Sample preparation induced artefacts in soft SAC-solders from uncooled and cooled Argon ion milling

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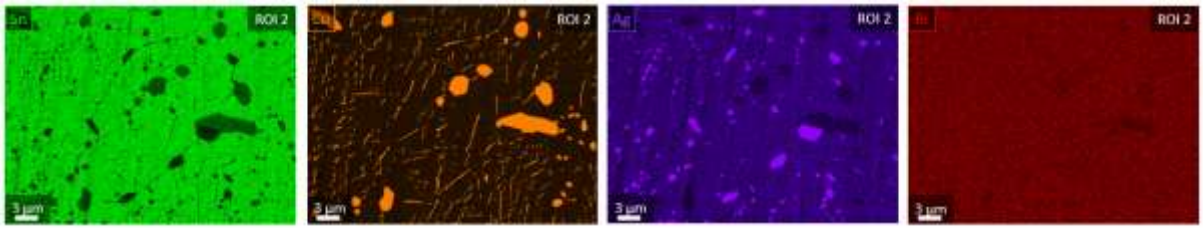
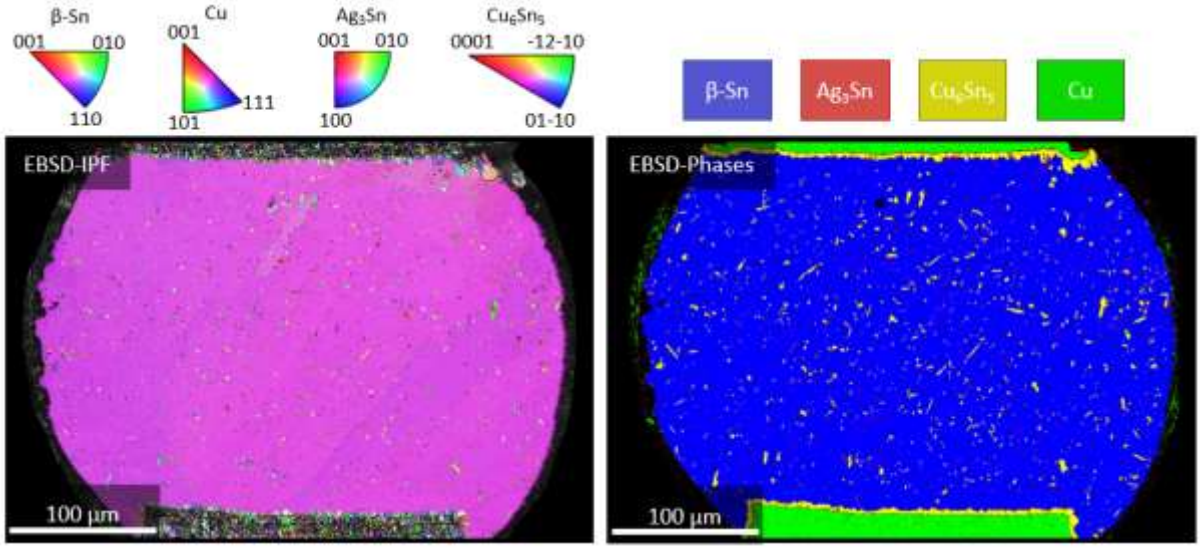
This study evaluates thermal effects that need to be considered for effective preparation of cross-sections from low-melting metals in multi-component, multi-material structures. Supplementary material is presented in the following.

Supplementary Figure 1: EDX mapping of ROI 2 showing line-shaped Cu-rich artefacts.



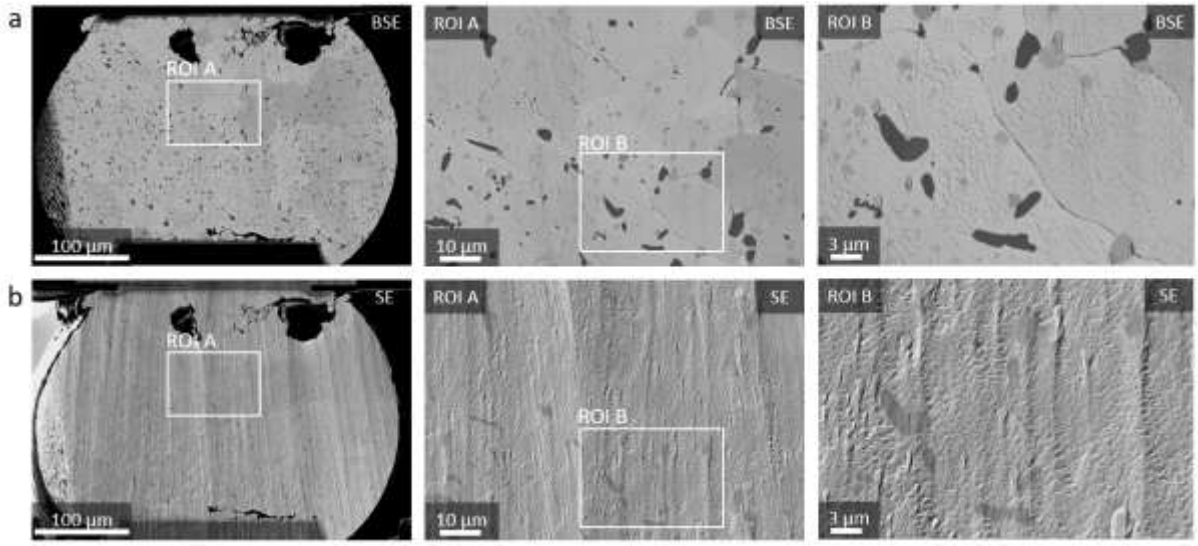
EDX mapping of ROI 2 on the solder ball cross-section that is prepared with an uncooled ion milling mask. Sn is mapped in green, Cu in orange, Ag in purple and Bi in red. Scalebars of 3 µm are valid for all images.

