Z-CONTRAST IMAGING OF InAs QUANTUM WIRES IN GaAs/AlAs QUANTUM WELLS

G. D. Lian*, E. C. Dickey*, J Wu**

*Department of Materials Science and Engineering, The Pennsylvania State University, University Park, PA 16802.
**Laboratory of Semiconductor Materials Science, Institute of Semiconductors, Chinese Academy of Sciences, P. O. Box 912, Beijing 100083, P.R. China

InAs/GaAs quantum wires (QWRs), have shown great promise for the next generation optoelectronic devices due to quantum confinement effects[1]. In order to assess this quantum size effect, which can be altered by strain fields, interfacial intermixing and defects, it is important to understand the structural details of the quantum wires. Here we present atomic structure and chemical analysis of InAs quantum wires embedded in GaAs and AlAs.

The growth details of the InAs quantum wires has been reported elsewhere[2]. In brief, multilayer InAs QWRs embedded in GaAs and AlAs were grown on (001) GaAs substrates by solid source molecular beam epitaxy. The epitaxial structures include 0.1um GaAs buffer layer, 4 periods of InAs layers/GaAs spacers, 4 periods InAs layers/AlAs spacers, and a capping layer of AlAs. The nominal thicknesses of the InAs layers and spacers are 7-15MLs and 15 nm, respectively. Transmission electron microscopy (TEM) and electron energy loss spectroscopy (EELS) were performed in a JEOL 2010F field emission TEM/STEM, operated at 200 kV. The microscope was equipped with an annular dark field detector, post-column EELS image filter (Gatan GIF200) and Oxford energy dipersive x-ray (EDX) detector.

Figure 1 shows typical high-resolution images of InAs QWRs in AlAs with the electron beam parallel to the $[1\bar{1}0]$ (a) and [110] (b) zone axes. In figure 1(a), the wire-line contrast indicates the InAs QWRs in the AlAs matix. Figure 1(b) shows the cross section of isolated InAs QWRs. No defects were apparent in the HREM images, indicating almost perfect epitaxial growth. It is difficult, however, to obtain the exact geometry of the InAs QWRs from these phase contrast image. Figure 2(a) shows an annual dark field (ADF) image taken along $[1\bar{1}0]$ zone axis. The intensity profile demonstrate that InAs QWRs are embedded in two different matrices—GaAs and AlAs. The averaged thickness of InAs layers, obtained from the Z-contrast image, is about 2.5 nm. The non-uniformity in thickness of InAs QWR is also revealed from Z-contrast images. Figure 2(c) is an ADF image taken along [110], from which the lateral dimension of the InAs QWRs is measured to be 3-5nm. Figure 2(d) is high-resolution Z-contrast image with electron beam parallel to $[1\bar{1}0]$ and taken from the thinnest part of the wires. This image shows an atomically abrupt interface between the two phases. Figure 2(e) is an EDX profile across one of InAs QWRs, which confirms that the QWRs are rich in In. The range of In rich region shown in the EDX profile is greater than that from intensity profile of Z-contrast is due to beam broadening effects.

References

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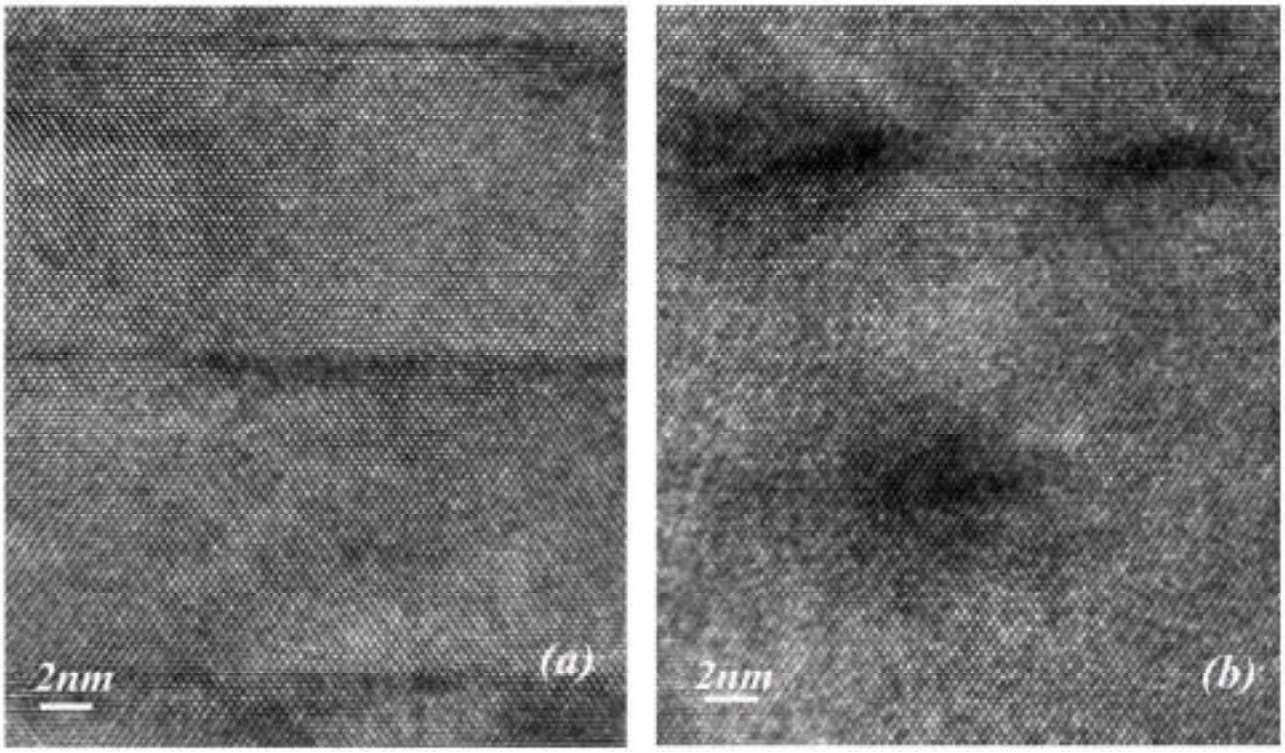

