(54) Titre : DIODE GAN D’EMISSION LUMINEUSE AMELIOREE
(57) Abrégé/Abstract:
A GaN based LED comprises: a three layer buffer (11) which is a template for growth of a high quality GaN platform for quality growth of subsequent layers; a light emitting structure (12); and complementary N and P electrode structures (115, 113) which spread current flowing between the electrodes fully across the light emitting structure (12).
(54) Title: IMPROVED GAN LIGHT EMITTING DIODE

(57) Abstract: A GaN based LED comprises: a three layer buffer (11) which is a template for growth of a high quality I GaN platform for quality growth of subsequent layers; a light emitting structure (12); and complementary N and P electrode structures (115, 113) which spread current flowing between the electrodes fully across the light emitting structure (12).
Published:  
— with international search report

(88) Date of publication of the international search report:  
27 June 2002

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
TITLE
Improved GaN Light Emitting Diode

TECHNICAL FIELD
This invention relates to GaN compound Light Emitting Diodes.

BACKGROUND OF THE INVENTION
A semiconductor light-emitting diode (LED) comprises: a substrate; a light emitting structure; and a pair of electrodes for powering the diode. Light Emitting Diodes which are based on Gallium Nitride compounds generally comprise: a transparent, insulating substrate, e.g. a sapphire substrate. With an insulating substrate, both electrodes must be connected from the front of the LED to layers of the light emitting structure.

It is common practice to utilize a Ni/Au contact layer between the window layers formed on the light emitting structure and a thick Au bond pad. This arrangement exhibits limited adhesion; and the contact layer tends to peel during wire bonding to the Au bond pad.

The magnitude of the light emitted by an LED depends on: (a) The percent of the light emitting region that is activated by current flowing between the electrodes; (b) The efficiency of the window structure; and (c) The internal losses of generated light.

DISCLOSURE OF THE INVENTION
In accordance with one aspect of our present invention, we provide a window structure which comprises: a semi-transparent, conductive outer layer and a complementary pair of P and N electrodes. The conductive outer layer and the electrodes together efficiently spread current across the face of the light emitting diode and maximize the light emitting area of the window. Our P electrode is formed in the shape of a stylized letter T. The head of the T is a bar formed on the top face of the window along one side of the window face. The leg of the T comprises a bond pad attached at the middle of the head. Our N electrode
comprises a bond pad assembly which attaches to the N cladding layer through an aperture located at the middle of the side of the face opposite to the head of the T.

Our P electrode is formed of a layer of Ti which passes through the contact layer and provides excellent adhesion to window layers formed on the light emitting structure. An Au bond pad is formed on, and in the form of the Ti electrode. Thus peeling is avoided.

BRIEF DESCRIPTION OF THE DRAWING

Figs. 1a and 1b are schematic showings of the top and side views of an illustrative embodiment of our improved LED.

DETAILED DESCRIPTION

The illustrative LED of Figs. 1a and 1b is a GaN based device. The structure of Figs. 1a and 1b comprises: sapphire substrate 101; buffer structure 11; GaN substitute substrate layer 105; light emitting structure 12; window layers 13; semi transparent conductive layer 111; bond pad adhesion layer 112; P electrode bond pad 113; and N electrode bond pad 115 which is not shown in Fig. 1b.

Layers 102 through 110 are grown in a Metal Organic Chemical Vapor Deposition MOCVD reactor. The details of MOCVD growth of the stated layers are well known in the industry and will not be discussed herein except to specify certain details of the growth process which are particularly relevant to our success.

The remaining components of our improved LED, namely, semi transparent layer 111, adhesion pad 112, P bond pad 113, and N bond pad 115 are formed by evaporation in apparatus other than a MOCVD reactor.

Buffer (11) between sapphire substrate and GaN

In the illustrative embodiment of our improved GaN based LED, the 0001 face of sapphire substrate 101 is exposed for growth of our first buffer layer 102. Our second buffer Layer 103 is formed of AlGaN to migrate to the lattice constant of GaN. The final buffer layer 104 is formed of GaN to provide a template for the growth of our high quality I GaN layer 105 which serves as a platform for growth of our light emitting structure 12.
Light emitting structure (12)

Our light emitting structure comprises N cladding layer 106, active region 107, and P cladding layer 108. Layer 106 is formed of Silicon doped GaAs.

In the illustrative example of Fig. 1b, active region 107 is a Silicon doped N type GaInN/GaN Multi Quantum Well (MQW) structure.

P cladding layer 108 is formed of Mg doped AlGaN.

