(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 August 2007 (16.08.2007)

PCT

(10) International Publication Number
WO 2007/091920 A2

(51) International Patent Classification:
C30B 25/18 (2006.01) *H01L 33/00* (2006.01)
C30B 29/38 (2006.01)

(21) International Application Number: PCT/RU2007/000055

(22) International Filing Date: 6 February 2007 (06.02.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2006103270 6 February 2006 (06.02.2006) RU

(71) Applicant and
(72) Inventor: ABRAMOV, Vladimir Semenovich [RU/RU]; ul. 26 Bakinskikh Komissarov, 10-2-95, Moscow, 119526 (RU).

(72) Inventors: SOSHCHIN, Naum Petrovich; ul. Prospekt Mira 10-54, Fryazino, Moskovskaya obl., 114195 (RU). **SUSHKOV, Valeriy Petrovich**; ul. Onezhskaya, 45/19-123, Moscow, 125413 (RU). **SHCHERBAKOV, Nikolay Valentinovich**; ul. Shcherbakovskaya, 55-21, Moscow, 105058 (RU). **ALENKOV, Vladimir Vladimirovich**; ul. 8 Marta, 7-10, Podolsk, Moskovskaya obl., 142111 (RU). **SAKHAROV, Sergei Aleksandrovich**; ul. Brateevskaya, 27-1-25, Moscow, 115612 (RU). **GORBYLEV, Vladimir Aleksandrovich**; ul. Akademika Vinogradova, 8-75, Moscow, 117133 (RU).

(74) Agent: Agency of Intellectual Property Protection Ermakova, Stoliarova & Association; Petroverigsky per., 4, Moscow, 101990 (RU).

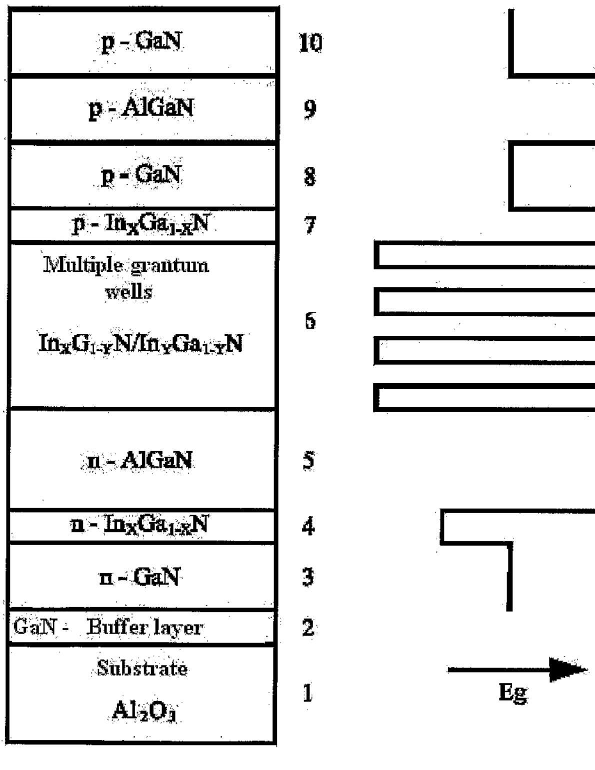
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH,

[Continued on next page]

(54) Title: A METHOD OF GROWING SEMICONDUCTOR HETEROSTRUCTURES BASED ON GALLIUM NITRIDE

(57) Abstract: The method of growing non-polar epitaxial heterostructures for light-emitting diodes producing white emission and lasers, on the basis of compounds and alloys in AlGaInN system, comprising the step of vapor-phase deposition of one or multiple heterostructures layers described by the formula $Al_xGa_{1-x}N(0< x \le 1)$, wherein the step of growing A^3N structures using (a)-langasite ($La_3Ga_5SiO_{14}$) substrates is applied for the purposes of reducing the density of defects and mechanical stresses in heterostructures.



WO 2007/091920 A2

GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report*

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.

A METHOD OF GROWING SEMICONDUCTOR HETEROSTRUCTURES BASED ON GALLIUM NITRIDE.

1. Field of the invention .

The invention is related to methods of manufacturing of semiconductor materials and devices, and more particularly, to manufacturing non-polar epitaxial heterostructures of third group elements nitrides (further A^3N structures) by Organometallic Vapor - Phase Epitaxy (further OMVPE) which are usually used for such devices, as lasers , light emitting diodes (LEDs), and particularly, white LEDs.

2. Description of the Related Art.

A^3N semiconductor heterostructures are basic materials for design and manufacture of high efficient light emitting diodes and lasers in visible and ultraviolet parts of optical spectrum of radiation, including white LEDs.

