LD-6-8

Direct Observation of $Al_xGa_{1-x}As/GaAs$ Superlattice by REM

N. Yamamoto and S. Muto*

Physics Department, Tokyo Institute of Technology, Oh-okayama, Meguro-ku, Tokyo 152, Japan.

*Fujitsu Limited, 1677 Ono, Atsugi 243-01, Japan.

Reflection Electron Microscopy (REM) has been developed as a powerful technique to directly characterize bulk crystal surfaces. The observations of reconstructed structures on clean Si surfaces, their phase transition and metal adsorption processes on them under ultra high vacuum condition have been reported.[1] However, observations of surface steps and other defects by REM are possible even with use of microscope of ordinary vacuum, if a crystal has a cleavage plane and provides a flat surface on an atomic scale. Several semiconductor materials such as Si, GaAs and other III-V compounds have been studied.[2] Recently we have succeeded to observe $Al_xGa_{1-x}As/GaAs$ superlattices by REM.

In comparison with usual transmission electron microscope techniques and other techniques for crystal characterization, the REM technique has following merits.

1. Sample preparation is simple and causes less damage to crystal structure.
2. Surface images are obtained in high resolution of about 10 Å along the lateral direction.
3. A wide surface area is observable due to the foreshortening effect along the incident beam direction.
4. An image contrast is sensitive to lattice strain of the order of 10^{-3}-10^{-4}.
5. No special instruments are necessary except for a standard goniometer and vacuum system of modern electron microscopes.

$Al_xGa_{1-x}As/GaAs$ crystals with various superlattice periods grown by the MBE technique were examined in a JEOL 200CX electron microscope. The crystals were mechanically thinned and finally creaved by a blade normal to the superlattice plane. Fig.1 shows a REM image of an $Al_{0.3}Ga_{0.7}As$(120 Å)/GaAs(80 Å) superlattice taken by the (880) reflection with the incident electron beam nearly parallel to the [1$\bar{1}$0] direction. The experimental configuration is illustrated in Fgi.2. A upper-right bright region is a GaAs substrate and dark stripe regions in an lower-left are $Al_{0.3}Ga_{0.7}As$ layers. The whole thickness of the superlattice region is 2.4 μm with total periods of 120. Ratio between the longitudinal and lateral scales, i.e. foreshortening, is 0.024. Due to severe foreshortening superlattices are not seen to be vertical. Focus of the image changes along the vertical direction, and a contrast between superlattice layers becomes minimum at an in-focus position indicated by an arrow. Several surface steps are seen nearly parallel to the [001] direction as marked by triangles, which were accidentally produced by a cleavage. Another line contrasts (marked by open circles) similar to those of the surface steps are due to the irregularities of the superlattice. The irregularities are clearly seen in Fig.3, where we see surface roughness of about 50 Å high on the GaAs substrate affects flatness of the successive superlattice layers growing on top of it. Such irregularities are seen to be aligned along the growing direction of [001].

However it is seen in Fig.1 that they are slightly different from the direction of the surface steps. It is found that the irregularities are almost relaxed over about 40 periods of superlattice layers from the substrate.

REM images taken with the incident electron beam normal to the superlattice showed a strain contrast in addition to the superlattice image. The observed contrast indicated that the strain is locatized especially near the boundary between the GaAs substrate and the superlattice region, and becomes relaxed towards the top layer.

The specimen crystals used in this study were produced in Fujitsu Limited under the project of next generation in commision of Ministry of International Trade and Industry.

References
1. K. Yagi, K. Takayanagi and G. Honjo, Crystals, Growth, Properties and Applications 7, Springer-Verlag, Berlin, Heidelberg (1982)47.
2. N. Yamamoto and J.C.H. Spence, Thin Solid Films 104(1983)43.

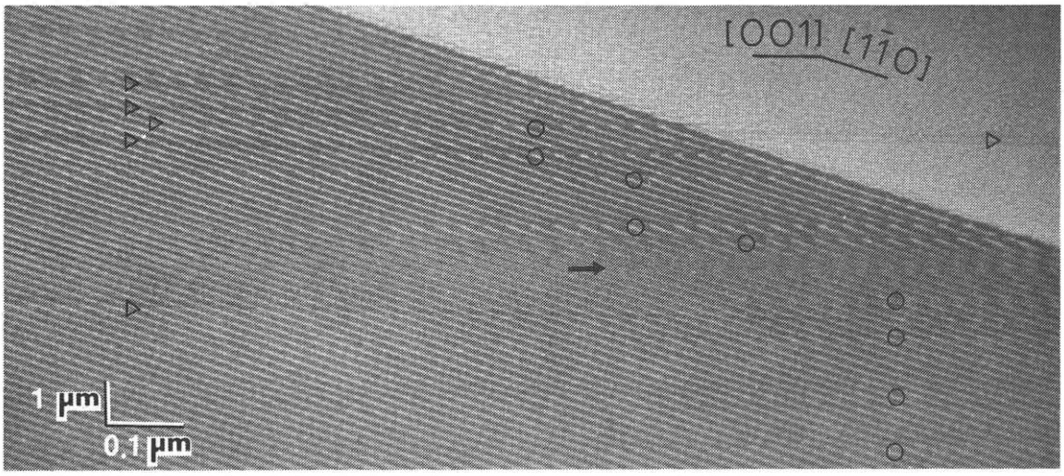

Fig.1 A REM image of $Al_{0.3}Ga_{0.7}As/GaAs$ superlattice

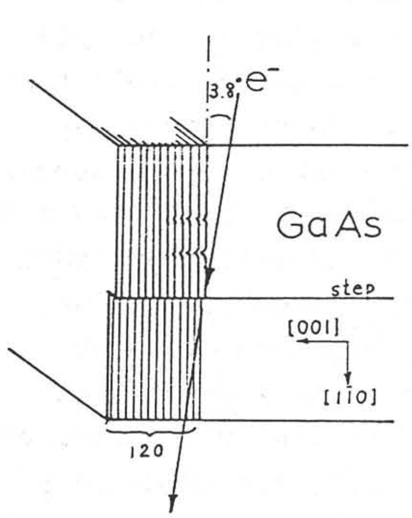

Fig.2 Experimental geometry

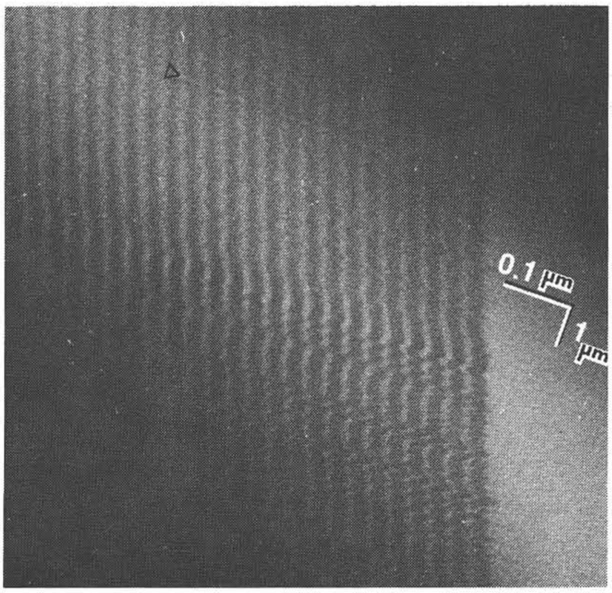

Fig.3 $Al_{0.3}Ga_{0.7}As/GaAs$ superlattice