High Growth Temperature Studies of InGaAs/InAlAs Superlattices for High-Quality QCL and QWIP Applications

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Motivations:

1. **MBE QCL growth temperature is typically below 550 degree C. MOCVD QCL growth temperature is usually above 650 degree C. MOCVD grown bulk crystals can provide lower defects materials**

2. **The interface defects in MOCVD grown QCLs and superlattice materials can create problems for QCL and superlattice device performance.**

3. **The purpose of the research is to**

(a) Explore the high growth temperature limit and

(b) Investigate how to control interface defects in MOCVD grown QCL and superlattice materials.

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Introduction

1. InGaAs/InAlAs quantum well system is the primary material system in this study. It is good for mid-infrared (3~ 12μm) QCLs.
2. The high growth temperature limits of InGaAs and InAlAs films were studied. Material Source are:
   In: Trimethylindium (TMI)
   Ga: Trimethylgallium (TMG)
   Al: Trimethylaluminum (TMA)
   As: Arsine (AsH3)
3. Study on InGaAs/InAlAs superlattices was then conducted to search the optimized growth parameters for superlattice and QCL growths.

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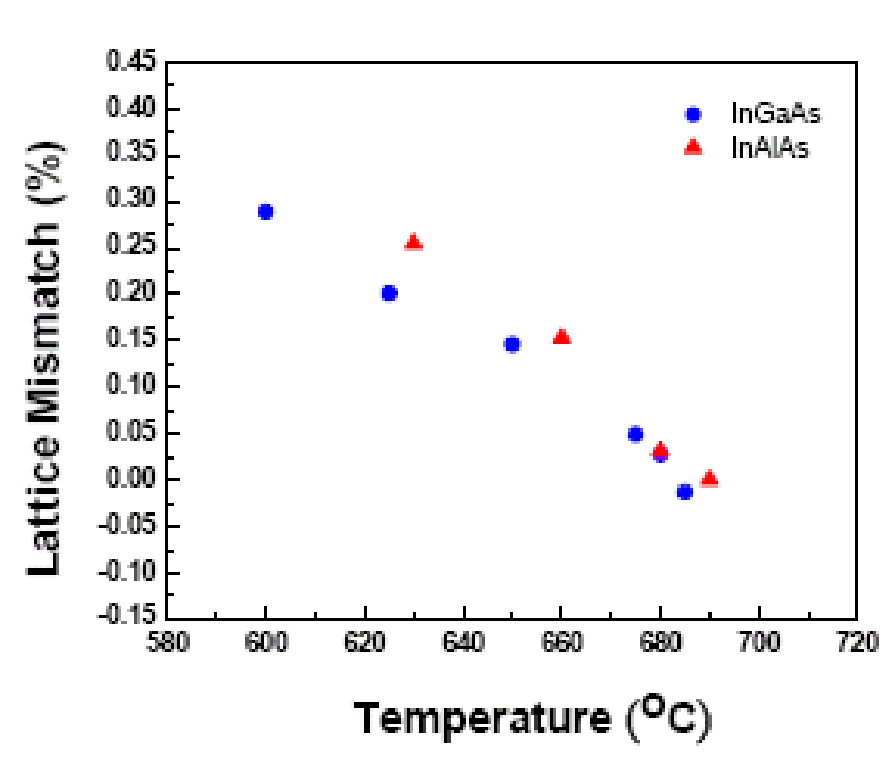
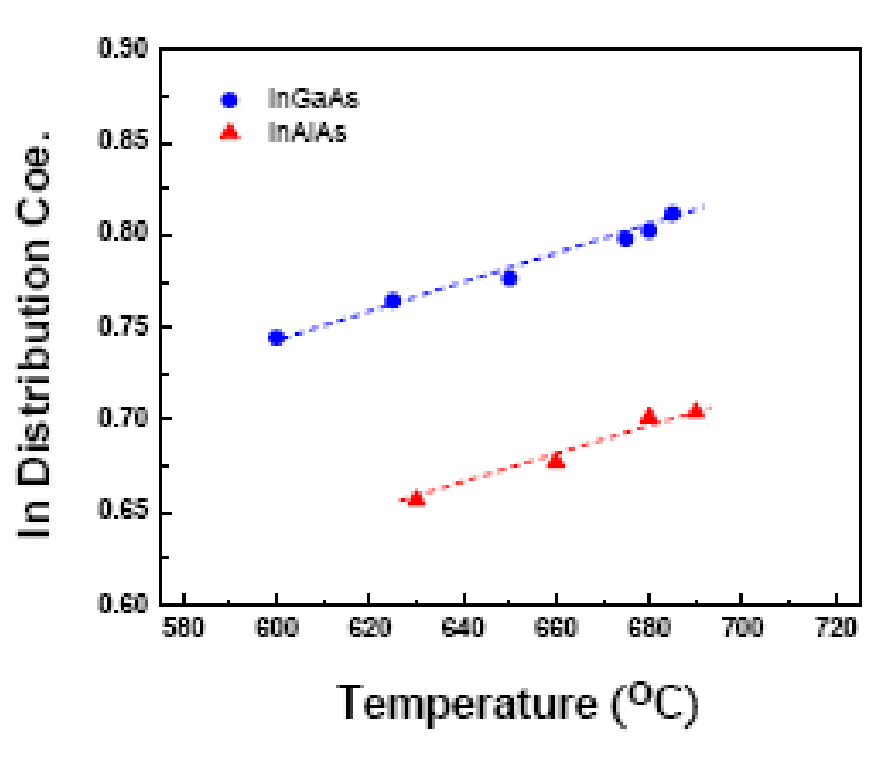
Epitaxial Growth of InGaAs and InAlAs