In the reference [1] use of converting dark blue and/or ultra-violet radiation of GaN-mis structures into longer wavelength radiation in visible part of spectrum with the help of covering these structures by stocks phosphors was offered for the first time.

In the reference [2] design of white light emitting diodes on the basis of dark blue p-n AlGaInN heterostructure emitters covered by Yttrium-Aluminum-Garnet phosphor has been offered. Part of the primary dark blue radiation of emitters is converted into yellow radiation of phosphor . As a result, mixing of blue radiation from an emitter and complementary yellow luminescence exited by the blue radiation in phosphor produce white light by LEDs with certain coordinates of chromaticity.

Three basic designs of white light-emitting diodes essentially differing from each other are known:

- light-emitting diodes on the basis of an emitter of dark blue color of luminescence which is covered by a layer of stocks phosphor converting a part of dark blue radiation into yellow radiation;

- light-emitting diodes on the basis of an emitter of ultraviolet radiation which is covered by a layer of stocks phosphor converting ultraviolet radiation into red, green and dark blue bands of luminescence (RGB system);

- full-color light-emitting diodes containing three separate emitters radiating in red, green and dark blue parts of spectrum (RGB system).

Despite of distinction, improvement of parameters of all listed types of white light-emitting diodes demands perfection of methods of epitaxial A^3N-heterostructures growth and increase of quantum output of radiation of phosphors.

For mass production of light emitting diodes the most preferable method of manufacturing A^3N-heterostructures is the method of Organometallic Vapor - Phase Epitaxy (OMVPE).

Sapphire (Al_2O_3), silicon carbide (6H-SiC), gallium nitride (GaN) and aluminum nitride (AlN) are used as substrates for A^3N epitaxial structures growth. Cheaper sapphire substrates are most of all used. Silicon carbide substrates in some times more expensive than sapphire ones and, therefore, are used not so often. Close to ideal there could be substrates made of GaN or AlN , but their mass production is not achieved yet.

Typical A^3N-heterostructures for light-emitting diodes contain following functional parts:

- a single crystal substrate of sapphire or silicon carbide which surface is crystallographic c-plane (0001) defining crystallographic type of A^3N epitaxial layers, for example, wurtzite type of their crystal structures and azimuthally orientation of crystallographic lattices;

•wide-bandgap emitters, as a rule, n-type and p-type $Al_XGa_{1-X}N$ layers providing effective injection of electrons and holes and their confinement in active region of the heterostructure;

•an active region containing, as a rule, a set of narrow-bandgap layers of such materials, as $In_XGa_{1-X}N$ alloys which are usually not specially doped;

•contact epitaxial GaN layers of n-type and p-type conductivity providing low specific resistance of ohmic contacts and uniform distribution of current density in a cross-section of a device.

In A^3N-epitaxial heterostructures used in various devices, in particular in light-emitting diodes and lasers, density of defects (dislocations, defects of packing, etc.) and also a level of mechanical stresses should be as low, as possible. For example, GaAs laser heterostructures usually have dislocation density not exceeding values of 10^2-10^3 cm^{-2}.

In A^3N- heterostructures basically exists two sources of defects, first of which concerns to a difference of lattice parameters of a substrate and A^3N epitaxial layers and second one concerns to a mismatch of lattice parameters of layers inside of a heterostructure , for example, between GaN and $Al_XGa_{1-X}N$ layers or between GaN and $In_XGa_{1-X}N$ layers. In the case of GaN or AlN substrates the contribution of the first defects source is decreasing and is comparable with the second defects source contribution.

A^3N single-crystal epitaxial layers which have wurtzite type of crystal structure: AlN (lattice parameter a=0,311 nm), GaN (a=0,316 nm) and InN (a=0,354 nm), grown on single-crystal Al_2O_3 substrates oriented in (0001)-plane (the oxygen sublattice parameter a=0,275 nm) or on 6H-SiC substrates (a=0,308 nm), always contain high density of defects, basically dislocations.

Dislocations are formed in interface “substrate – epitaxial layer” because there is an essential difference of lattice parameters of a substrate and a epitaxial layer. Lattice parameters of epitaxial layers are larger than a lattice parameter of a substrate (discrepancy up to 16 %) and dislocations will spread through heterostructure layers. In typical AlGalnN heterostructures used in blue and green light-emitting diodes, which have been grown on sapphire substrates, dislocation densities may have values 10^8-10^{10} cm^{-2}. For similar heterostructures grown on SiC substrates dislocation densities may have values $10^7 10^9$cm^{-2}. Thus, the contribution of the first source of defects is defined by a value 10^7-10^9cm^{-2}, the contribution of the second source of dislocations formation inside a heterostructure is equal to 10^6-10^7cm^{-2}. In particular, formation of high density of dislocations and even cracking AlGaN layers is caused by a difference of lattice parameters of GaN and AlN layers (discrepancy of 3,5 %) and by their differences in thermal expansion coefficient values.

