Quantum Well Intermixing of InP-Based AlInGaAs Quantum Wells Using IFVD Technique and the Mask Boundary Effect

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Introduction

- Quantum Well Intermixing (QWI) is a post-growth technique that allows the energy band gap of a quantum well (QW) to be modified without any regrowth and thus can be used in the fabrication of PICs to reduce or eliminate epitaxial regrowth.
- During the QWI process, the diffusion of different atoms into the QW changes the material composition of the well. The band gap of the QW typically increases (thus blue-shift) as a result of the QWI.
- IFVD results in little or no damage to the surface of the epitaxial wafer and requires no extra treatment to the epitaxial wafer, such as a sacrificial layer.
- This paper proposed on the effect of QWI's mask boundary on the laser wavelength shift. This QWI technique and the boundary effect will be a useful reference for further photonic integration design and fabrication.

QWI Using IFVD

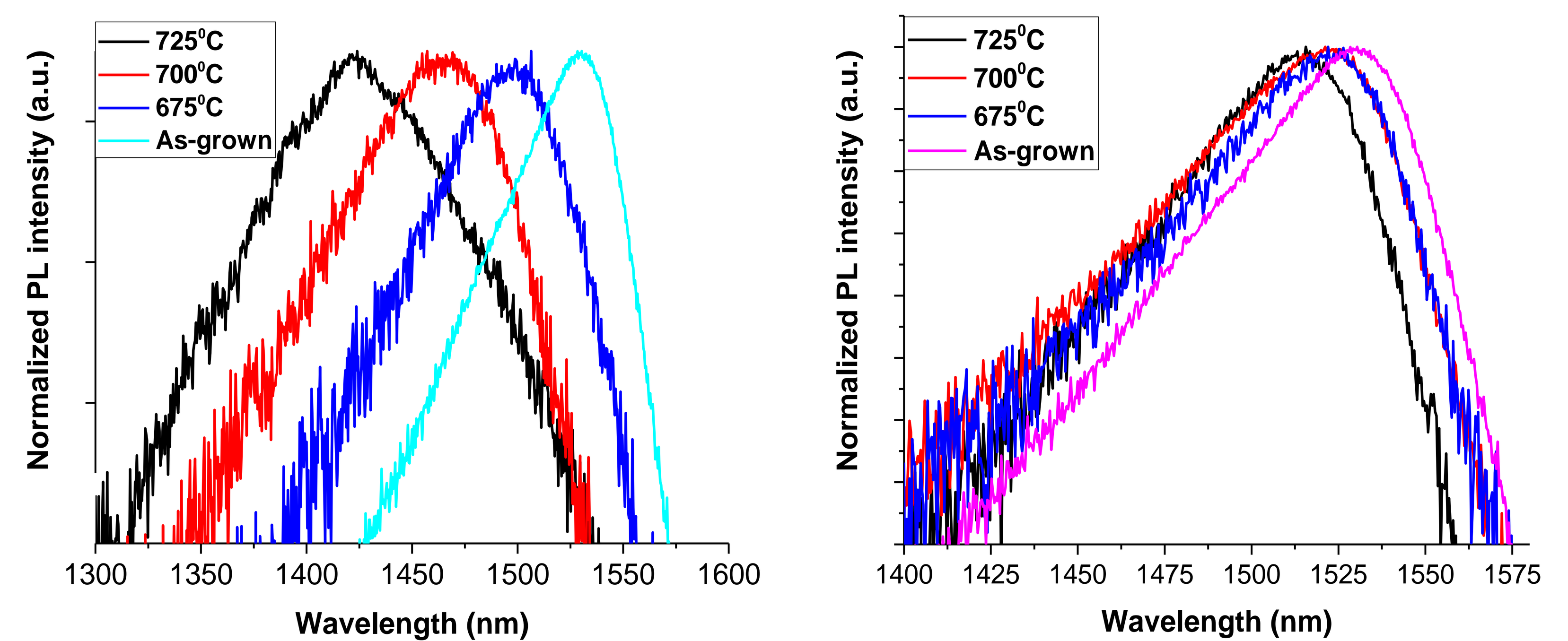

Figure 1(a). PL spectra of the samples capped with SiN_x (left) and Figure 1(b). SiO_2 films by PECVD and annealed under different temperature (right).

