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Characterization of Recrystallization and Microstructure Evolution in Lead-Free Solder Joints Using EBSD and 3D-XRD

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Development of vulnerable high-angle grain boundaries (and cracks) from low-angle boundaries during thermal cycling by means of continuous recrystallization was examined in fine-pitch ball grid array (BGA) packages with Sn-3.0Ag-0.5Cu (wt.%) (SAC305) lead-free solder joints. Electron backscatter diffraction (EBSD) and differential-aperture x-ray microscopy (DAXM or 3D-XRD) were used for surface and subsurface characterization. A large number of subgrain boundaries were observed in the parent orientation using both techniques. However, unlike studies of anisotropic deformation in noncubic metals at much lower homologous temperatures, no streaked diffraction peaks were observed in DAXM Laue patterns within each 1 μm^3 voxel after thermal cycling, suggesting that geometrically necessary dislocations (GNDs) are effectively absorbed by the preexisting subgrain boundaries. Storage at room temperature ($0.6T_m$) prior to DAXM measurement may also facilitate recovery processes to reduce local GND contents. Heterogeneous residual elastic strains were found near the interface between a precipitated Cu_6Sn_5 particle and the Sn grain, as well as near particular subgrain boundaries in the parent orientation. Grain boundary migration associated with recrystallization resulted in regions without internal strains, subgrain boundaries, or orientation gradients. Development of new grain orientations by continuous recrystallization and subsequent primary recrystallization and grain growth occurred in the regions where the cracks developed. Orientation gradients and subgrain structure were observed within newly formed recrystallized grains that could be correlated with slip systems having high Schmid factors.

Key words: Lead-free solder, Sn crystal orientation, recrystallization, EBSD, synchrotron 3D-XRD, strain

INTRODUCTION

Synchrotron x-ray diffraction (XRD) has been used to characterize melting and solidification behaviors,[1–4] interfacial reactions,[2,5] and intermetallic compounds (IMCs)[6,7] in lead-free solders. In prior studies,[8] microstructure and crystal orientation evolution was examined *in situ* for the full volume of the solder joint using transmission synchrotron XRD. An increase in elastic strain developed after thermal cycling was reported. By focusing the x-ray beam to the submicron scale, microdiffraction techniques can be used to assess the gradients in local strain/stress measurements at the micron scale. One example of using this technique was to study the effects of strain on Sn whisker growth.[9–11]

In this paper, the evolution of recrystallization is examined on a thermally cycled package having a moderately strongly strained package design[12] using

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