For the partial solution of these problems can be used methods.In first of them before growing a AlGaN layer, for example, n –type emitter layer, a thin $In_{0.1}Ga_{0.9}N$ layer is grown (thickness about 0.1 microns) to prevent cracking a subsequent $Al_XGa_{1-X}N$ (x=0,15-0,20) layer. In the second method instead of a bulk $Al_XGa_{1-X}N$ n –type emitter layer with a constant x-value a strained multiquantum superlattice AlGaN/GaN layer is grown. The thickness of each layer in the superlattice is about 0.25 nm.

A very special feature of Organometallic Vapor - Phase Epitaxy for A^3N-heterostructures growth is necessity of abrupt changing temperature of substrates during a technological process. So, at growing a buffer layer (usually a very thin amorphous GaN or AlN layer) the temperature of sapphire or silicon carbide substrates is rapidly decreased from 1050^0C-1100^0C down to 550^0C and after finishing the amorphous GaN or AlN layer growth the substrate temperature is rapidly increased up to the temperature of growth of a single crystalline GaN layer(1050°C). If process of heating substrates with a buffer GaN or AlN layer is slow, it will lead to crystallization of a thin (about 20 nm) GaN layer and subsequent growing a thick GaN layer leads to formation of a nonplanar film which has great number of defects and figures of growth.

Another necessity of change of substrate temperature during growth is realized at growing $In_XGa_{1-X}N$ layers (at $x > 0.1$) in active region of the heterostructure. These layers have a tendency to thermal decomposition at temperatures above 850°C - 870°C. In this case growing $In_XGa_{1-X}N$ layers is completed at a lower (800^0C – 850^0C) temperature. During increasing the substrate temperature up to 1000^0C – 1050^0C the process of heterostructure growth should be interrupted by disconnecting submission of metalloorganic Ga, Al and In precursors to substrates. With the purpose to exclude thermal decomposition of $In_XGa_{1-X}N$ layers they are sometimes covered with a thin (~20 nm) protective $Al_{0,2}Ga_{0,8}N$ layer. This layer has sufficient stability to dissociation up to temperatures about 1050°C. Sharp change of temperature of a substrate with deposited epitaxial layers (except during a GaN or AlN buffer GaN layer growing) can lead to additional formation of defects and cracking grown layers , for example, AlGaN layers. Thus, it is desirable to have such methods of A^3N-heterostructures growth, in particular structures for super bright light-emitting diodes, which allow smooth change of growth temperatures and exlude interruptions of a growth process at $In_XGa_{1-X}N$ layers growing. These methods of growth have also to reduce density of dislocations generated in interfaces of A^3N heterostructure layers. Reduction of dislocations penetrating into a (0001) heterostructure grown on sapphire or silicon carbide substrates can be achieved by use of special techniques including lateral epitaxial overgrowth (LEO-technology). At first, in this technology a thin buffer GaN layer is usually grown at a low temperature. Then a SiO_2 or Si_3N_4 film is deposited on the structure surface. In this film narrow long parallel each other windows are etched down to the buffer layer and then, during the next epitaxy process, a thick GaN layer has been grown on SiO_2 or Si_3N_4 film surface at a high temperature. In the same process a A^3N heterostructure is also grown up. It is easy to see, that the LEO-technology is much more complex and more labour-consuming, than usual technology.

Theoretical and, partially, experimental investigations predict advantage of use non-polar *a*-plane (further $a\text{-}A^3N$) heterostructures in a lot of devices, in particular, in light-emitting diodes and lasers. In comparison with usual polar heterostructures grown along the polar *c*-direction [0001] in $a\text{-}A^3N$ non-polar heterostructures strong electrostatic fields along the direction of growth are absent. Owing to it, spatial separation of injected electrons and holes in the active region of non-polar *a-A3N* heterostructures is eliminated and, as consequence, increase of internal quantum efficiencies of radiation in light-emitting diodes and lasers made on their basis can be expected.

A lot of publications is devoted to growth of a-A^3N non-polar heterostructures. In the patent application [3] growth of *a*-GaN (1120) films on *r*-plane (1102) sapphire substrates is described. In the publication [4] advanced *a*-A^3N non-polar heterostructures grown on *a*-GaN substrates are proposed by Sh. Nakamura.

At last, in the patent application [3] the opportunities of *a*-A^3N non-polar heterostructures growth on silicon carbide, silicon, zinc oxide, lithium aluminates, lithium niobate and germanium substrates are mentioned.

Thus, *a*-A^3N non-polar heterostructures growth providing low dislocations and structural defects densities is rather actual direction of technology developments to solve problems of increasing internal quantum efficiencies of light-emitting diodes and lasers and their life-times.