Experiments show that the SiN_x deposited by PECVD works as the promotor while the SiO_2 by PECVD acts as inhibitor in our QWI technique.

Mask Boundary Effect

- 12 FP lasers are designed with a 40μm wide SiN_x mask but with different distances between the centre of the ridge waveguide of the FP laser to the edge of the mask from: -20μm (negative numbers mean that the ridge is fully covered with the mask) to 21.25μm. All the lasers were 500μm long with 2.5μm wide ridges, using one deep etched facet and one cleaved facet.
- The fabrication process is a typical Fabry-Perot semiconductor laser process using conventional photolithography and etching techniques.
- The FP lasers with the ridge waveguide non-fully covered or several microns (0 to around 7.5μm) away from the edge of the SiNx mask also show a blue-shift of the lasing peak wavelength, but shows less blue shift as the distance increases. When the distance is more than 7.5μm, the QWI effect is no longer observed to affect the lasing performance.

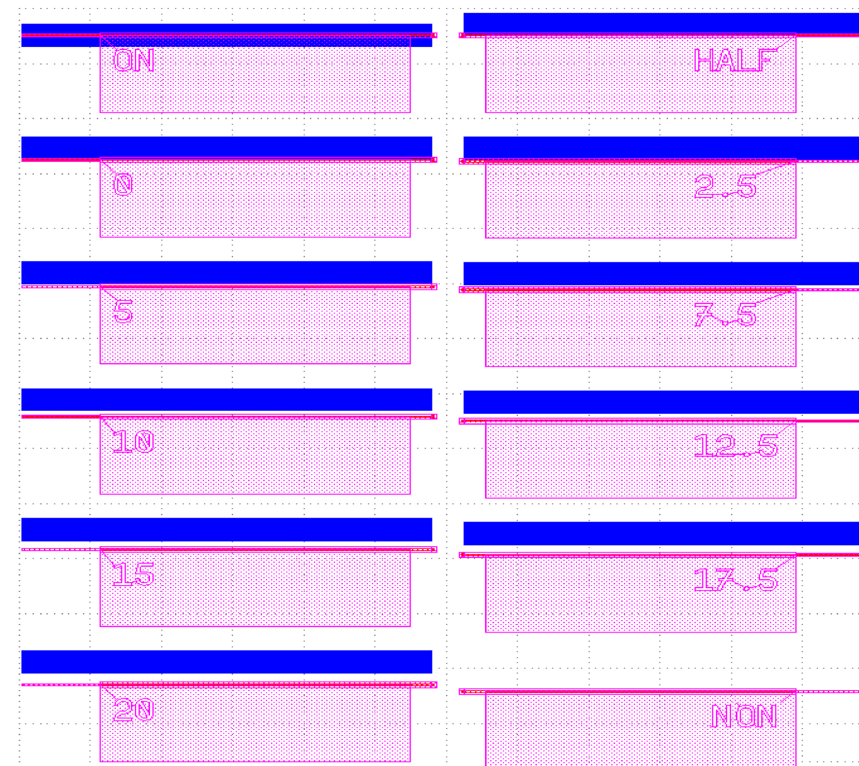

Figure 2. 12 lasers with different distances (the numbers on the chip design represent the distance from edge of the mask to the edge of the ridge) on the QWI boundary

