氮化銦奈米點之拉曼光譜和X-ray繞射和微螢光光譜應力分析

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中文摘要

本篇論文主要是利用微拉曼光譜（μ-Raman）、X-ray 繞射（X-ray diffraction）以及微螢光光譜（μ-PL）等實驗技術去研究有關 InN 奈米點（nano-dots）在不同的成長溫度和不同的奈米點高度的影響之下所承受的應變(strain)，以及對應相關的發光特性。

隨著不同奈米點(nano-dots)的高度，我們觀察到X-ray的繞射角(X-ray diffraction angle)以及拉曼散射(Raman scattering)的E_2 mode都有明顯的位移，因此推測當奈米點的高度越小時 InN 奈米點所承受到的應力(stress)越大，也藉由繞射角(diffraction angle)算出不同高度的奈米點(nano-dots)所承受的應變(strain)，與文獻上利用

穿隧式電子顯微鏡 (TEM)在相似高度InN奈米點所得到的應變結果相似。利用拉曼散射E_2 mode的位置，以及對應的X-ray 繞射結果，我們可以求出無應力(strain-free)時，InN E_2 mode 的頻率。

由於 InN 奈米點與緩衝層(buffer layer)的熱膨脹係數(thermal expansion coefficient)不一樣，所以從高溫冷卻到室溫的過程中會有殘餘的熱應變(residual thermal strain)，我們對不同的長晶溫度所殘餘的熱應變也作分析；成長的溫度越高所殘餘的熱應變越大，而對應的拉曼散射以及 X-ray 繞射結果都可以觀察到這個現象，所以我們也可以比較不同的長晶溫度以及不同的奈米點高度對於 InN 產生應變(strain)影響。

針對不同高度的奈米點在發光時所產生的藍移(blue shift)，我們用量子效應(quantum effect)以及應變效應(strain effect)所產生的藍位移來分析這現象，結果發現可以影響發光頻譜位置是由 InN 奈米點的量子效應和其所承受的應變合成之主要因素。

最後針對奈米點加上一層覆蓋層(capping layer)時所產生的應變作研究時，發現此覆蓋層會使得原本在奈米點與緩衝層(buffer layer)之間的應力增加，這樣的現象可以與拉曼散射以及 X-ray 繞射觀察到的結果互相吻合。

Strain analysis of InN nano-dots by Raman and X-ray and μ–PL measurements

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Abstract

In this thesis, we studied the strain and the optical properties of InN nano-dots with different dot height, which were grown at different temperature, by μ-Raman, μ-PL and X-ray diffraction measurements. The diffraction angle (2θ) and the Raman E_2 mode were observed to shift obviously with dot height. We found that the smaller InN dots experience the larger compressive stress in the a-b plane. The c-axis lattice constant can be calculated by X-ray diffraction angle (2θ), so that the strain along c-axis was calculated and compared with recent reports.

From the measured Raman E_2 and the calculated strain, we attempted to determine the strain-free frequencies of E_2 by interpolation. The

calculated strain results of both InN epilayer and dots are reasonable.

In addition to the intrinsic strain, the residual thermal strain cannot be neglected. The main cause for the residual thermal strain is the difference in the thermal expansion coefficient between film and substrate. Hence, we will analyze the effects due to intrinsic strain and thermal strain in our samples.

For the blue shift of μ–PL results, we checked the quantum confinement and strain effects and found that both effects are important in our samples.

Finally, we studied the GaN capping effect on InN dots. When the surface dots are covered by a cap layer, the compressive strain will be induced. Hence, the Raman shift increases that is consistent with X-ray diffraction results.