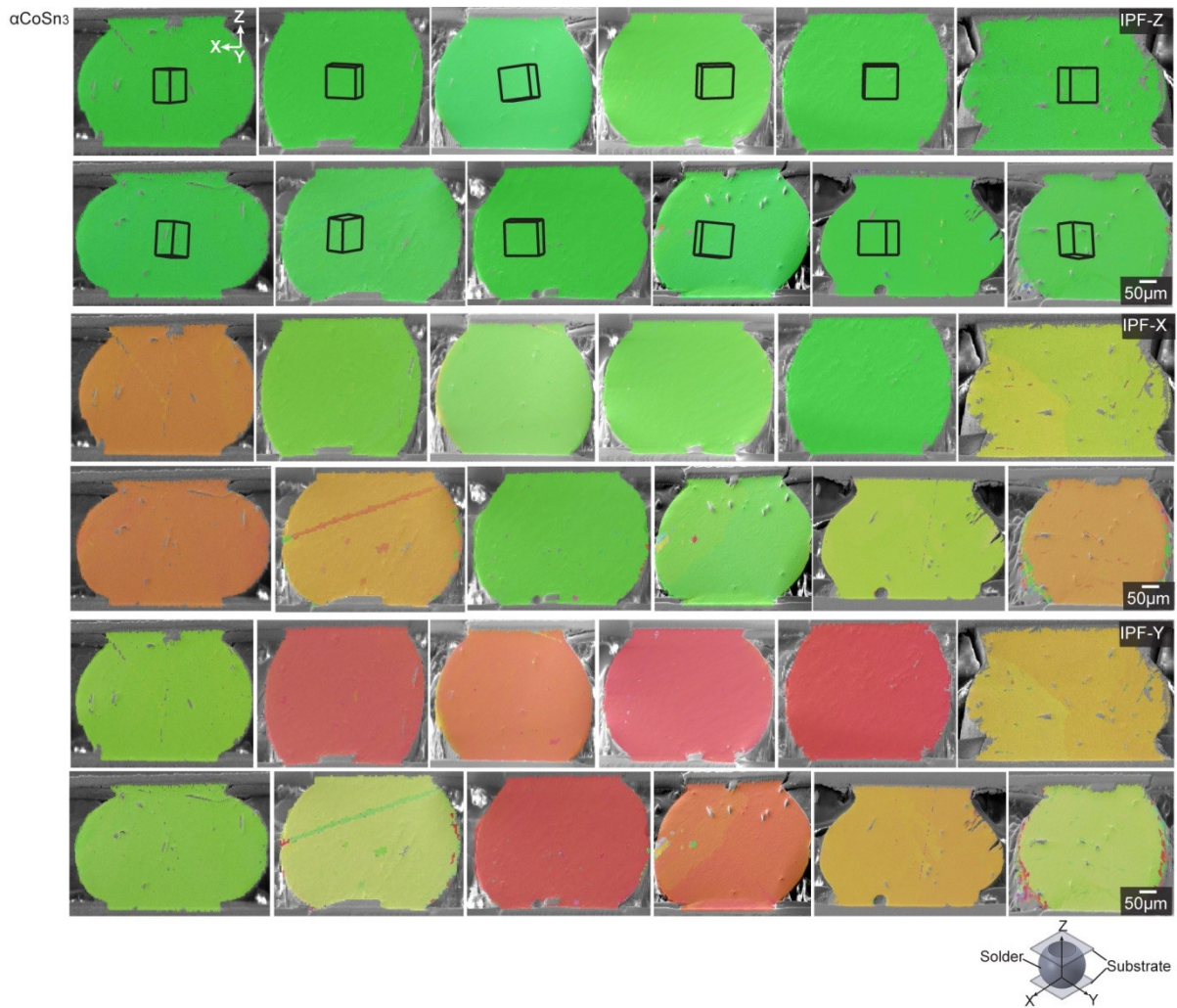
**Supplementary Figure 1** A typical example of Sn droplets solidified on the (001) facet of  $\beta\text{IrSn}_4$  and the corresponding EBSD maps. **a** The backscatter electron image. **b** IPF-X map. **c** IPF-Y map. **d** IPF-Z map. This is an expanded version of Figure 3d.