Supplementary Figure 2: Overview EBSD mapping of the cross-section prepared with an uncooled mask.



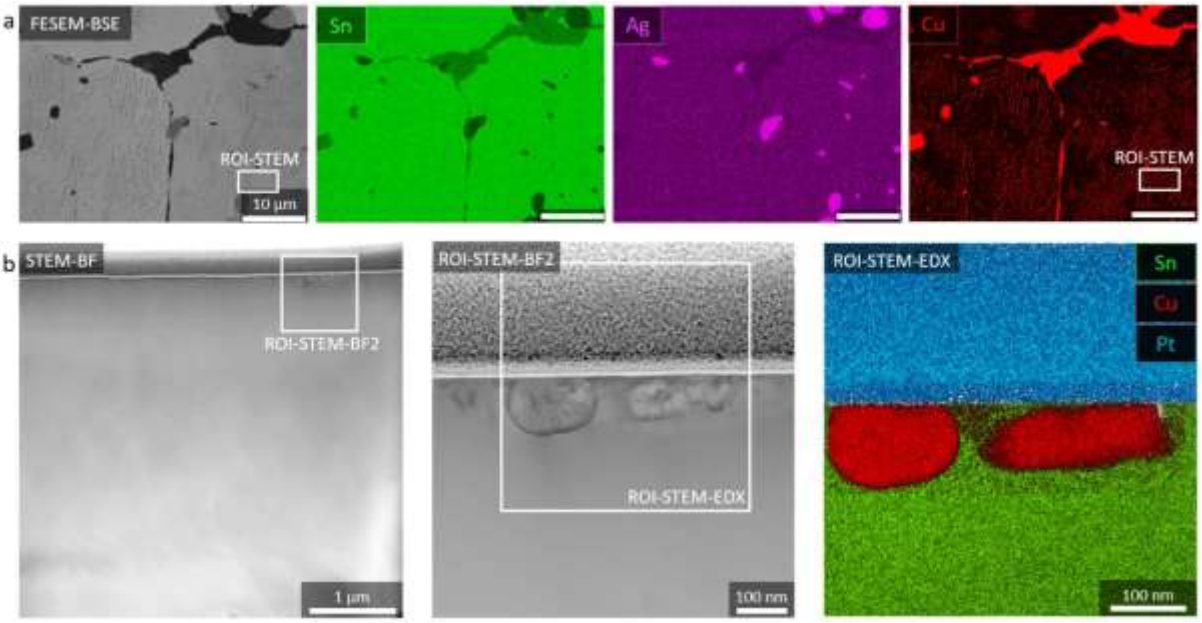
Overview EBSD mapping of the solder ball cross-section in **Fig. 2**, which is prepared with an uncooled ion milling mask. In the phase mapping, β-Sn is shown in blue, Ag_3Sn in red, Cu_6Sn_5 in yellow and Cu in green. Scalebar of 100 µm is valid for both images.

Supplementary Figure 3: Additional cross-section prepared with an uncooled milling mask.



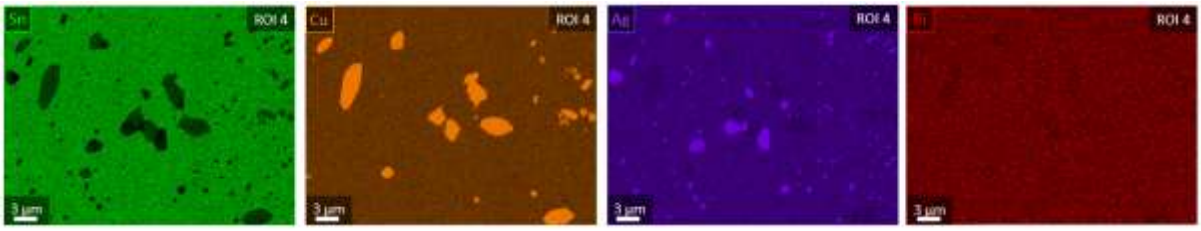
a From left to right: FESEM-BSE micrographs of a solder ball cross-section with increasing magnifications. **b** From left to right: FESEM-SE micrographs with increasing magnifications. Scalebars from left to right for 100, 10 and 3 µm, respectively.

