Dynamic Change of Growth Front of InGaAs/InP Observed by X-ray Crystal Truncation Rod Scattering and Cross-Sectional STM

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We have observed the interface structure between InGaAs and InP grown by organometallic vapor phase epitaxy (OMVPE) by X-ray crystal truncation rod (X-ray CTR) scattering. When InP is grown continuously on InGaAs, As atoms of noticeable amount exist deep into several monolayers as shown in Fig. 1 (a), that was revealed by X-ray CTR scattering measurements mondestructively[1)]. Using this measurement technique, optimization of growth sequence was investigated. Much wider distribution of Ga atoms found in Fig. (b) and this distribution was difficult to control. Discussion on this topic is presented at the conference.

Though X-ray CTR scattering measurement is a powerful technique and we often use it to reveal the atomistic scale composition profile *nondestructively,* it cannot distinguish the profiles diffusive or stepwise in the atomistic scale. We conducted cross-sectional STM (XSTM) on the same samples grown in the same research group.

Figure 2 (a) shows an XSTM in the electron extraction mode (images of As and P are observed). It is clear that the bottom interface InGaAs/InP is quite abrupt. It is understood that P atoms of a higher vapor pressure at the InP growth front was easily vaporized and removed from the growth front when As atmosphere was introduced to start the growth of InGaAs.

The problem is the upper interface of InP/InGaAs that is very unclear. When observed carefully, the interface was found to be made of numerous steps and terraces as delineated in Fig. 2 (b). The averaged amount of As at the interface was calculated from Fig. 2 (b). It was quite similar to the As profile shown in Fig. 1 (a) at the upper interface. By the XSTM it was clearly demonstrated that the deep extension of As atoms into InP is the stepwise growth of InGaAs of small sizes.

Moreover, the XSTM revealed isolated As atoms exist in InP much deeper as shown in Fig. 2 (3). We understand that those As atoms were taken into InP from gas phase mixed with the As source gas in the preceding InGaAs growth or As atoms re-evaporated from the inner wall or the susceptor of the growth system.

The XSTM in the electron injection mode (to obtain Ga profiles) is not successful yet. The large distribution of Ga observed by the X-ray CTR scattering measurements was not examined by the XSTM, but the growth conditions to obtain an abrupt interface of InP/InGaAs were found in our group. Detailed with be presented at the conference.

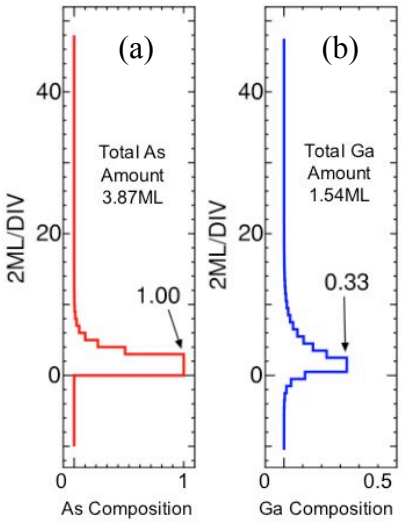

Fig. 1 As and Ga profiles obtained by X-ray crystal truncation rod scattering. As changes abruptly at the bottom interface but is graded at the top interface. Ga is widely distributed unexpectedly and does not reach the values 0.47 that is the lattice-matching condition.

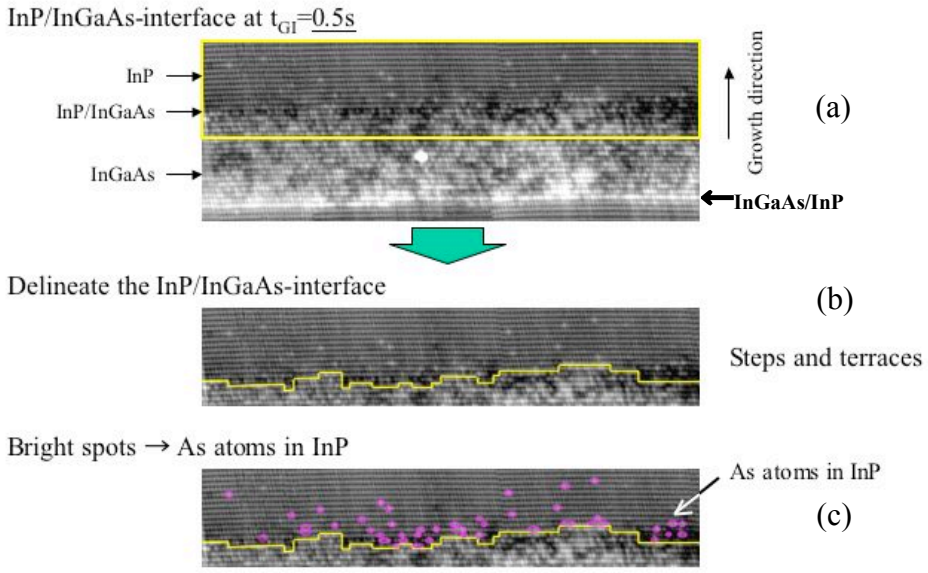

Fig. 2 Observation of As and P distributions in InP/InGaAs/InP. The bottom Interface is quite sharp as indicated in Fig. (a) but the top interface is very unclear. It is understood that the interface is made of numerous number of steps and terraces.

Reference

(1) M. Tabuchi, Y. Takeda et al., Appl. Surf. Sci., Vols. 159-160. pp. 250-255 (2000) .