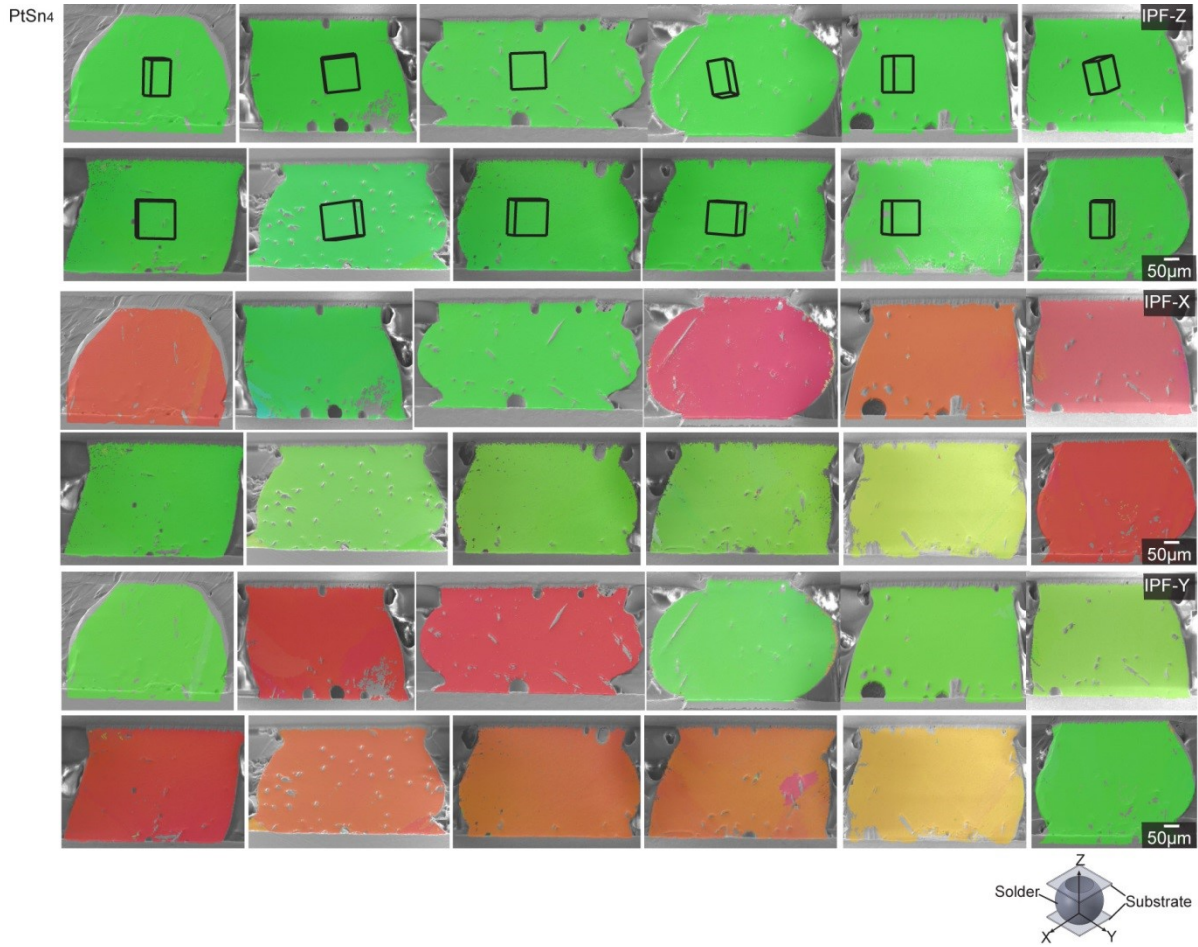
**Supplementary Figure 2** Microstructure of a typical Cu/Sn-3Ag-0.5Cu or Sn-3.5Ag + IMC/Cu solder joint. **a** The macrostructure of a joint in which the seed crystal and numerous primary  $\text{Cu}_6\text{Sn}_5$  phases can be seen. There are no primary  $\text{Ag}_3\text{Sn}$  phases. The microstructures shown **b**  $\beta\text{Sn}$  dendrites and **c**  $\beta\text{Sn} + \text{Cu}_6\text{Sn}_5 + \text{Ag}_3\text{Sn}$  ternary eutectic.



