Identification of Burgers vectors along \langle 111 \rangle in In-doped GaAs, by X-ray transmission topography and image simulation.

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Abstract

Long dislocations with Burgers vectors along \langle 111 \rangle are unusual in f.c.c. lattices. X-ray topographs have been obtained of as-grown GaAs crystals doped with 10^{20} atoms cm^{-3} of In, where the usual extinction criterion \( g \cdot b = 0 \) leads to this type of defect. However, for several \( g \) satisfying the condition \( g \cdot b = 0 \) with \( b = a \langle 111 \rangle \), the images of these dislocations were still clearly visible. Comparison between experimental and computer-simulated X-ray topographic sections of these defects confirms the existence of Burgers vectors along \langle 111 \rangle.
Table 1. Maximum values of \( g \cdot R \) around the dislocation line for six reflections

<table>
<thead>
<tr>
<th>( g )</th>
<th>((g \cdot R)_{\text{max}})</th>
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<tbody>
<tr>
<td>224</td>
<td>0.40</td>
</tr>
<tr>
<td>202</td>
<td>1.13</td>
</tr>
<tr>
<td>022</td>
<td>0.79</td>
</tr>
<tr>
<td>220</td>
<td>1.90</td>
</tr>
<tr>
<td>242</td>
<td>2.68</td>
</tr>
<tr>
<td>422</td>
<td>3.02</td>
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ing more conclusive comparisons to be made with the experimental images. In this technique, the best images are obtained with the narrowest X-ray entrance slit. Fig. 2 is an experimental section of a dislocation of Fig. 1. The reflection was 440 and the entrance slit was 0.030 mm wide. This width is rather too large to provide a high-quality image, but it was imposed by our experimental set up. This situation and perhaps the relatively high In concentration can explain the absence of Pendellösung fringes in the experimental image. Fig. 3(a) is the corresponding computed image with a 0.001 mm wide ‘theoretical’ entrance slit, and the Burgers vector \( \frac{a}{3} [111] \). The comparison is satisfactory and all other tentative Burgers vectors gave less resemblance. For instance, Fig. 3(b) is the same computed section with the Burgers vector \( \frac{a}{2} [110] \). It can be seen that the distribution and the shape of the fringes do not fit the experimental topograph: the fringes are too abruptly curved and the bottom of the image is white instead of black. In Fig. 3(c) the theoretical slit width was increased to 0.017 mm (maximum value allowed by the program) and both parallel and perpendicular polarizations of the X-ray beam were introduced in the computation, to get more realistic conditions. The Burgers vector was again \( \frac{a}{3} [111] \). Here the correspondence between experimental and theoretical images is quite good.

These results confirm the existence of Burgers vectors along \langle 111 \rangle in GaAs. Such a direction of Burgers vector is usually invoked for partial dislocations in f.c.c. structures, but these dislocations are associated with a stacking fault. In our case, the resolution of the topographs and of the related simulation does not allow one to decide whether the defect is a perfect \langle 111 \rangle dislocation (high-energy defect) or a complex defect involving two or more Frank partials associated with stacking faults. It must be recalled here that the defects involved in this study are growth defects and not purely stress-induced ones. In addition, the high concentration of In may induce the formation of particular defects, as happens in Te-doped GaAs where condensation of Te along \langle 111 \rangle planes induces complex stacking faults (Maksimov, Ziegler, Khodos, Snighiryova & Shikhsaidov, 1984). Finally, it must be pointed out that Burgers vectors along \langle 111 \rangle have already been observed within grain boundaries in Czochralski-grown Si (Bourret, Desseaux-Thibault & Lancon, 1983).

This study demonstrates the usefulness of computational imaging techniques when the usual criteria of identification of defects do not lead to straightforward conclusions, and it shows again the influence of dopants on defect structure in semiconductors, particularly in III–V compounds.

References


Fig. 2. Section topograph, \( g = 440 \).

Fig. 3. Computed section topographs. (a) \( b = \frac{a}{3} [111], g = 440, \) entrance slit = 0.001 mm, (b) \( b = \frac{a}{2} [110], g = 440, \) entrance slit = 0.001 mm, (c) \( b = \frac{a}{3} [111], g = 440, \) entrance slit = 0.017 mm.