様式9

論文審査の結果の要旨

報告番号	甲　先　第　　　　号	氏　名	金（キム）　度（ド）　亨（ヒョン）
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学位論文題目

The research on p-type formation of AlGaN by Al_4C_3 and the application to light-emitting diodes
Al_4C_3によるp型AlGaN層の形成及び発光ダイオードの応用に対する研究

審査結果の要旨

本論文は，AlGaNのP型化を目指し，カーボン材料を新たな研究対象としたものである。まず，サファイア，SiC，Si基板上にAlC 1 μmを積み，その物性を調べた。その組成はAl_4C_3 になっており，サファイア，SiC，Siの上に成長出来るのは1000-1350 ℃程度の温度であった。光を感知し，空気中で酸化することを示した。AlC の拡散，分解のメカニズムが記述された。AlGaN にAlCを拡散あるいは分解でカーボンをAlGaNの中に入れることができ，それらはもともとはｎ型であったものがｐ型になっていた。さらに，サファイア上に400 nm のＬＥＤを形成し，カーボンがｐ型化材料になっている事を示した。さらに，従来からのｐ型化材料，Mgで形成したものと同程度のＶ－Ｉ特性であった。

以上本研究は，AlGaN のｐ型がカーボンでできることを示した論文であり，本論文は博士（工学）の学位授与に値するものと判定する。

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論 文 内 容 要 旨

報告番号	甲 先 第 **203** 号	氏 名	きむ ど ひょん 金 度 亨
学位論文題目	The research on p-type formation of AlGaN by Al_4C_3 and the application to light-emitting diodes Al_4C_3によるp型AlGaN層の形成及び発光ダイオードの応用に対する研究		

内容要旨

AlGaN material is used to fabricate a near-ultraviolet (300–350 nm) light-emitting diode (LED), but the maximum external quantum efficiency (EQE)is less than 8%. The reasons are AlGaN easily cracks and the p-type doping is low. The accepter magnesium (Mg) is difficult to use in x > 0.33 of $Al_xGa_{1-x}N$.

Recently, there is a report about carbon (C)-doping in AlGaN. Tetrabromomethane (CBr_4) was used as a C dopant. C-doped (0001) plane p-type $Al_xGa_{1-x}N$ ($0.06 \leqq x \leqq 0.55$) was reported and hole concentration (p) was in the range of (6-7) x 10^{18} cm^{-3}. A light-emitting diode (LED) structure C-doped $Al_{0.27}Ga_{0.73}N$/u-GaN/Si-doped $Al_{0.10}Ga_{0.90}N$ was also demonstrated.

Our research group studied aluminium carbide (Al_4C_3). C was detected in Al_4C_3 (0001)layer grown by metalorganic vapor phase epitaxy (MOVPE). Therefore, the research on p-type AlGaN with Al_4C_3 dopant was planned.

In this research, p-type doping characteristic of AlGaN with Al_4C_3 was confirmed by means of the diffusion and the doping methods. Also, the photo-induced current (PIC) of Al_4C_3 grown as a p-type dopant for AlGaN was reported.

At first, the growth experiment of Al_4C_3 was demonstrated by MOVPE.
Then, the growth rate, the crystallite and the optical conduction of Al_4C_3 were investigated. The hexagonal structure Al_4C_3 was confirmed by X-ray diffraction (XRD). The oxidation of Al_4C_3 layer was analyzed by energy dispersive X-ray (EDX) spectroscopy. Photo-induced current in Al_4C_3 was confirmed. As a result, it was sensitive to the near-ultraviolet wavelength. But, it was degraded with an increase time in air.

Al_4C_3 diffusion experiment in AlGaN was fulfilled at the low-pressure MOVPE. The experiment results were as follow. The conductivities of GaN and AlN with diffusion at 1000 °C were n-type and insulator. p- and n-type conductivities were detected in AlGaNwith diffusion experiment. The diffusion length of C was decreased by increasing in Al composition.
The calculated diffusion coefficient was the same tendency. Also, the diffusion length of Al_4C_3 was observed at the surface of AlGaN.

The Al_4C_3 doping experiment in AlGaN was accomplished by the manufacture of C-doped p-AlGaInN LED. It was clearly proven that u-$Al_{0.19}Ga_{0.81}N$ became p-$Al_{0.19}Ga_{0.81}N$. Manufactured LED device showed various electrical performances at a certain distance from the inserted Al_4C_3. The high concentration of C was founded at the edge of 2 inch substrate. Only edge of 2 inch grown wafer showed the electric performance of C-doped AlGaInN LED. The electroluminescence characteristic was almost the same as Mg-doped AlGaInN LED. In addition, the degraded Al_4C_3 layer was also investigated.