氮化物薄膜摻雜效應之特性研究

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摘　要

在本論文中，我們使用有機金屬化學氣相磊晶法來成長銦原子等價摻雜 *p* 型氮化鎵，並利用拉曼散射光譜、冷激光光譜、霍爾量測、掃瞄式電子顯微鏡、原子力顯微鏡等量測方法，來探討薄膜之光電物理特性。

在氮化鎵的摻鎂雜質之研究上，我們發現鎂雜質極容易融入氮化鎵薄膜且迅速達到高飽和濃度的狀態。在高摻雜樣品中，鎂原子的摻雜會引發晶格空缺、原子置換和空隙填擠等缺陷產生。同時也被認為是氮化鎵產生高補償 *p* 型效應的主要原因之一。實驗證據顯示，鎂原子的摻雜，雖然有助於氮化鎵材料電洞濃度的提昇，但稍有過量的摻雜卻易於造成晶體結構的破壞，導致大量缺陷的產生，反而不利於 *p* 型材料的製作。我們利用銦原子等價摻雜 *p*-GaN，在適度的銦原子摻雜下，經由掃描式電子顯微鏡的分析結果發現可有效的改善 *p*-GaN 薄膜的表面平整度，且樣品在經 700℃退火 40 分鐘，其電洞濃度可高達 9×10^{17} cm^{-3}，電阻也下降至 1 Ω-cm 的元件製備水準。在螢光光譜的量測上，發覺銦原子的加入可增強 3.1 eV 的躍遷，並進一步推測，銦原子摻雜 *p*-GaN 可有效的降低深層自我補償中心及淺層施子--氮空缺的缺陷密度，同時也可降低在長晶過程中利用氫氣當載流氣體及氨氣分解時融入薄膜中所造成的氫化效應，可進一步大大的提昇電洞的濃度。同

時藉由變溫螢光光譜對時間關係的量測，我們更得到一介於淺層受子能階(Mg_{Ga})游離至價帶間的能障 ~ 103 meV，相較於傳統 *p* 型氮化鎵 ~ 69 meV，可知銦原子的加入有助於淺層受子能階的電洞數增加並使得此能階的躍遷機率增加。

Characterizations of doping effects in nitride films

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Abstract

We have carried out systematic studies on epitaxial growth of d In isoelectronic doping p-GaN using metalorganic vapor phase epitaxy technique (MOVPE).

For the isoelectronic In-doping effects on Mg-doped GaN films, The preliminary results indicate that when In atoms are added, the surface morphology is greatly improved, and a virtually featureless structure can be obtained. properties, The Hall resulting optimum hole concentration and resistivity are 9×10^{17} cm^{-3} and 1 Ω-cm, respectively. Perhaps the most striking result is the observance of a linear I-V characteristic on the as-deposited sample, which indicates the good Hall properties associated with such types of film.

The Photoluminescence (PL) studies of In-doped GaN:Mg films revealed that the Mg-related emission at 3.1 eV is enhanced by more than one order of magnitude on the shoulder of the broad band centered at 2.8 eV for GaN:Mg after an optimal In concentration was added into the films. This enhancement of the 3.1 eV band is believed to be associated with the reduction in the number of self-compensation centers. A slow decay in PL intensity evolution was also observed, which may be ascribed to a local energy barrier that impedes carriers that relax into the valence band. The temperature dependences of the decay time constants were measured and a barrier

energy as high as ~ 103±7 meV was obtained for In-doped GaN:Mg as compared with 69±8 meV for GaN:Mg.