1808
doi:10.1017/S1431927610059301
Microsc. Microanal. 16 (Suppl 2), 2010

Correlated Twins in Nanowires

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Semiconducting nanowires offer the possibility of nearly unlimited complex bottom-up design which allows for new device concepts. The control in defects (i.e. twin planes) and the crystal structure are crucial for an optimal device performance. Normally twin planes occur randomly during growth, leading to imperfection in the crystal quality of the nanowire, resulting in electronic and optical barriers. However, control in defect positions, such as twin superlattices[1,2] along the nanowires axis, could lead to new technologies since they are predicted to induce a direct bandgap in normally indirect bandgap semiconductors. Here we present[3,4] how growth parameters influence the formation of planar defects and the importance of the nanowire morphology on twin development. Additionally, in HRTEM studies on GaP nanowires we found a new type of twinning, correlated planar twin formation. Here a first planar twin is formed at a random position, rapidly followed by the formation of a second twin plane of which the position is directly related to that of the first one (Fig. 1). HAADF/STEM electron tomography studies revealed a triangular morphology of this type of nanowire, which is rotated over 180° at a single twin plane and is reversed to its original shape upon passing a paired set of twin planes (Fig. 1c-e). HRTEM studies under various zone axis conditions completed the information of morphological transition at single and paired twin events (see fig. 2). We show that the triangular morphology is a key element in the formation of these twin pairs. We have expanded our previous kinetic nucleation model, enabling it to describe the development of the nanowire morphology and the formation of single and paired twin planes.

References

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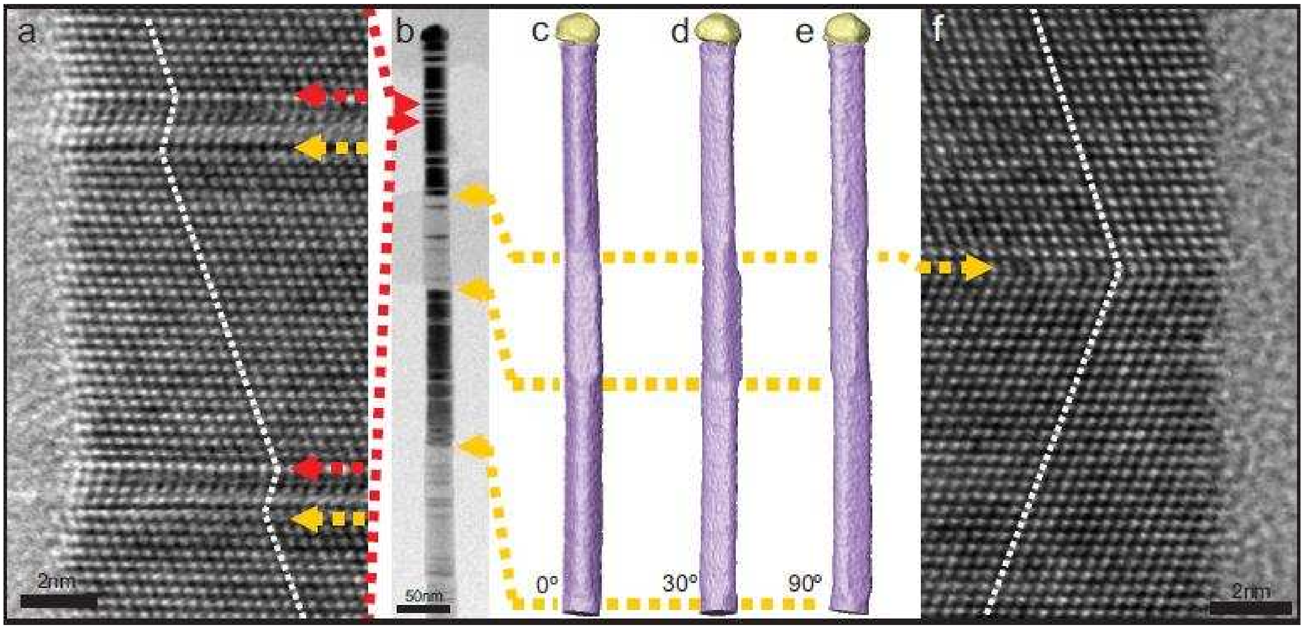

FIG. 1. TEM images of a multiply twinned GaP nanowire. **b**. Bright field TEM image of the nanowire revealing single and paired twin domains. The transitions in contrast indicate the positions of the twin planes. The single twin boundaries are indicated by the yellow arrows. The white and black stripes are two twins spaced closely together, forming a 'twin pair'. **c,d,e.** A surface rendering representation of a tomographic reconstruction of a STEM/HAADF tilt series. Three viewing directions are displayed, ranging from parallel to perpendicular to {11-2} side facets. For 0°, 30° and 90° this results in the [11-2], [01-1], and [-110] viewing directions, respectively. Clearly, the single twins induce 180° rotations of the truncated triangular cross-section, whereas in the regime of twin pairs the morphology remains unchanged. **a,f**. HRTEM micrographs of paired (**a**) and single (**f**) twin planes imaged along the <110> zone axis, showing the zinc-blende crystal structure and two twin pairs in **a**. The first (random) and the second (paired) twin planes are indicated by yellow and red arrows, respectively.

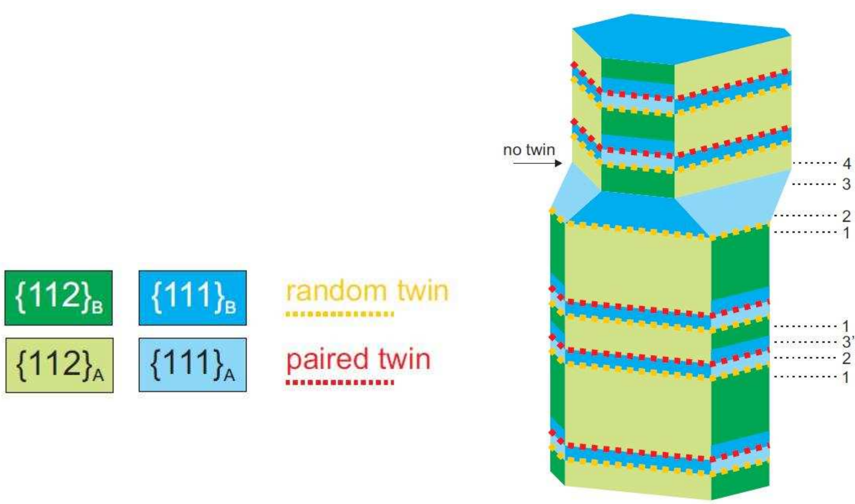

FIG 2. Schematic representation of the nanowire morphology containing random (dashed yellow lines) and paired (dashed red lines) twins.

https://doi.org/10.1017/S1431927610059301 Published online by Cambridge University Press