

This Week's Citation Classic

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Abrahams M S, Weisberg L R, Buiocchi C J & Blanc J. Dislocation morphology in graded heterojunctions: GaAs_{1-x}P_x. *J. Mater. Sci.* 4:223-35, 1969. [David Sarnoff Res. Center, RCA Labs., Princeton, NJ]

The details of the formation, propagation, interaction, and densities of misfit dislocations are combined into a simple model quantitatively predicting dislocation densities for both abrupt and compositionally graded heterojunctions. Transmission electron microscopy was used for a comprehensive study of dislocations in a series of GaAs_{1-x}P_x heterojunctions. The main features of the above model were corroborated. [The *SCI*[®] indicates that this paper has been cited over 100 times since 1969.]

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"In the mid-1960s, Jim Tietjen showed me an epitaxial layer of gallium arsenide-phosphide that he grew on a gallium arsenide substrate. It is from such layers that the ubiquitous red light-emitting diodes evolved which are seen now in watches, calculators, cameras, games, as well as scientific instruments. To the unaided eye, an orthogonal array of lines was observed. It seemed possible that this structure was related to dislocations of the strain-relieving variety. These, of course, are now known to arise from the difference in lattice parameters between the substrate and the epitaxial layer. The nature of this structure began to interest us and with the availability, from Tietjen, of a variety of epitaxial structures, we began to characterize the dislocation morphology in the GaAs_{1-x}P_x crystal system. The team involved with this work, which was done at the David Sarnoff Research Center, RCA Labora-

tories, Princeton, NJ, consisted of Len Weisberg, Chuck Buiocchi, Joe Blanc, and myself.

"The strain-relieving, or misfit dislocations, present in an abrupt epitaxial composite, like germanium grown on gallium arsenide, basically lie in one plane, near the original growth interface. However, when an alloy of gallium arsenide with gallium phosphide is desired, the ratio of arsenic-to-phosphorus atoms is compositionally graded to that of the desired alloy by increasing the phosphine—while reducing the arsine—flows in the vapor stream. The grading was carried out over many micro-meters in the growth direction; the same was found to be true for the misfit dislocations. For most of this work, the specimens were examined on a plane normal to the growth axis and I recall observing what appeared to be two distinct sets of dislocations: misfit dislocations which formed a square-like array parallel to the growth plane and another set of dislocations which appeared to propagate roughly parallel to the growth direction. I called this latter set, 'inclined dislocations.' We speculated initially (and were later able to show) that these dislocations joined the planes of misfit dislocations.

"We found the visualization of the inclined dislocations difficult even with stereo-pairs. This provided the impetus to develop cross-sectional samples, which did the job.¹ The cross-sectional micrograph in this paper was the first of its type ever published and we've been using cross-sectional samples successfully ever since. I think the paper has been frequently cited because it clearly illustrated that dislocations are generated at heteroepitaxial interfaces, but that their density can be controlled by varying the rate of change of alloy composition. The now-recognized effects of such dislocations on device performance add a practical impact to our early study."

1. Abrahams M S & Buiocchi C J. Cross-sectional specimens for transmission electron microscopy. *J. Appl. Phys.* 45:3315-6, 1974.