Superdislocation characterization by means of large angle convergent beam electron diffraction

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Superdislocations play an important role for the mechanical properties of ordered intermetallic compounds. For instance, in Ni base superalloys the formation of superdislocations and their glide/climb across the ordered γ' phase (Figure 1) are key elementary processes in high-temperature creep [1]. An accurate understanding of the superdislocation structure is important to further increase the performance of these alloys by tailoring the formation and mobility of the superdislocations. Difficulties in the analysis of superdislocations are caused by their complex dislocation core structures sometimes comprising four partial dislocations connected by anti-phase boundaries and complex stacking faults.

A key element of the characterization of dislocations is the Burgers vector (**b**) analysis. The conventional approach is based on the "invisibility criterion" which states that under two-beam conditions for a reflection **g** the dislocation is invisible if $\mathbf{g}\cdot\mathbf{b} = 0$. The criterion has been successfully applied to dislocations in various materials. However, in many cases residual contrast resulting from either $\mathbf{g}\cdot(\mathbf{b}\times\mathbf{u})$-contributions (**u** dislocation line vector), anisotropic elasticity or extended core structures has led to uncertainties in the evaluation of the Burgers vector. An alternative technique is large angle convergent beam electron diffraction (LACBED) which is even more powerful since it enables determination of the complete Burgers vector, including its direction, sign and modulus. The LACBED technique was first introduced by Tanaka et al. [2] and later used by Cherns and Preston [3] for the characterization of crystal defects. The advantage of LACBED is that a shadow image is formed in the diffraction disc combining real space and reciprocal space information. In the vicinity of a dislocation the distortion of the lattice causes the Bragg-lines of the pattern to displace and split into subsidiary maxima. Combined with the knowledge of the sign of the excitation error and using the so-called finish-start/right-hand convention for the definition of the Burgers circuit [3, 4] a full characterization of the Burgers vector is possible by evaluating the number and orientation of splittings n via the relation $n = \mathbf{g}\cdot\mathbf{b}$.

Figure 1 shows a bright field TEM image and a weak beam dark field image of a superdislocation which exhibits a pronounced splitting (~10 nm) into two superpartials. The conventional characterization using the invisibility criterion indicated a total Burgers vector parallel (or antiparallel) to [110]. However, the dislocation has not been completely out of contrast for any two beam condition leaving space for interpretation of the dislocation type. The LACBED investigations shown in figure 2 confirmed, by solving the linear system of equations below, that the overall Burgers vector of the superdislocation corresponds to [110] which means that the dislocation has screw character.

$$\begin{aligned} 5u + 5v - 1w &= 10 \\ 7u + 3v - 1w &= 10 \\ -3u - 5v + 1w &= -8 \end{aligned}$$

Due to the large Burgers vector of superdislocations the Bragg-lines may split into a large number of subsidiary peaks, as can be seen from figure 2, making a precise alignment of the microscopy mandatory. The Burgers vectors of the individual superpartials cannot be determined by the LACBED technique. However, they certainly must be equal to ½[110] in agreement with the similar contrast of both partials in the conventional TEM images (Fig. 1).

In this work the LACBED technique has been employed for superdislocation characterization. It was found that a full characterization including sign and modulus of the superdislocation with complex core structures and comprising several partial dislocations is possible. The results were in good agreement with conventional dislocation characterization. [5]

References

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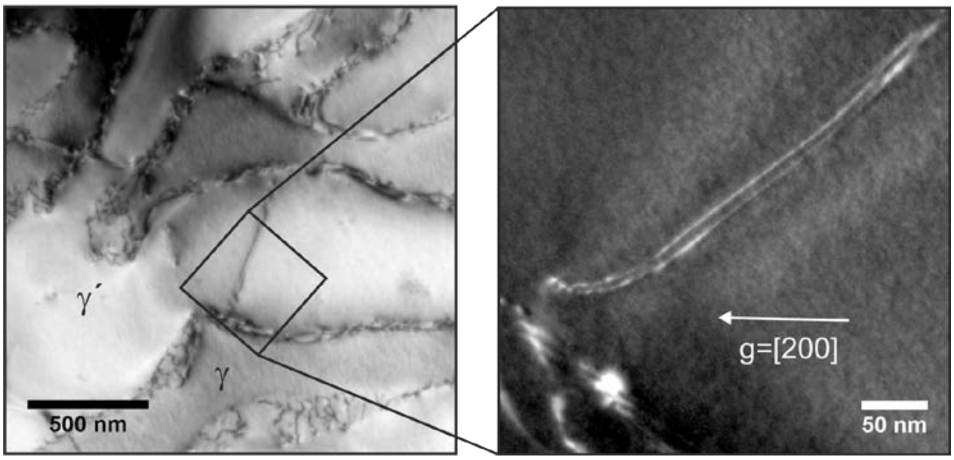