- **Strain vs. Growth Temperature**

  When growth temperature increases, the mismatch becomes more compressive (Indium rich). This is caused by higher decomposition rate of TMI at higher temperature.





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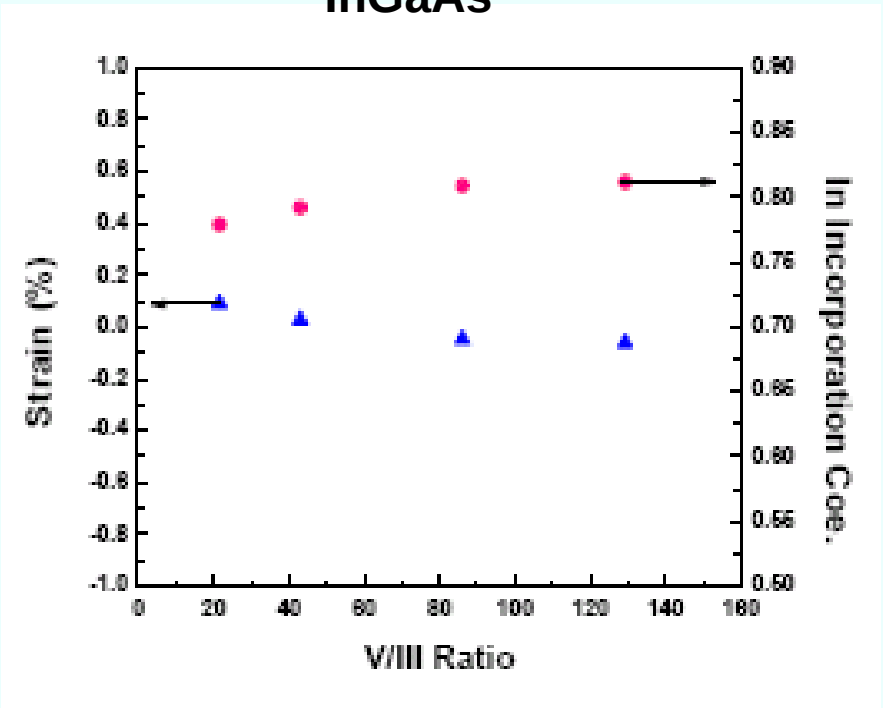
Epitaxial Growth of InGaAs and InAlAs

