A NEW TECHNIQUE FOR MEASURING THE SEPARATION OF CLOSELY SPACED DISLOCATIONS USING RESIDUAL CONTRAST CONDITIONS[‡]

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In order to measure the spacing of closely spaced dislocations, a method with sufficient spatial resolution must be used. High resolution imaging provides one method of determining the spacing of paired dislocations¹, but care must be taken since these authors have shown that thin film effects can give rise to structures not present in bulk materials. To date, the most widely used method of determining the spacing of paired dislocations is the weak-beam dark field method^{2,3}. This method has proved extremely useful in the study of many systems, see Cockayne³ for a review. One of the difficulties of weak-beam method is that the observed peak positions must be correlated with the true dislocation separation. This can prove difficult since the correlation depends on the deviation parameter, foil thickness, and position of the dislocations within the foil. Kinematical theory^{2,4} predicts a peak intensity (an extrema of the kinematical integral) for an isolated screw dislocation as:

$$x|_{x=x_p} = -\frac{gb}{2\pi s_g}$$

In this method, then, when two closely spaced dislocations are present, there are expected to be two peaks corresponding to each dislocation. As stated earlier, the separation of the peaks is not simply related to the separation of the dislocations². In addition, for closely spaced dislocations, it is difficult to determine any specific feature which easily allows for determining the dislocation separation. This is illustrated in figures 1(a) and 1(b) which are (g,3g) $g = [2-20]$ weak-beam dark field images for an edge dislocation, $l = [11-2]$, $b = 1/2[1-10]$, in copper which has dissociated into partials separated by 20 and 30 Ångstroms, respectively. It would be difficult to distinguish the partial separation for these cases on the basis of their image profile.

The residual contrast method relies on finding another extrema of the kinematical integral. In this case, we look for the inflection points in the dislocation contrast, thus the acronym inflection point contrast (IPC)⁵. This amounts to finding the points at which the derivative to this integral varies from $-\infty$ to $+\infty$. This is simply the values of x at which the derivative of the displacement field changes sign. Mathematically this can be written as:

$$\lim_{x \rightarrow x_i} \left(s_g + \frac{d}{dz}(g \cdot R) \right) = \lim_{x \rightarrow x_i} \left(\frac{d}{dz}(g \cdot R) \right) = \pm \infty$$

where the +/- sign depends on which side of the inflection point you are approaching. Inflection point contrast is of use since, in practice, it is independent of the exact deviation parameter. For the case of an isolated dislocation, there is an inflection point along the dislocation core. For any arrangement of dislocations, there is an inflection point at each core so that it may be possible to exploit inflection point contrast to determine the dislocation separation. Figure 2(a) and 2(b) illustrate the method for an edge dislocation in copper which has dissociated into partials separated by 20 and 30 Ångstroms, respectively. These figures are both (g,1.5g) $g = [-2-24]$ dark field images which is a residual contrast condition for the perfect dislocation since $g \cdot b = 0$. In both cases the separation of the dislocations is easily determined from the full width of the line profile.

Simulation of many dislocation and diffraction geometries, including different incident electron energies, show that the residual contrast method is insensitive to the exact experimental conditions. Applications of this method to copper, NiAl, and Ni₃Al will be discussed.

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Figure 1: Line profiles for a dissociated edge dislocation, $\mathbf{l} = [11\bar{2}]$, $\mathbf{b} = 1/2[1\bar{1}0]$, in copper. The dislocation lies in the middle of a foil 836 Å thick. Both images are $(\mathbf{g}, 3\mathbf{g})$ $\mathbf{g} = [2\bar{2}0]$ weak-beam dark field images calculated using the column approximation and including four beams in the simulation. In (a) the partial separation is 20 Å, while in (b) the partial separation is 30 Å. The position of the partial dislocations are indicated in each figure.

Figure 2: Line profiles for the same dislocation configuration as in figure 1, but obtained using the residual contrast method. Both simulations (a) and (b) are $(\mathbf{g}, 1.5\mathbf{g})$ $\mathbf{g} = [2\bar{2}4]$ dark field images for dissociation distances of 20 and 30 Å, respectively. As in figure 1, the position of the dislocation cores are indicated by the lines in each figure.

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