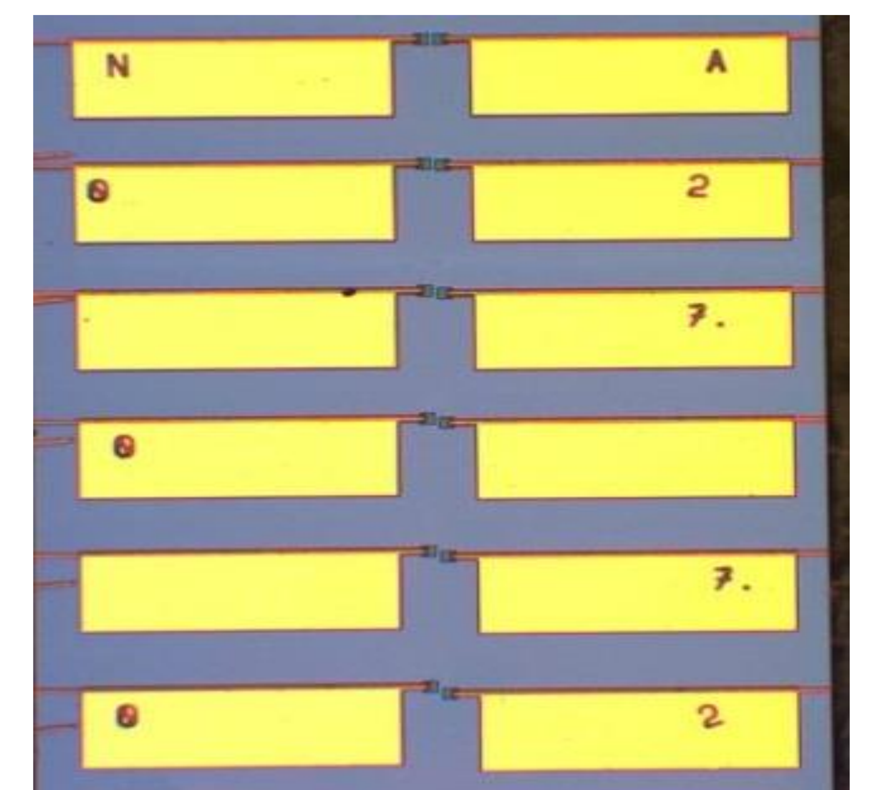

Figure 3. Microscopic picture of the fabricated FP lasers array.

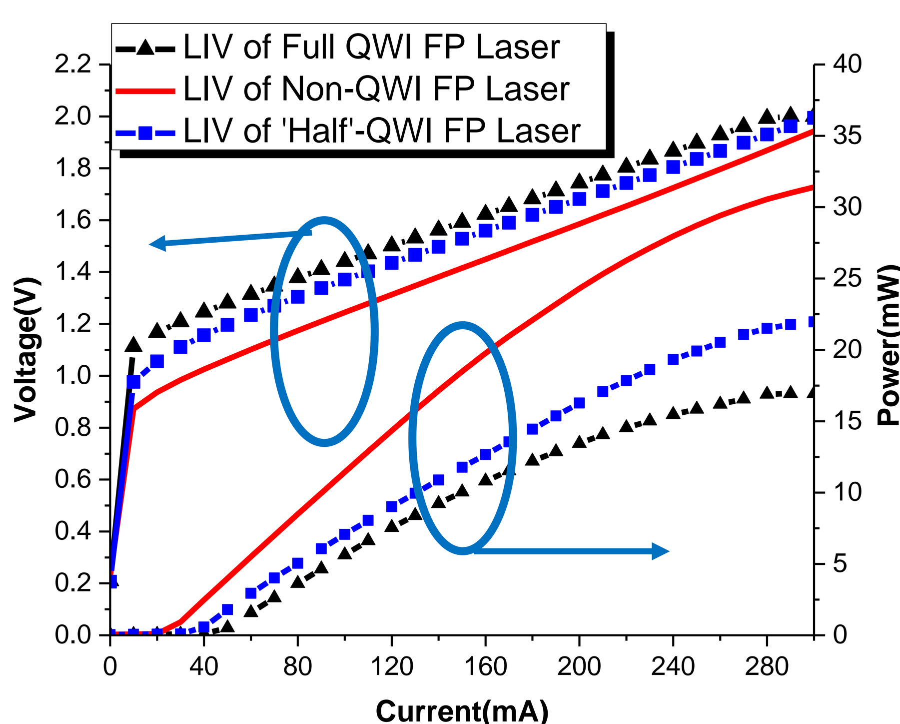

Figure 4. Characteristics of current--voltage and output power--current at 20˚C of non-QWI FP laser, 'Half'-QWI FP laser and Full-QWI FP laser

