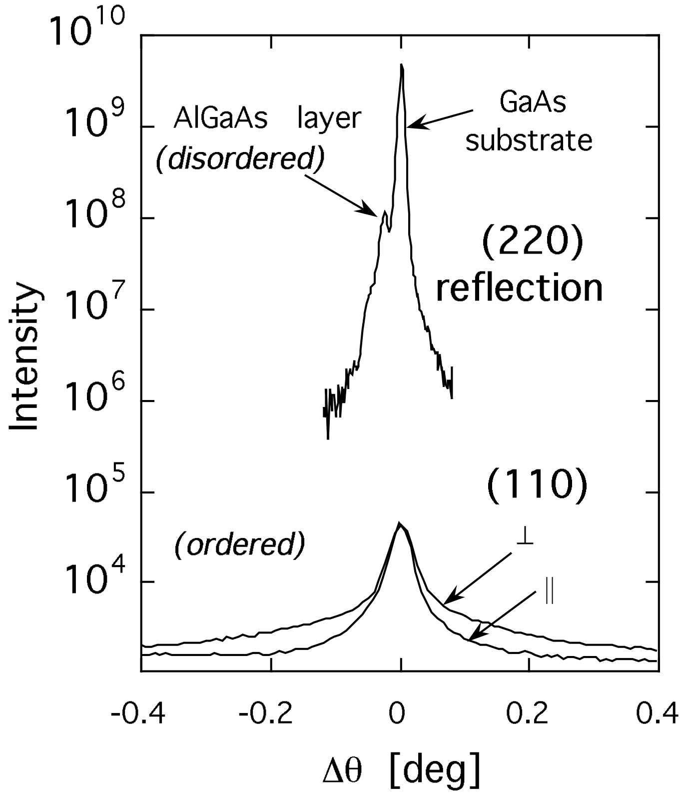
14 Spontaneous Ordering in AlGaAs

B.D. Patterson (Univ. Zürich); H. Auderset, C. Brönnimann and U. Staub (PSI); M. Moser, A. Vonlanthen (CSEM), P. Pattison (Univ. Lausanne), K. Knudsen (ESRF) and R. Mathiessen (Univ. Trondheim)

A spontaneous ordering of Al and Ga ions on the group-III sublattice of the compound semiconductor $Al_xGa_{1-x}As$ has been observed for the first time using X-ray diffraction. The material, with a nominal Al-concentration x= 0.75, was grown as a 500 nm thick epitaxial layer on a [110] GaAs substrate wafer. High intensity synchrotron radiation was required to observe the very weak superlattice diffraction peaks and to demonstrate a strongly anisotropic diffuse scattering component.

The ternary III-V semiconductor $Al_xGa_{1-x}As$, grown in the form of epitaxial layers on GaAs substrates, is an important material both from the point of view of fundamental quantum-well physics and in terms of technological applications (e.g., heterostructure transistors and laser diodes). Its usefulness derives from the fact that the aluminum concentration x can be varied continuously between 0 and 1, producing a large shift (87%) in the direct electronic bandgap but a small change (0.14%) in the lattice constant. This allows the growth of elasitcally-strained epitaxial barrier layers on GaAs substrates. The most common growth techniques are molecular-beam epitaxy (MBE) and organo-metallic vapor phase epitaxy (OMVPE), and the standard substrate orientation is [100].



Due to the similar covalent radii of Al and Ga, it has generally been accepted that $Al_xGa_{1-x}As$ is a random alloy, with the Al and Ga ions occupying uncorrelated positions on the group-III sublattice of the cubic zincblende structure. In 1985, however, Kuan, et al [1] could observe, using electron diffraction, superlattice reflections in $Al_{0.75}Ga_{0.25}As$ samples grown with OMVPE on [110] substrates. The diffraction pattern implied a weakly developed spontaneous ordering of Al and Ga in the CuAu I structure, with alternating (100) Al- and

Ga-rich atomic planes. Although stimulating much theoretical work, to date no independent observation of this spontaneous ordering has been published.

We have used OMVPE to grow a 500 nm $Al_{0.75}Ga_{0.25}As$ on a [110] GaAs substrate at a growth temperature of 780° C. Upon investigation with 0.7 Å synchrotron radiation (at the Swiss-Norwegian Beamline of the European Synchrotron Radiation Facility, Grenoble), we observed weak reflections satisfying the selection rule (h+k=even, k+l=odd) specific to the CuAu I structure. The Figure shows the observed diffracted intensity as a function of scattering angle for the zincblende-allowed (220) reflections from the GaAs substrate and the epitaxial layer and for the CuAu I (110) superlattice reflection. The extreme weakness of the superlattice diffraction peak makes the use of high-intensity synchrotron radiation a necessity. The Figure shows (110) diffraction results for both the $\theta(\|)$ and $\theta - 2\theta(\perp)$ scanning modes. The former samples reciprocal space parallel to the wafer surface and the latter perpendicular. In spite of the weakness of the signals, one clearly sees a broad diffuse scattering component perpendicular to the surface, indicative of finely-spaced stacking faults running perpendicular to the [110] layer growth direction.

Although this anisotropic diffuse scattering was also seen in the earlier electron diffraction experiment, the present high-resolution X-ray results permit a quantitative evaluation of the stacking fault correlation. It is believed that the long diffuse tails make a substantial contribution to the integrated scattering intensity.

References

[1] T.S. Kuan, et al, Phys. Rev. Lett. 54, 201 (1985)