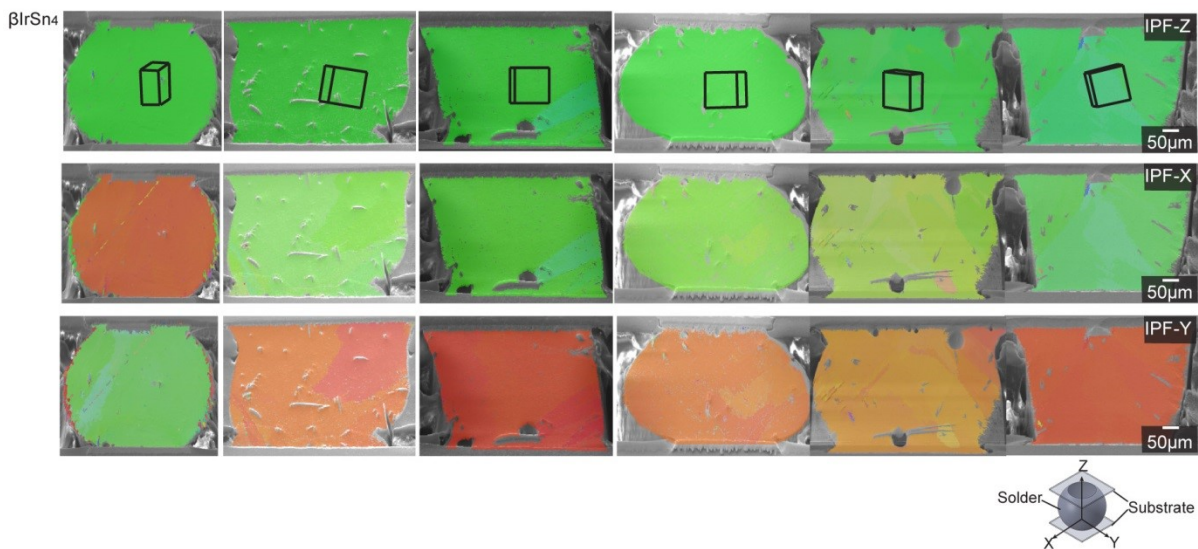
**Supplementary Figure 3** An expanded version of Figure 5d showing EBSD maps