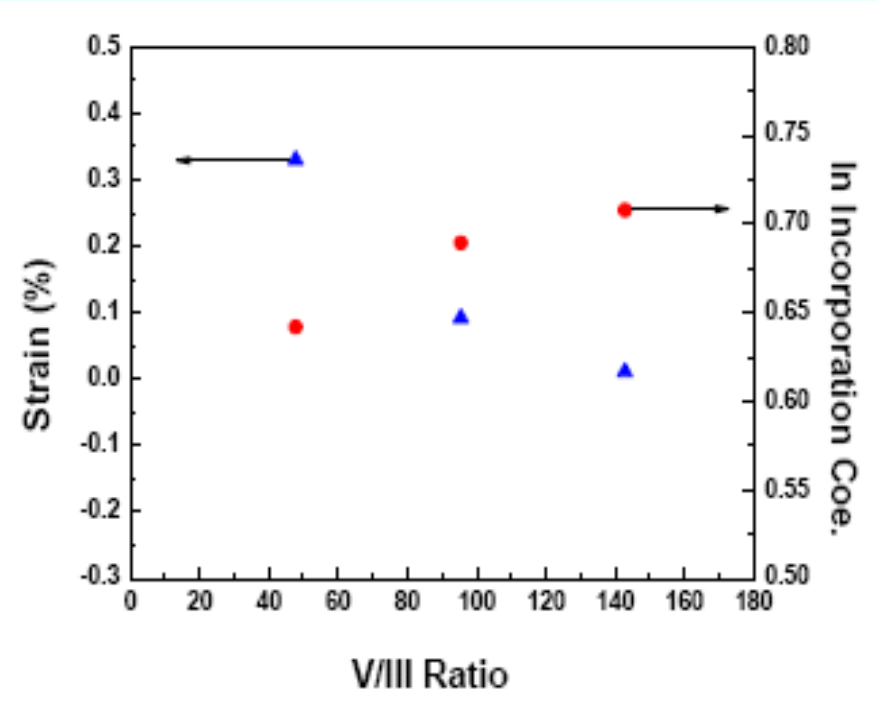
V/III Ratio Effect:

Bonding between Al-As atoms is easier to form than that of the In-As atoms. As a result, In atoms have lower incorporation coefficient. When the V/III ratio decreases, the epitaxial films become more compressive.

