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Grain evolution during annealing of a semisolid Al-Cu alloy studied with lab-based diffraction contrast tomography

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Background incl. aims

3D experimental data of simultaneously high temporal and spatial resolution is key to validation of computational modelling of materials phenomena. In this study, we exploit lab-based diffraction contrast tomography (DCT) [1], to capture the evolution of grain structure over a series of interrupted annealing treatments of a semisolid Al-Cu alloy [2,3]. The time resolved response measured on the present Al-Cu model system provides insights into the rearrangement, densification and coarsening of powder compacts at late-stage sintering. The wealth of the experimental data lends itself particularly well to investigations of both grain size and orientation (rotation) evolution.

Methods

The semisolid Al-Cu alloy specimen was subjected to ten sequential isothermal heat treatments, each 15 min at 630°C, and we used lab-based DCT to non-destructively track the microstructural evolution of individual grains through the corresponding eleven temporal states of interrupted annealing. The lab environment setting allows us to reconstruct the results and analyze changes to the microstructure before subsequent treatment of the sample. Furthermore, we take advantage of the recently developed DCT advanced acquisition schemes [4] to cover a large sample volume of 10 mm³.

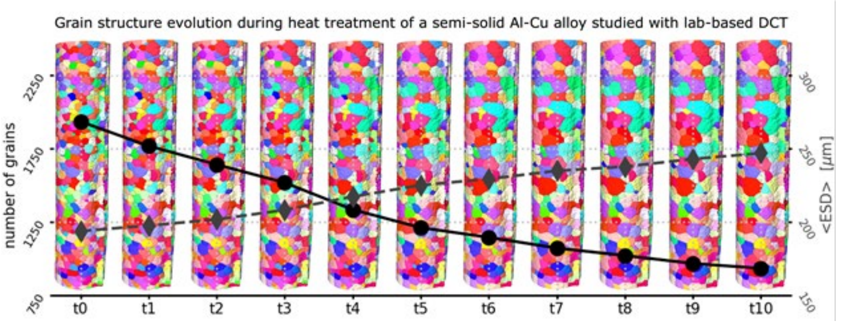
Results

During the experiment, we observe both grain coarsening (from 1934 grains with a mean grain size of 194 µm at the initial state to 934 grains with a mean grain size of 247 µm after ten annealing steps) and grain rotations. A statistical study of the evolving grain structure reveals that the disappearing grains are generally among the smaller ones at the beginning of the experiment. In addition, the rotations of individual grains are typically small fluctuations irrespective of grain size, but when an abruptly large rotation is observed, it is more likely to occur for a smaller grain at the last annealing step(s) before the grain vanishes. Finally, the experimental data indicates that Σ3 twin boundaries are especially stable, and that grains sharing such a boundary will rotate together in their local environment to keep the boundary intact.

Conclusion

Our investigations show that the crystallography of grain contacts undoubtably plays a pivotal role in the microstructural evolution of semisolid systems during heat treatment and should be included in predictive simulations of coarsening. To help incorporate our experimental observations into the next generation of models, the eleven grain maps have been made publicly available to the scientific community via the Materials Data Facility [5].

Graphic:



Keywords:

Lab-based DCT, Coarsening, 4D structure

Reference:

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