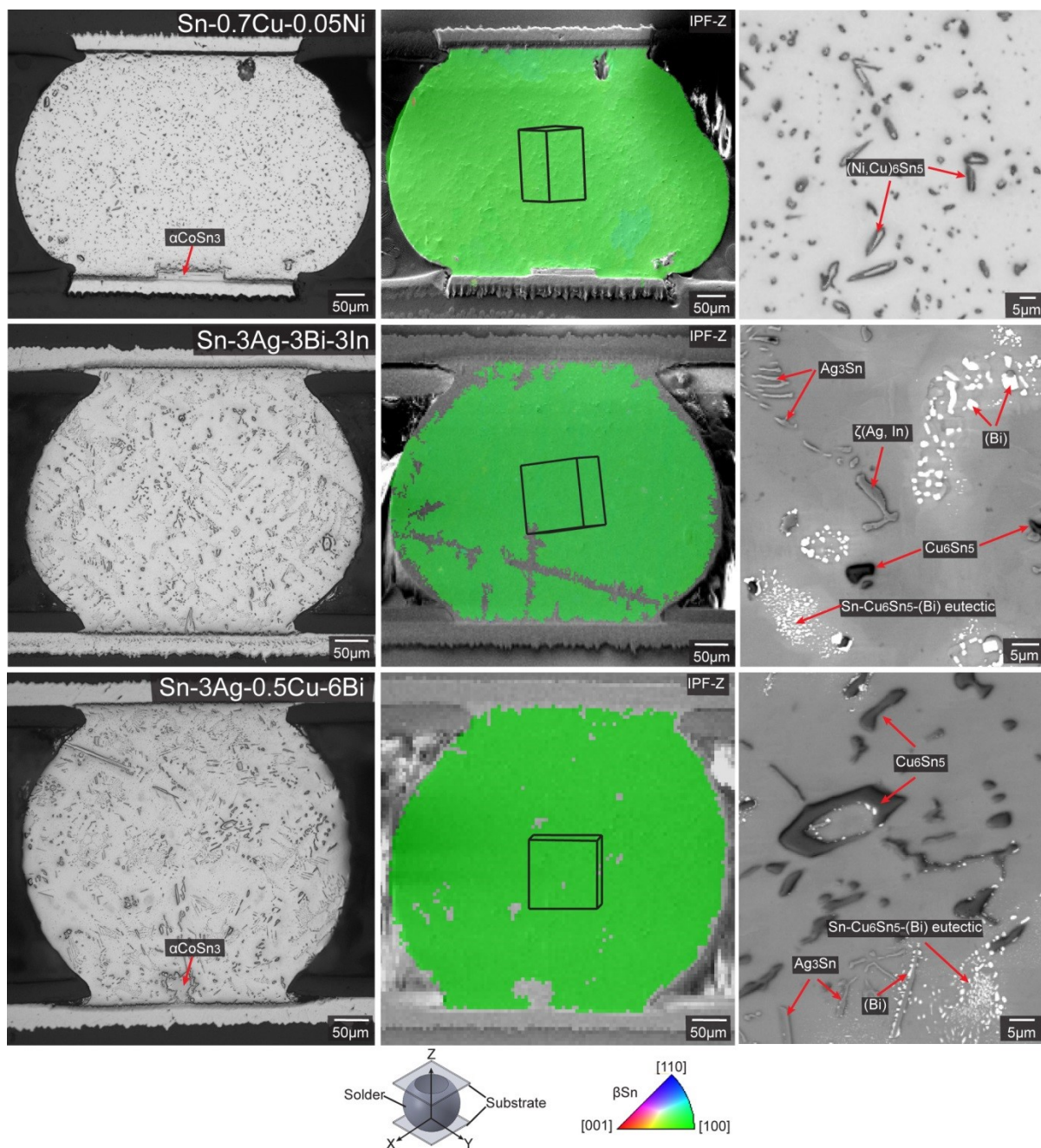
**Supplementary Figure 4** An expanded version of Figure 6a showing EBSD maps. Note that the mechanical twin across one sample and minor orientations at the sample edges were caused by deformation during sample preparation.



**Supplementary Figure 5** An expanded version of Figure 6b showing EBSD maps.



**Supplementary Figure 6** An expanded version of Figure 6c showing EBSD maps .



**Supplementary Figure 7 c-axis orientation control in joints of different alloys.** The nucleant IMCs used are  $\alpha\text{CoSn}_3$ . From left to right, optical micrographs, EBSD IPF-Z maps, and micrographs shown phases in solder joints.

**Supplementary Table 1 Compositions of lab-made alloys measured by XRF spectroscopy**

| Alloys           | Ag<br>[wt%] | Cu<br>[wt%] | Co<br>[wt%] | Pb<br>[wt%] | Sb<br>[wt%] | Bi<br>[wt%] | Ni<br>[wt%] | Fe<br>[wt%] | Zn<br>[wt%] | In<br>[wt%] | Sn<br>[wt%] |
|------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| SAC305           | 3.200       | 0.470       | <0.001      | 0.006       | 0.018       | <0.001      | 0.002       | <0.001      | <0.001      | 0.002       | Bal.        |
| Sn-3.5Ag         | 3.300       | 0.006       | 0.001       | 0.008       | 0.019       | <0.001      | 0.003       | 0.003       | <0.001      | 0.009       | Bal.        |
| Sn-3Ag-3Bi-3In   | 2.830       | 0.005       | <0.001      | 0.020       | <0.001      | 2.990       | 0.004       | 0.006       | <0.001      | 3.150       | Bal.        |
| Sn-3Ag-0.5Cu-6Bi | 2.540       | 0.512       | <0.001      | 0.009       | 0.016       | 6.080       | 0.006       | 0.006       | <0.001      | <0.001      | Bal.        |