Figure 1 HREM images with electron beam parallel to [110] (a) and [110] zone axes.

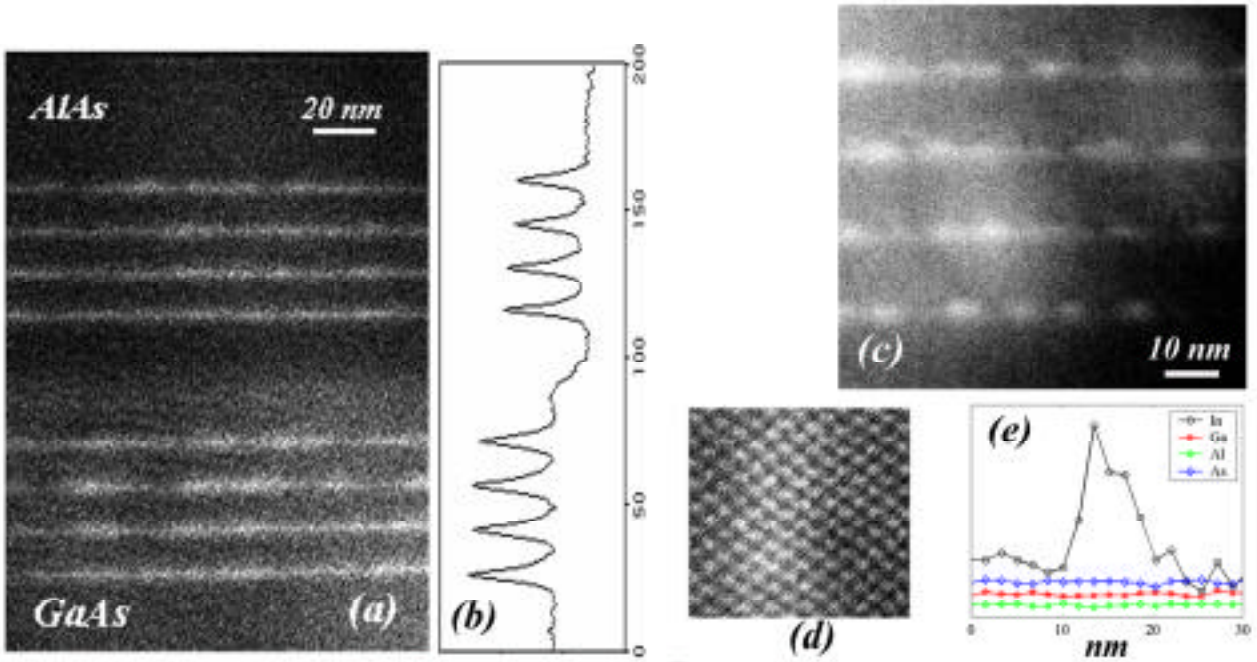

Figure 2 Z-contrast image(a) taken along [1$\bar{1}$0] and intensity profile(b) indicate that InAs QWRs in GaAs and AlAs layers, a portion of the Z-contrast image(c) from [110] zone axis shows the cross section of InAs QWRs, high resolution Z-contrast image (d), and EDX profile cross InAs QWR.