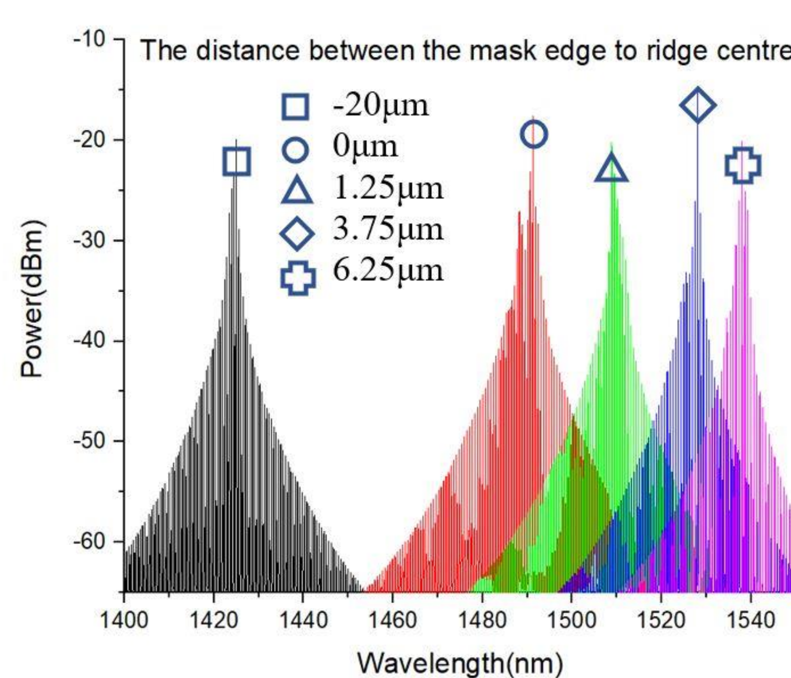

Figure 5. The lasing spectra of the FP laser annealed at 725˚C with different distance between the ridge centre to the edge of the QWI mask

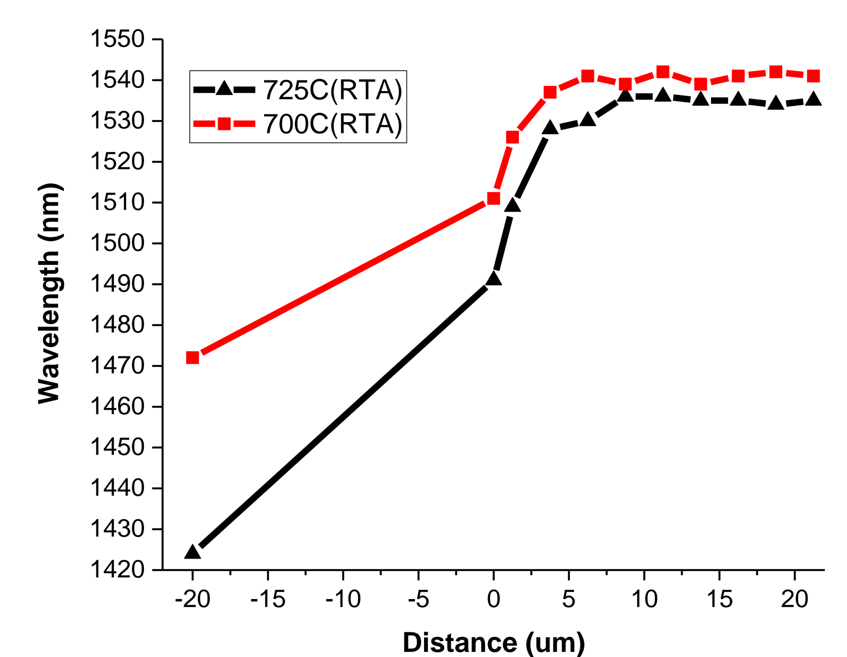

Figure 6. The lasing peak wavelength vs the distance between the ridge centre to the edge of the QWI area mask (all the FP lasers are tested under 40mA and the same other condition). Here, "-20" and "0" represent the ridge is in the centre of the mask and half covered by the mask (right).

Conclusion

- We have successfully demonstrated a QWI technique using IFVD method with SiNx by PECVD as promoter and SiO2 by PECVD as inhibitor and protector. A 120nm blue shift was obtained using InP-based AlInGaAs/AlInGaAs multiple quantum wells, further proved by Fabry-Perot ridge waveguide lasers fabricated with this technique. The QWI mask boundary effect was investigated, which shows the QWI mask edge needs to be more than 7.5μm away from the area where the intermixing is not desired. This QWI technique and the mask boundary effect result will be beneficial for the monolithic integration of photonic devices using AlInGaAs quantum well material.

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