Misfit Dislocation Interactions in Low Mismatch P/P+ Silicon Epitaxy

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The propagation and interaction of individual misfit dislocations was studied using double crystal x-ray topography. We determined that as a gliding 60° misfit dislocation encounters a strain field in its path, it will cross-slip to a specific lattice direction, which we believe depends on the film thickness at the time of the interaction. We studied these misfit dislocation interaction characteristics in strained p/p+ Si wafers. The epitaxial layer thicknesses ranged from 2.5 μ to 6 μm and were grown on substrates with off-orientations from the (001) that ranged from 0° to 5°. The strain employed is on the order of 10^{-4} and the layer thickness is as much as five times the thermodynamically predicted critical thickness. Misfit dislocations nucleated only at the wafer edges, providing a well controlled source of these defects. The use of different substrate off-orientation magnitudes and directions helped distinguish misfit dislocations with different Burger's vectors and also helped to experimentally determine the cross-slip and pinning mechanisms operating at the intersection of orthogonal dislocations. The relatively thick layers and low misfit densities (≈ 100 cm^{-1}) are highly compatible with double crystal x-ray topography. Since a misfit dislocation generates a strain field around its path and thus reduces the unstrained channel on top of the interface, an orthogonal misfit segment may encounter resistance as it glides across the pre-existing misfit segment. If the layer is sufficiently thin, the crossing threading dislocation may not proceed gliding on the original glide plane because of an apparent local decrease in the layer thickness and thus either get pinned or undergo cross-slip. Individual dislocations were also observed during subsequent high temperature anneal steps. We studied the differences in interaction behavior during epilayer growth and during subsequent annealing cycles. No occurrence of annihilation or multiplication reaction of crossing dislocations was detected in this system. This study points to some key experiments for in-situ topography measurements of dislocation interactions.

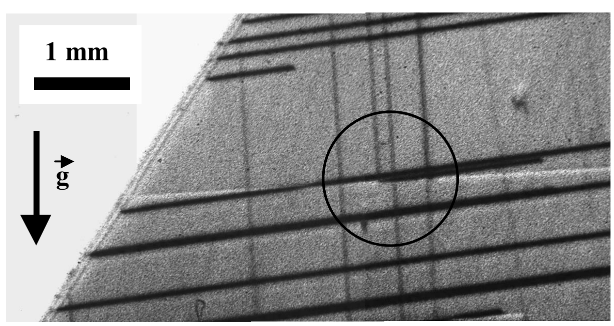

Figure 1. Double crystal x-ray topograph from an as-grown (001) p/p+ Si test wafer with 6 μm epilayer. The substrate was off-oriented towards a [101] axis. The misfit dislocations appear as white and black lines - due to the different tilt components of the Burger's vectors - extending from the wafer edge. Cross-slip of a single misfit dislocation segment as it approaches an orthogonal misfit dislocation segment of a specific Burger's vector is highlighted with a circle.