InGaAs



InAlAs



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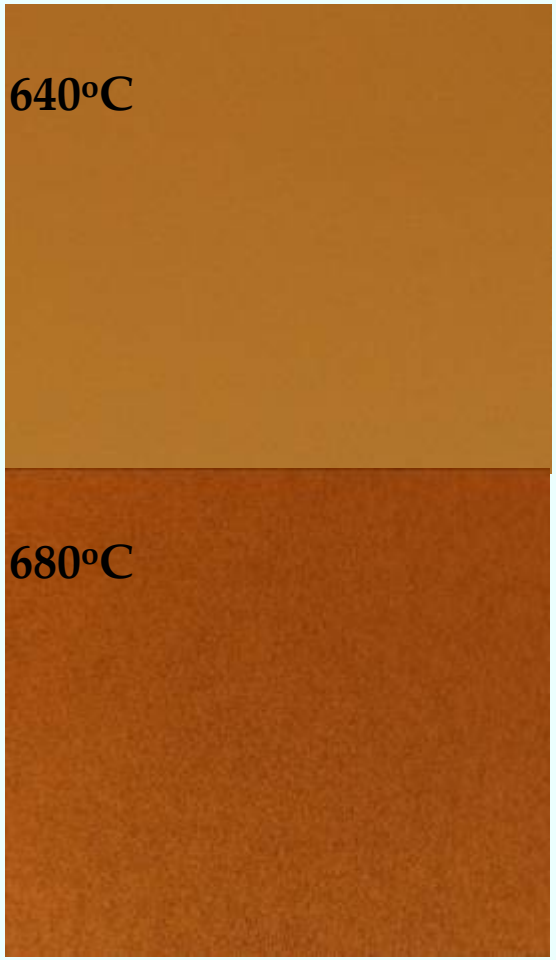
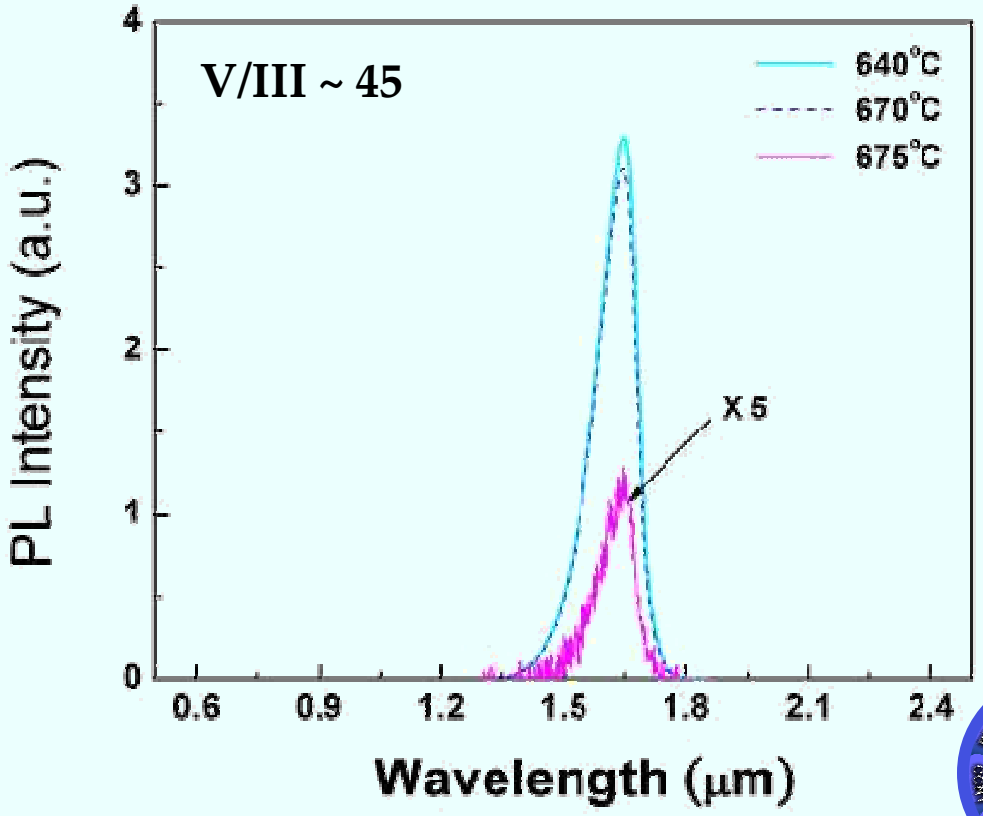
Optimization of InGaAs Epilayers

Effects of Growth Temperature



- As the growth temperature increased, more As atoms desorbed from the epilayers.