Supplementary Figure 4: Correlative STEM micrographs of a Cu-needle rich region after uncooled Ar-ion milling.



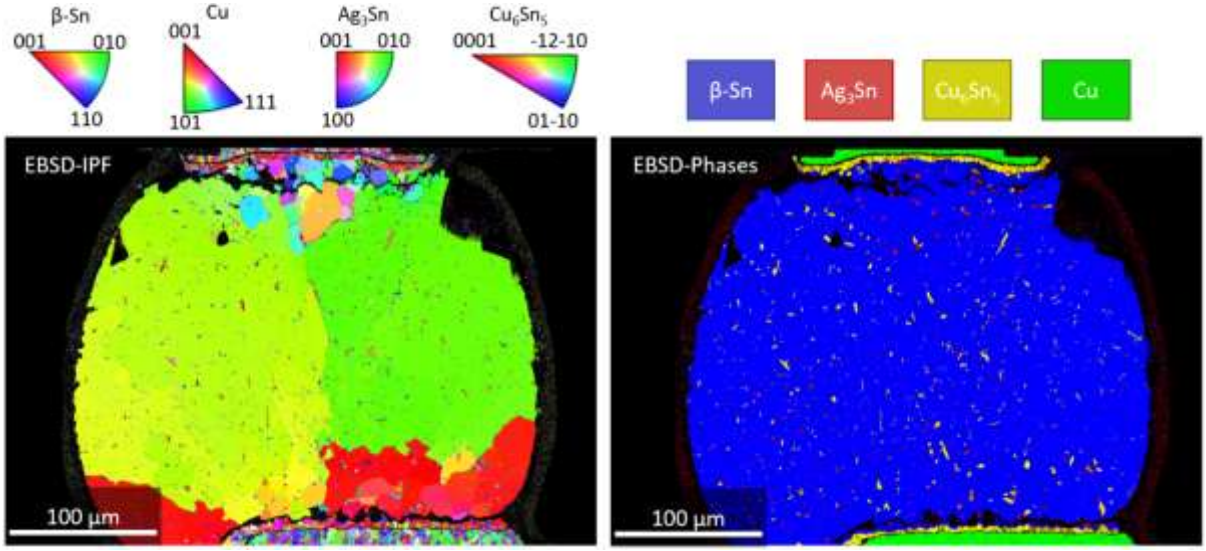
a From left to right: FESEM-BSE micrograph, FESEM EDX mappings showing Sn (green), Ag (purple) and Cu (red) of a solder ball cross-section after uncooled Ar-ion milling. The ROI for STEM-lamella lift-out is marked with white rectangles. Assuming a 3-dimensional arrangement of Cu-rich needles, dotted areas in the FESEM cross-section would imply needle-growth into the depth of the cross-section, i.e. in the direction of STEM-lamella lift-out. **b** From left to right: Overview STEM bright field (BF) micrographs of the ROI-STEM in **a**, STEM-BF detail of the cross-sectional surface (ROI-STEM-BF2) and STEM-EDX mapping of Cu-rich agglomerations directly beneath the cross-sectional surface. Aside from these two Cu-rich agglomerations, no Cu-rich needles or dots are present in the STEM-lamella.

Supplementary Figure 5: EDX mapping of ROI 4.