Figure 1. *A superdislocation is shown in the bright field image on the left. In the right image a weak beam dark field image showing the splitting of the two superpartial dislocations can be seen.*

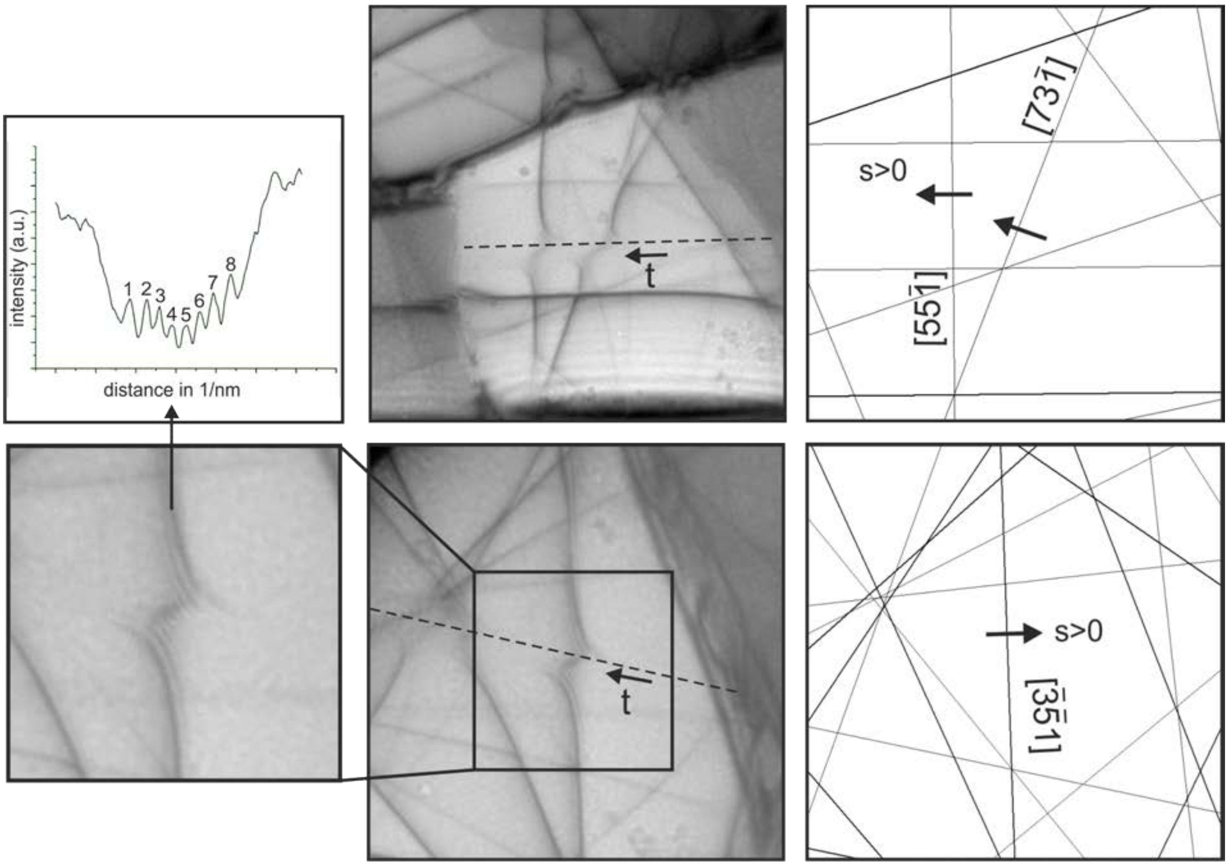

Figure 2. *LACBED analysis of the Burgers vector of the superdislocation shown in figure 1 (see text).*