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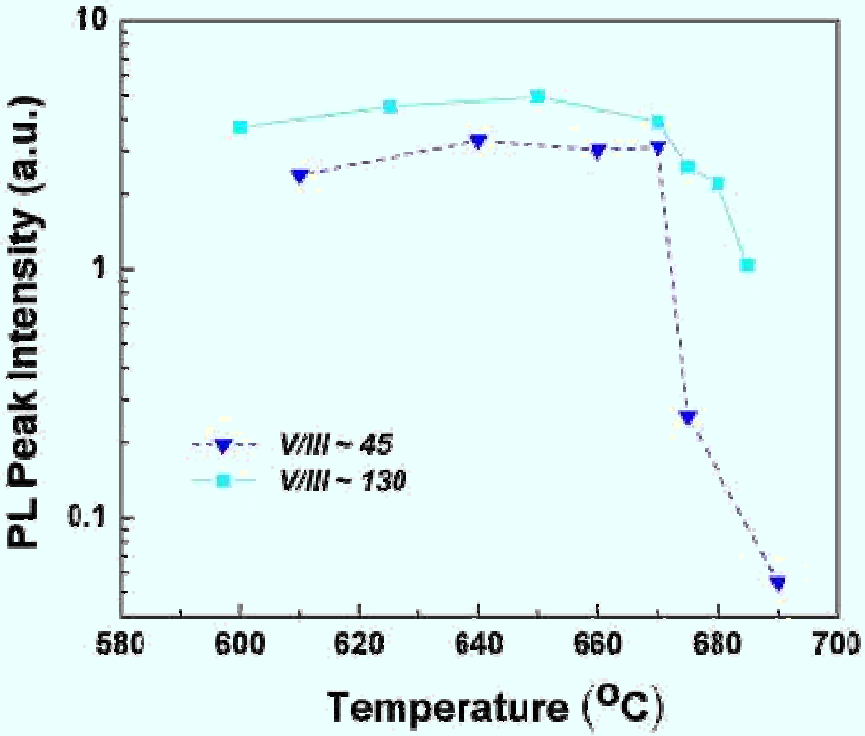
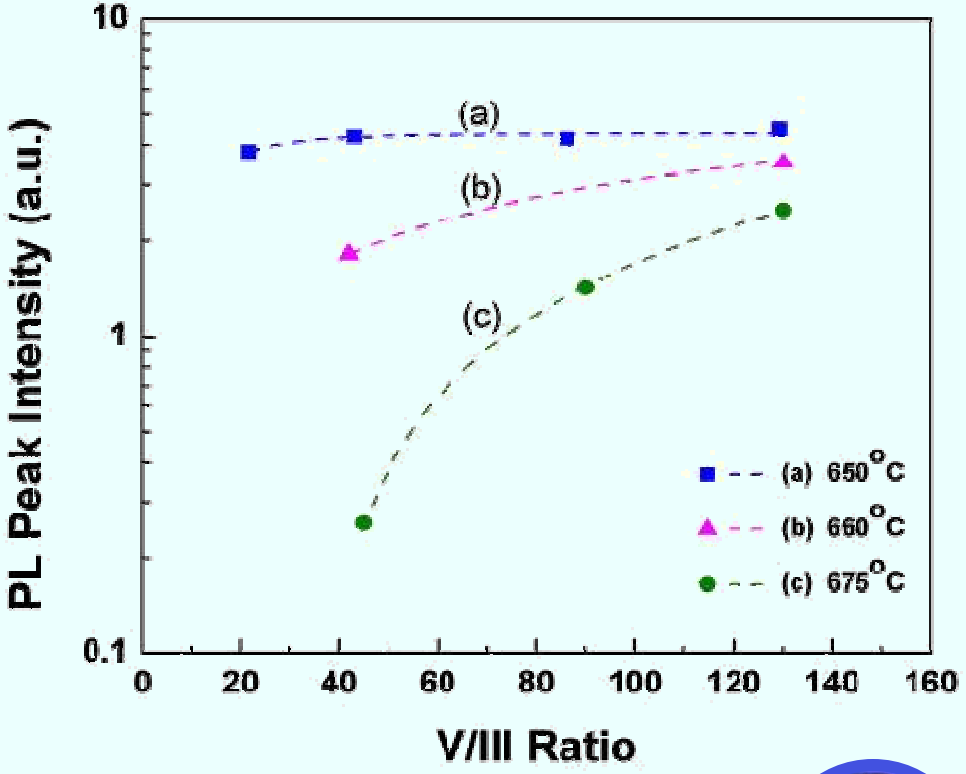
Optimization of InGaAs Epilayers

Effects of V/III Ratio and GrowthTemperature

- Low temperature is good for the growth of InGaAs.
- High temperature growth requires more AsH_3 to compensate the desorption loss of As from the surface.





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Optimization of InAlAs Epilayers

■V/III Ratio Effects:

Worse surface morphology produced at higher AsH_3

V/III ~ 60

V/III ~ 150

■Buffer Layer Effects:

InGaAs buffer layer can improve the InAlAs because of smooth growth front and less impurities.

