Means for Improving In Incorporation in the MOCVD Growth of InGaN

Field of the Invention

This invention relates the manufacture of semiconductor light-emitting devices. In particular, the invention is directed towards improving light extraction from such devices.

BACKGROUND OF THE INVENTION

Group III- nitride compounds have wavelength emissions in the green and blue range of visible light. Because single crystals of gallium nitride are difficult to grow, commercial GaN substrates are unavailable for the epitaxial growth of GaN-based devices. Currently, most GaN-based light emitting devices (LEDs) are epitaxially grown on a sapphire substrate. The difference in lattice constants between the sapphire substrate and the GaN-based semiconductors makes it difficult to grow a high quality GaN-based epitaxial layer on the sapphire substrate. Furthermore, a highly conductive p-type GaN semiconductor is nearly impossible to obtain due to combinations of high n-type background concentration and low p-type doping activity. Although the basic heterojunction device concepts have been well understood for many years, these difficulties stymied the development of efficient heterojunction lasers and LEDs emitting green or blue light using an AlGaInN material system.

During the late 1980s, a highly efficient GaN-based LED became a possibility when researchers discovered the importance of growing GaN or AlN buffer layers at low temperatures. Growing a buffer layer on a sapphire substrate at low temperatures improves the morphology of the subsequently grown GaN layer and reduces the n-type background concentration of the GaN materials. This coupled with post-growth thermal annealing or low energy electron beam irradiation

to activate the p-type dopants has made growing conductive p-type GaN easier. These technological advances have greatly accelerated the progress in device development of an AlGaInN material system for optoelectronics and other applications.

Due to the relatively high growth temperatures required for MOCVD growth for InGaN, two major problems arise. At high growth temperatures, re-evaporation of indium from the growing surface occurs. The indium incorporation in the solid decreases as the temperature increases. This problem can be reduced by providing a high vapor pressure of N_2. Secondly, premature trimethylindium decomposition can happen when the gas phase temperature is high. This can result in the formation of indium droplets on the substrate surface.

SUMMARY OF THE INVENTION

The invention uses N_2 as an ambient and/or alkyl carrier gas to provide a high N_2 vapor pressure and low gas phase temperature to promote the growth of InGaN. A low temperature grown GaN buffer layer is deposited on the sapphire substrate. A 1-4 μm Si-doped GaN is formed directly on the low temperature buffer layer. A 30Å InGaN layer is formed directly on the Si-doped GaN layer in a growth atmosphere containing nitrogen as the ambient gas and/or alkyl carrier gas. A comparatively thick Mg-doped GaN layer is formed over the InGaN layer.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a light emitting device having a quantum well structure.

Figure 2 illustrates a characterization structure for measuring indium composition in the quantum well.

Figure 3 illustrates a process flow chart corresponding to the device shown in Figure 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 illustrates a light emitting device 10 having a quantum well structure. A low temperature grown GaN buffer layer 12 is deposited on a sapphire substrate 14. A thick layer of Si-doped GaN 16 is formed directly on the low temperature buffer layer 12. A thin InGaN layer 18 is formed directly on the Si-doped GaN layer 16 in a growth atmosphere containing nitrogen as the ambient gas and/or alkyl carrier gas. A comparatively thick Mg-doped GaN layer 20 is formed over the InGaN layer 18.

Figure 2 illustrates a characterization structure for measuring the indium composition of the thin InGaN quantum well. The structure is the same as Figure 1 except the last layer 20' is undoped.

Figure 3 illustrates a process flow chart that for growing the device shown in Figure 1. In step 30, a 200 Å thick GaN layer is first formed directly on the c-face sapphire substrate at a temperature between 500 - 550C. In step 40, the Si-doped GaN layer is formed directly on the thick GaN layer at a growth temperature at approximately 1050C, while the thickness may vary between 1 μm, to 4μm. In step 50, the thin InGaN layer is formed directly on the Si-doped GaN layer at growth temperatures at approximately 800C, while the thickness is kept at about 30Å. Nitrogen is introduced into the growth atmosphere as ambient gas and/or alkyl carrier gas during the growth of the InGaN layer. In step 60, the comparatively thick Mg-doped GaN layer is formed over the InGaN layer.

These layers may be grown using one of many available techniques such as organometallic vapor phase epitaxy (OMVPE), metal-organic chemical vapor deposition (MOCVD), molecular beam epitaxy (MBE), gas source MBE (GSMBE), or hydride vapor phase epitaxy (HVPE). The InGaN layers may or may not have the same chemical composition (i.e., same x molar ratio).



CLAIMS

I claim:

1. A method for creating a light emitting device comprising the steps of:

growing a Si-doped GaN layer on a sapphire substrate (30,40);

growing a thin quantum well active layer of InGaN over the Si-doped GaN layer, in a growth atmosphere containing nitrogen (50); and

growing a Mg-doped p-type GaN layer over the thin quantum well active layer (60).

2. A method, as defined in claim 1, wherein the growth atmosphere includes nitrogen as a carrier gas.

3. A method, as defined in claim 1, wherein growth atmosphere includes nitrogen as the ambient gas.

4. A method, as defined in claim 3, wherein the growth atmosphere includes nitrogen as the carrier gas.