Window layers

The first window layer 109 is formed of Mg doped GaN. Layer 109 has a nominal thickness of 300 nm. The second window layer 110 is similarly formed of Mg doped GaN. However, layer 110 is more highly doped to permit an ohmic contact between that layer and NiOx/Au contact layer 111.

Completion of the MOCVD growth process

Growth of GaN layers is achieved with introduction of gaseous flows of Gallium with H₂ as a carrier gas, NH₃ as a group V material, and Mg as a dopant. In the absence of an appropriate cool down protocol, Hydrogen passivation of the Mg may occur. In which case, the conductivity of a Mg doped layer is reduced.

In order to avoid Hydrogen passivation of the Mg doped layers 108, 109 and 110, the following described cool down protocol has been adopted upon completion of the MOCVD growth.

1. The ambient gas of the reactor is switched from H₂ to N₂ immediately after completion of the LED structure;
2. The reactor temperature is ramped down from the growth temperature to about 900 degrees C in about 2 minutes;
3. The flow of NH₃ is terminated;
4. The reactor temperature is further ramped down to about 750 degrees C in about 2 minutes;
5. Temperature of about 750 degrees C is held for about 20 minutes;
6. The heater of the reactor is shut off and the reactor is allowed to complete cool down naturally. Experience shows that cool down to 120 C occurs in about 30 minutes after heater shut off.

The resulting product exhibits the expected desired physical and electrical...
characteristics.

**Formation of the electrode structures**

The top view of Fig. 1a and the side view of Fig. 1b together illustrate the locations and forms of both the P electrode 113 and of the N electrode 115.

Layer 111 is a thin, semi-transparent, conductive layer of NiO$_2$/Au which is deposited over the entire exposed face of layer 110. A first opening, identified as 114 in both figures, is etched through layers 111 to 107 to reach N cladding layer 106.

As seen in Fig. 1a, a second opening 116 is formed in layer 111 to permit deposit of a Titanium adhesion structure 112 to contact window layer 110. In addition to reaching through to layer 110, titanium structure 112 is deposited on NiO$_2$/Au layer 111 in the shape of the Au bond pad as illustrated in Fig. 1a. As seen in Fig. 1a, the top view of the Au bond pad forms a stylized “T”. The bar of the T is deposited as shown along left side of the figure, and the leg of the T is the semi-circular portion which joins that bar. The Au bond pad 113 is deposited on top of titanium structure 112.

Gold Bond pad 115 is deposited on N cladding layer 106 to form an ohmic contact therewith.

The combination of the T bar of the P electrode bond pad 113 along one side of the outer surface, the conductive NiO$_2$/Au layer 111, and the placement of the N electrode centrally along the opposite side of the outer face spreads current flowing between the electrodes evenly to more fully activate the light emitting region of MQW structure 107.

Since the Mg doped layers do not suffer from Hydrogen passivation, it is not necessary to heat treat the structure to activate the Mg doping in those layers. However, we do heat NiO$_2$/Au layer 111 and the Ti and Au contact structures in an atmosphere of molecular nitrogen and air. Thus the Ni is converted to a form of nickel oxide. We have found that this heat treatment improves the quality of the contact structures.

The invention has been described with particular attention to its preferred embodiment; however, it should be understood that variations and modifications
within the spirit and scope of the invention may occur to those skilled in the art to
which the invention pertains.
CLAIMS:

1. A GaN based Light Emitting Diode comprising:
   a substrate;
   a light emitting structure comprising an N cladding layer, an active region, and a
   P cladding layer;
   a window structure grown on said P cladding layer;
   an N electrode in ohmic contact with said N cladding layer; and
   a P electrode in ohmic contact with said P cladding layer, wherein:
   said window structure comprises a thin, transparent, conductive outer layer having
   an exposed surface with four sides; and
   a complementary pair of P and N electrodes formed along opposite sides of said
   exposed surface, wherein:
   said P electrode is formed on said exposed surface and has a T-shape when
   viewed from the top, with a head of the T-shape being a bar formed along one side of
   said exposed surface, and a leg of the T-shape being a semi circular portion which joins
   the bar; and
   said N electrode comprises a bond pad assembly formed on said N cladding layer
   through an aperture located at the middle of the side of the face opposite to said one side.

2. A GaN based Light Emitting Diode in accordance with claim 1 wherein:
   said conductive outer layer is a NiOx/Au layer.

3. A GaN based Light Emitting diode in accordance with claim 2 wherein:
   said P electrode comprises a layer of Ti formed on said conductive layer and a
   layer of Au in the same shape formed on said Ti layer.