Grown on InGaAs buffer layer

Grown on InP substrate

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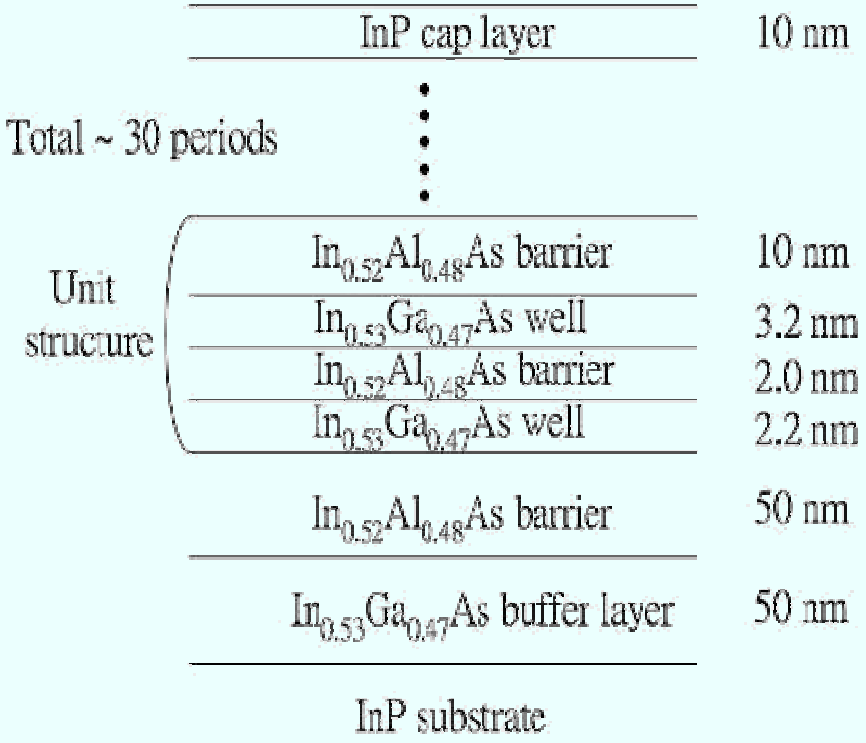
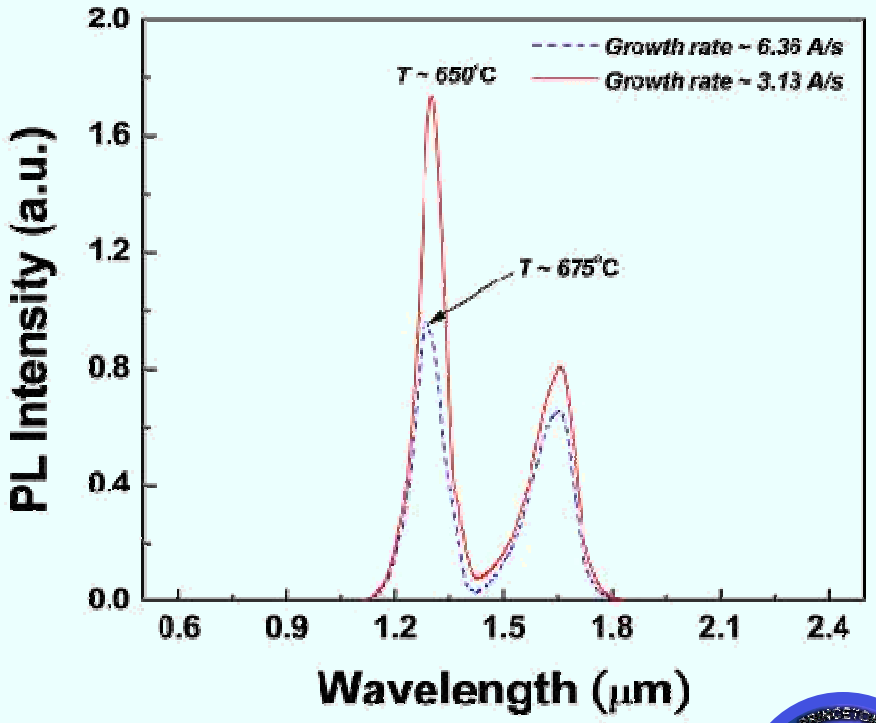
InGaAs/InAlAs Superlattices

Despite high growth temperature utilized to reduce the impurities, PL intensity is worse at higher growth rate which is necessarily used to avoid surface decomposition.





