HREM AT ORTHOGONAL PROJECTIONS OF GaAs ISLANDS ON SILICONF. A. Ponce^o and C. J. D. Hetherington*^o Xerox Palo Alto Research Center, Palo Alto, CA 94304

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HREM studies typically examine only one projection of a structure and information in the electron beam direction is lost. In most cases, the structure in this direction is uniform and already known, but in others a second projection needs to be observed. This could involve preparing a second specimen sectioned at right angles to the first, or as described here, tilting a specimen through $\pm 45^\circ$ and observing the same volume in orthogonal projections. The specimen used here was of GaAs islands on $\langle 001 \rangle$ silicon, examined in the Atomic Resolution Microscope at LBL.

In the effort to grow defect-free GaAs films on silicon substrates, understanding of the early stages of growth is required^{2,3}. For this experiment we chose a specimen of ultra-thin GaAs grown on silicon substrate by metal-organic chemical vapor deposition (MOCVD). The GaAs was grown at 550°C for a nominal thickness of 20nm from trimethyl gallium and arsine sources. The growth conditions lead to three-dimensional growth of islands bound by $\{111\}\text{A}$ planes, terminated on Ga layers⁴. The $\langle 100 \rangle$ direction of the silicon structure has a four-fold symmetry. The sphalerite structure of GaAs has only a two-fold symmetry in the $\langle 100 \rangle$ orientation. Because of this difference in symmetry, two basic configurations of GaAs islands exist on $\langle 001 \rangle$ silicon having long axes parallel to $\{110\}$ or $\{1-10\}$ directions. This has been observed in planar views, and individual $\{110\}$ cross sections have revealed the two possible projections of the islands⁴. However, no single island has been examined in detail under orthogonal projections.

For this study, a sample with appropriately spaced islands was chosen so that their images would not overlap in thin sections. An amorphous silicon layer was deposited to protect the islands during ion milling, and a $\{100\}$ cross section was prepared. The specimen was aligned in the holder so that the interface lay midway between the $\pm 40^\circ$ tilt axes where the net tilt approaches $\pm 55^\circ$. The ARM was operated at 800kV and images taken at the $\{110\}$, $\{100\}$ and $\{1-10\}$ zone axes as shown in figure 1 and explained schematically in figure 2. The mechanical stability of the holder at 45° tilt allowed 0.17 nm spaced $\{113\}$ fringes to be observed in an adjacent island. Beam alignment was preserved between tilts by focussing with the specimen height control.

From the images presented here, the anisotropy between the $\{110\}$ and $\{1-10\}$ projections of the GaAs islands is evident. In addition to the difference in shape, the defect structure is strikingly different: stacking faults are quite common in the $\{1-10\}$ but virtually absent in the $\{110\}$. This is expected to be due to the anisotropic $\{100\}$ growth process of GaAs. This work demonstrates the feasibility of obtaining orthogonally projected HRTEM views of the same objects in order to provide detailed information of the 3-D atomic structure.

References

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Figure Captions

Figure 1: HRTEM micrographs of single GaAs island shown in (a) [100], (b) [110], and (c) [1-10] projections. From image in (c) the TEM specimen thickness is measured to be 22nm. Island height is 29 nm.

Figure 2: Schematic diagram of GaAs island morphology (a) TEM section of island bound by {111}A (original surfaces, shaded) and {100} (TEM specimen surfaces) planes, (b) TEM section of island (shaded) with projected axes indicated, (c) projections shown in Figure 1.

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FIGURE 2