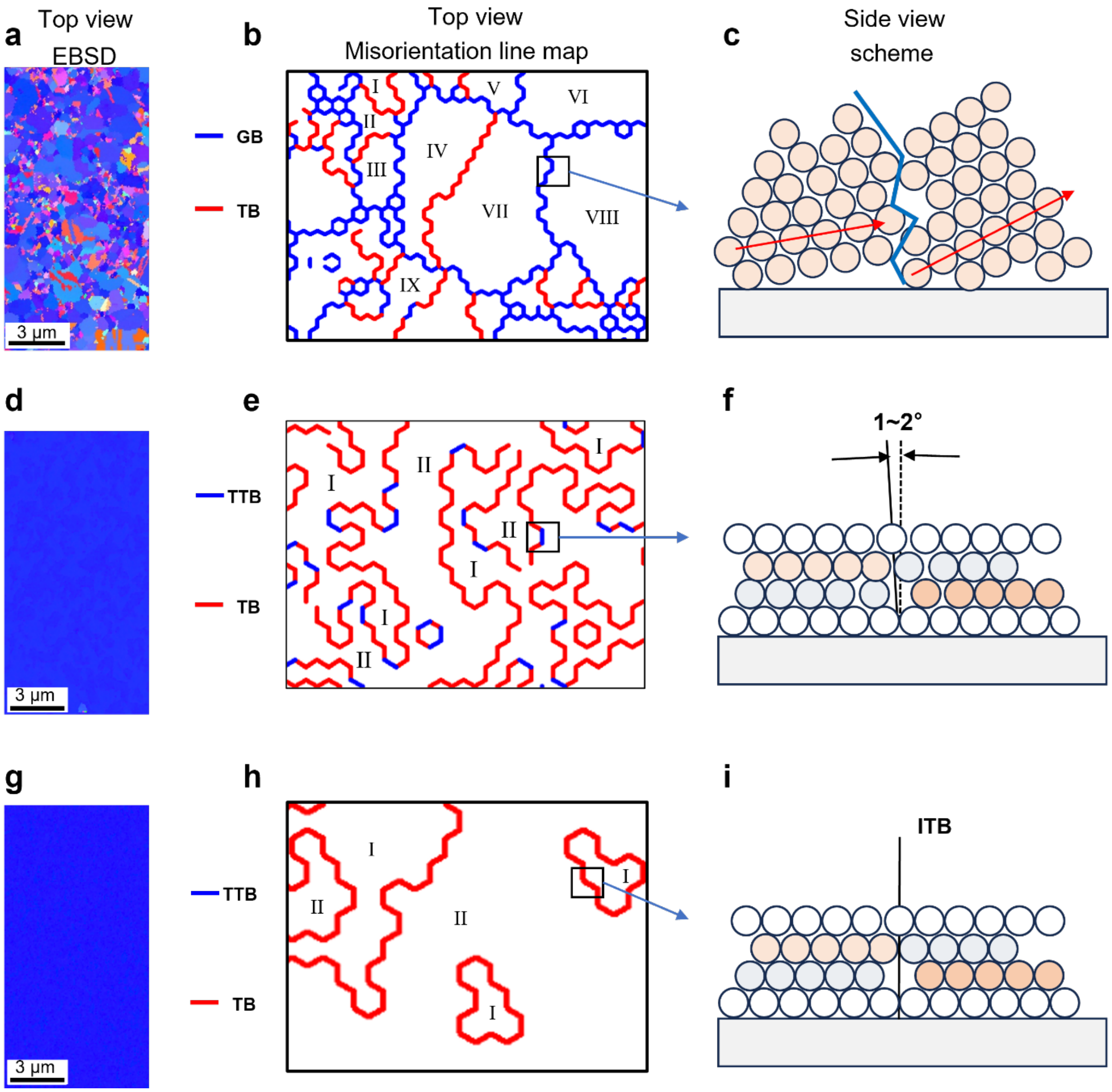

Extended Data Fig. 1. | Comparison of grain boundaries (GBs), twin boundaries (TBs), and tilted twin boundaries (TTBs) observed in three different Cu thin films. **a**, EBSD map of polycrystalline and **b**, misorientation line map of the GB-dominant Cu thin film. **c**, Schematic illustration showing the crystallographic relationships near the representative regions indicated in the GB case. **d**, **g**, EBSD maps of single-crystalline Cu thin films exhibiting perfect alignment along the out-of-plane (111) direction. **e**, **h**, Misorientation line maps of **d** and **g** consisting predominantly of TBs, including **e** regions containing slightly TTBs and **h** regions composed exclusively of coherent TBs without tilted segments. Schematic illustrations of the local microstructures associated with **f.** TTB and **i.** coherent TB.