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EBSD Analysis Optimised for Twin-related Boundaries

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The nickel-based superalloy Nimonic PE16 is precipitation strengthened by the presence of gamma-prime. Overaging the alloy results in an increase in the pinning force on the boundary of at least a factor of two, and the grain size is very stable when the alloy is annealed below the gamma-prime solvus, namely 880°C [1,2]. Another microstructural feature of PE16 is that annealing twins are readily formed because of its low stacking-fault energy. Experiments have been conducted to explore the evolution of grain boundary parameters in PE16. Specimens of commercially heat treated PE16 were annealed in air at 850°C, i.e. 30°C below the gamma-prime solvus, for times of 1h, 10h and 100h. Misorientation data across interfaces were obtained by use of an electron back-scatter diffraction (EBSD) system from HKL Technology in a Philips XL30 SEM [3]. Several orientation maps with a grid step size of 0.5μm were collected and analysed from each specimen.

Figure 1 shows a typical example of an orientation map from overaged PE16. In the coincidence site lattice (CSL) system boundaries are categorised by Σ, the reciprocal density of coinciding sites. In figure 1 Σ3 boundaries are represented as thick white lines, Σ9 and Σ27 boundaries are thin white lines and other boundaries are black. The statistics for the $\Sigma 3^n$ family are shown in figure 2. Apart from Σ3, plus some Σ9 and Σ27, there were almost no other Σ boundaries recorded. There was a small increase in Σ3 proportion from 43% after 1h annealing to 50% after 100h. More than 90% of the total length of Σ3 in the map is within 2° of the exact reference misorientation, which indicates that these Σ3s are predominantly annealing twins. The remaining 10% of Σ3 length deviates by more than 2° from the reference structure. It is evident from the morphology of these higher deviation Σ3s that they are more akin to grain boundaries than to twins.

Higher $\Sigma 3^n$ boundaries in the microstructure are usually generated by impingement of two appropriate $\Sigma 3^n$ boundaries, e.g. $\Sigma 3+\Sigma 3 \rightarrow 9$, $\Sigma 3+\Sigma 9 \rightarrow 27$. The proportions of Σ9 and Σ27 in the present data are particularly low, which is an indication that there has been little movement and interaction of Σ3s, hence disallowing their impingement. This also explains why most Σ3s are twins: there has been very little impingement to produce Σ3s via 'back' reactions of the type $\Sigma 9+\Sigma 3 \rightarrow \Sigma 3$, which is expounded in the 'Σ3 regeneration model' [4]. This near-stagnation in the grain boundary population is a result of the strong grain boundary pinning by gamma-prime precipitates which inhibited grain boundary migration.

References

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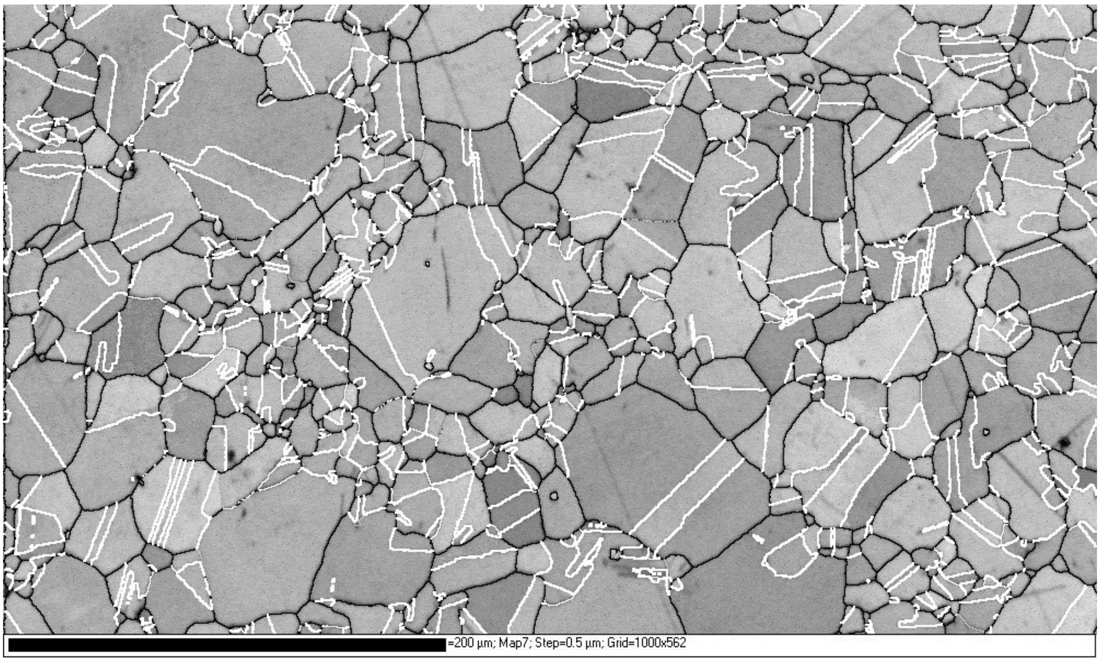

Figure 1. Example of an orientation map from PE16 after annealing for 10h. Σ3 boundaries are represented as thick white lines, Σ9 and Σ27 boundaries are thin white lines and other boundaries are black.

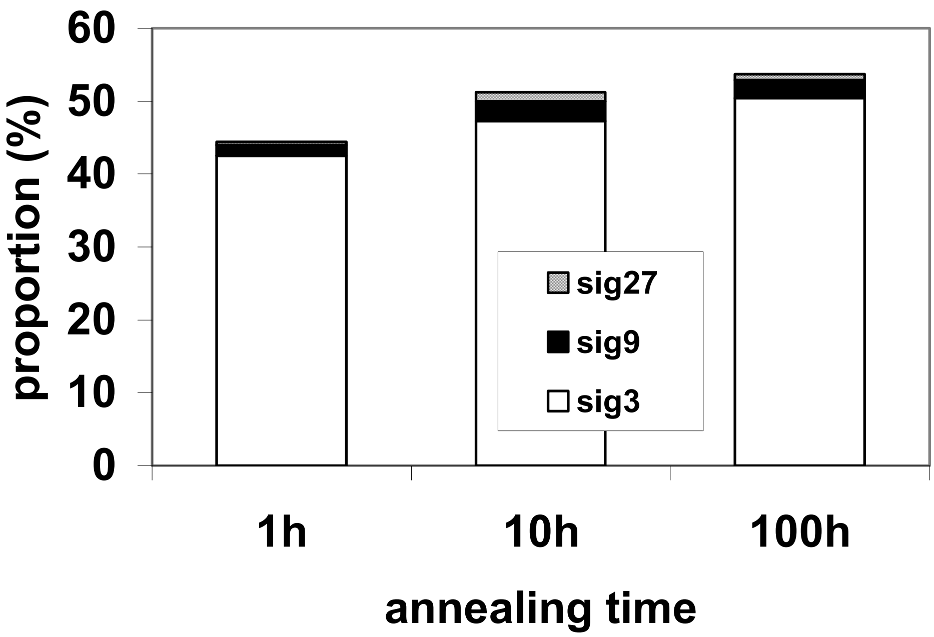

Figure 2. Proportions of $\Sigma 3^n$ boundaries after 1h, 10h and 100h annealing below the gamma-prime solvus. The scale bar is 100µm.

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