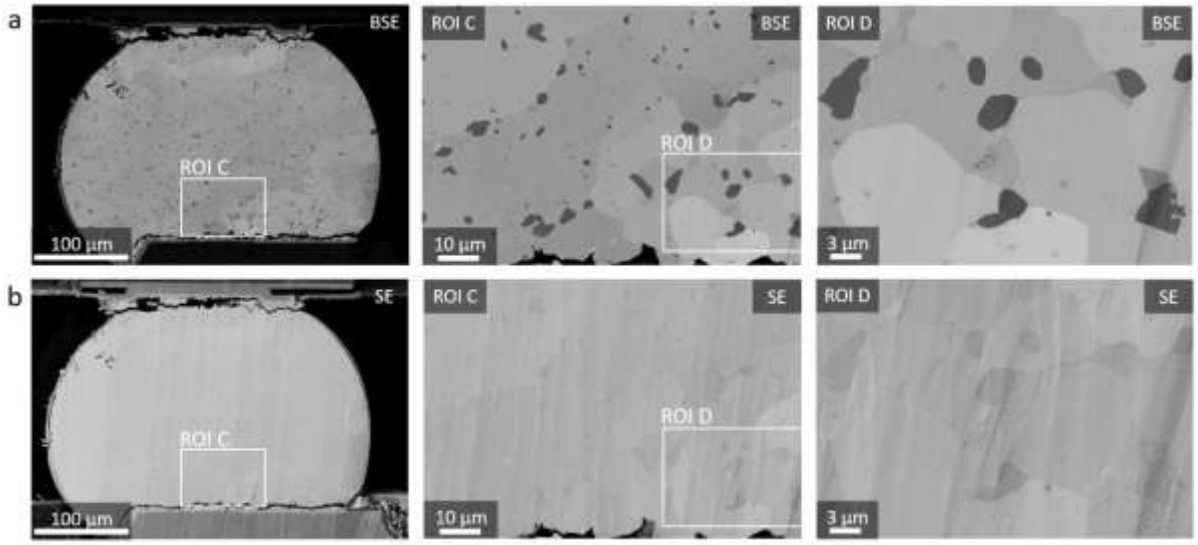
EDX mapping of ROI 4 on the solder ball cross-section that is prepared with an actively cooled ion milling mask. Sn is mapped in green, Cu in orange, Ag in purple and Bi in red. Scalebars of 3 µm are valid for all images.

Supplementary Figure 6: Overview EBSD mapping of the cross-section prepared with an actively cooled mask.



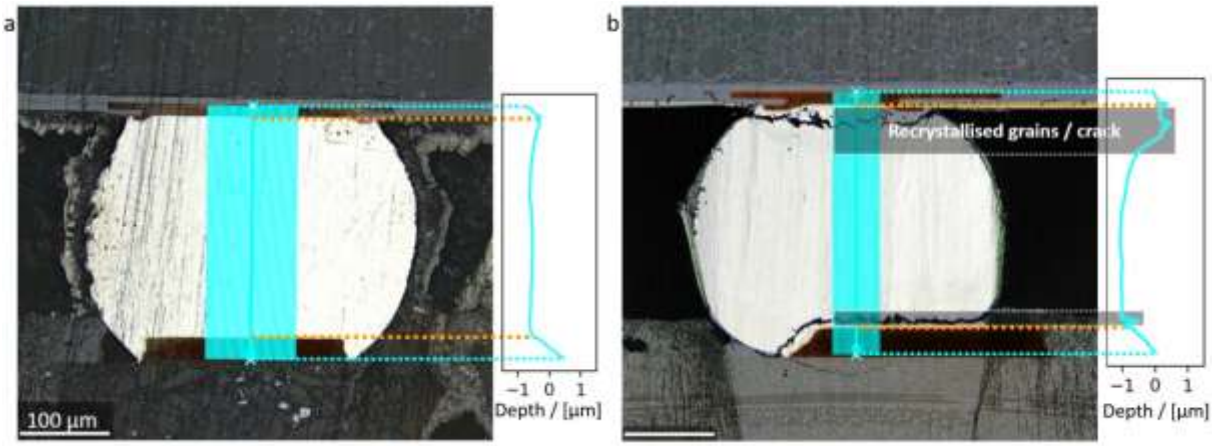
Overview EBSD mapping of the solder ball cross-section in **Fig. 3**, which is prepared with an actively cooled ion milling mask. In the phase mapping, β-Sn is shown in blue, Ag_3Sn in red, Cu_6Sn_5 in yellow and Cu in green. Scalebar of 100 µm is valid for both images. Intergranular cracks are visible on the top and bottom of the ball.

Supplementary Figure 7: Additional cross-section prepared with an actively cooled milling mask.



a From left to right: FESEM-BSE micrographs of a solder ball cross-section with increasing magnifications. **b** From left to right: FESEM-SE micrographs with increasing magnifications. Scalebars from left to right for 100, 10 and 3 µm, respectively.

Supplementary Figure 8: Laser confocal surface profiles of Ar-ion milled cross-sections.



Light optical micrographs and laser confocal surface profiles of **a** a cross-section that is milled with an uncooled milling mask from **Fig. 2** and **b** with an actively cooled milling mask from **Fig. 3**. The cyan shaded areas represent line profiles that are averaged. The average line profile is plotted in cyan for the respective cross-section. The surface profiles, shown in are acquired with a Keyence 3D Surface Profiler VK-X3000, utilising a 20 X magnification. The edges of Cu metallisations from the chip and PCB are correlated with the line profiles with dotted orange lines. Recrystallised grains and cracks are indicated with shaded grey areas in **b**. Scalebar of 100 µm is valid for both images.