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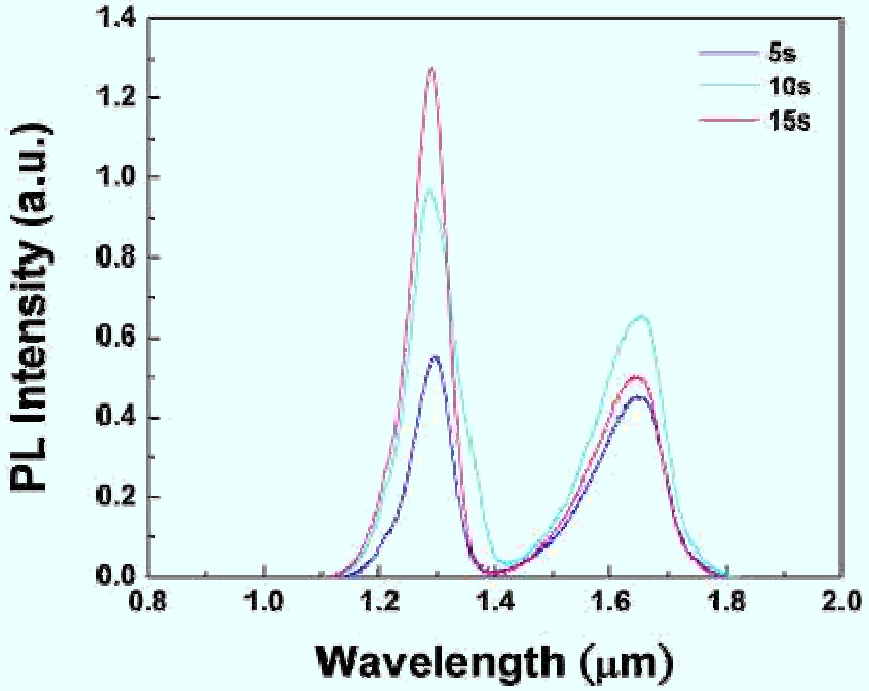
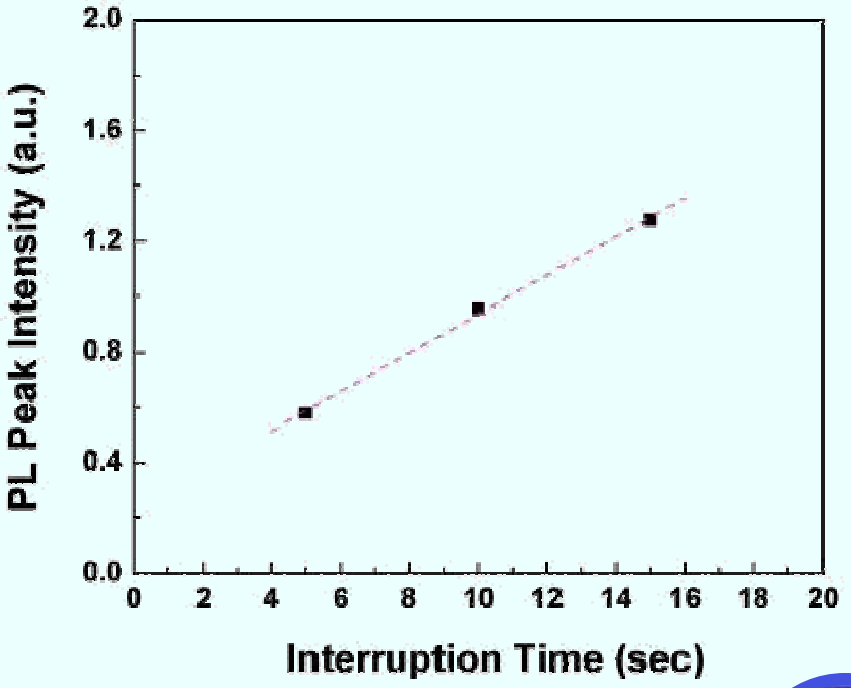
Interruption Effects

- To improve the interface quality at high growth temperatures and growth rates, effects of interruption periods between individual layers were investigated.
- Longer interruption by AsH_3 purging enhances the PL intensity.





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Summary

- To grow high-quality InGaAs films, high growth temperature is preferred to reduce impurities. However, the surface will decompose at higher temperature. To remedy this, high V/III ratio needs to be used for compensating the surface decomposition.

- To grow high-quality InAlAs films, the growth temperature has to be as high as possible. V/III ratio cannot be too low because the group V atoms will decompose; however, it cannot be too high since the Al atoms will be prohibited to migrate to their desired sites, which will affect the surface morphology.

- To grow high-quality InGaAs/InAlAs superlattice, high growth temperature is required (~ 660oC) and V/III ratio needs to be controlled during 50 ~ 150. By interrupting the growth process between individual layers with longer purging time, high-quality superlattices were obtained.

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