The brief description of the invention.

The subject of this invention is a new method of growing non-polar a-A^3N epitaxial homo- and/or heterostructures on the basis compounds and alloys in AlInGaN system on which have low dislocations and structural defects densities in layers on LANGASITE (*a*-$La_3Ga_5SiO_{14}$) substrates instead substrates made of other known materials to use these A^3N- structures in design and manufacturing light- emitting diodes and lasers. The properties of A^3N materials and langasite are presented in Table1.

According to the first aspect of the invention a method of growth in which for decreasing dislocations density at the interface "the first epitaxial $Al_XGa_{1-X}N$ layer - the substrate" and in other functional layers of light-emitting heterostructure *a*-langasite substrate is used. Mismatch of *c*- lattice parameters of the substrate and the first epitaxial $Al_XGa_{1-X}N$ layer is no more, than within the limits from -2.3 % at x=1 up to +1.7 % at x=0, and mismatch of their thermal expansion coefficients in the direction along the *c*-axis is no more, than within the limits from +46 % at x=1 up to-15 % at x=0. Thus, there are particular x-values at which mismatch of *c*- lattice parameters of the substrate and the first epitaxial $Al_XGa_{1-X}N$ layer and mismatch of their thermal expansion coefficients in the direction along the *c*-axis are absent (Table 1).

In conformity with the second aspect of the invention, for manufacturing a "white color heterostructure with built-in phosphor" the langasite substrate is doped by special impurities to convert part of the primary dark blue radiation of the A^3N heterostructure (λ_{MAX}=455nm) into yellow radiation of the substrate, thus the substrate structure corresponds to formula $La_{3-x-y}Ce_xPr_yGa_5SiO_{14}$.

According to the third aspect of the invention, a topology of the langasite substrate and a design of the emitter chip are offered, at that all dark blue radiation of heterostructure is directed into the substrate to increase radiation power and to achieve uniform spatial distribution of color temperature of white radiation.

Table1.

Physical properties	A^3N type nitrides				Langasite
	AlN	GaN	InN	$Al_{0.44}Ga_{0.56}N$	$La_3Ga_5SiO_{14}$
Crystal structure	wurtzite	wurtzite	wurtzite	wurtzite	Trigonal group P321
Lattice constant *a*, Å (direction perpendicular to *c-axis*)	3.112	3.189	3.548	3.155	8.173
Lattice constant *c*, Å (direction parallel to *c-axis*)	4.982	5.185	5.760	5.099	5.099

Ratio of lattice constants $c_{A3N}/c_{La3Ga5SiO14}$	0.977 (-2.3%)	1.017 (+1.7%)	1.130 (+13%)	1.00 (0%)	-
Thermal expansion $(\Delta c/c)$,K^{-1} (direction parallel to *c-axis*)	5.3×10^{-6}	3.17×10^{-6}	3.0×10^{-6}	4.11×10^{-6}	3.56×10^{-6}
Thermal expansion $(\Delta a/a)$,K^{-1} (direction perpendicular to *c-axis*)	4.2×10^{-6}	5.59×10^{-6}	4.0×10^{-6}	4.98×10^{-6}	5.11×10^{-6}
Ratio of thermal expansion coefficients $(\Delta c/c)_{A3N}$ / $(\Delta c/c)_{La3Ga5SiO14}$ (direction parallel to *c-axis*)	1.49 (+49%)	0.89 (-11%)	0.84 (-16%)	1.15 (+15%)	-

The brief description of drawings.

The drawings included in this application provide detailed description of advantages of the invention and help to understand its essence. Similar reference numbers represent corresponding parts throughout.

Figure 1 is a drawing of a polar light-emitting A^3N-heterostructure grown by a usual method of epitaxy –prototype [2].

Figure 2 is a drawing of a non-polar light-emitting A^3N-heterostructure grown on a langasit substrate.

Figure 3 is a schematic view of a light-emitting heterostructure on a langasite substrate with an additional Ce- and Pr-doped langasite layer grown on the surface of the A^3N-heterostructure.

Figure 4 represents an emission spectrum produced by the light-emitting diode on the Ce- and Pr-doped langasite substrate.

Detailed description of the invention.

The present invention is described below with references to drawings.

Figure1 representes a typical light-emitting diode heterostructure and changing bandgap energy in heterostructure layers corresponding to prototypes; U.S. Patent 5,290, 393 3/1994, Nakamura; U.S. Patent 5,993,542 1 1/1999, Yanashima; U.S. Patent 5,909,036 6/1999 Tanakana. This heterostructure contains an additional n-$In_XGa_{1-X}N$ layer (4) grown to prevent cracking a following n-AlGaN (5) emitter layer which is grown before a multiple quantum wells $In_XGa_{1-X}N/In_YGa_{1-Y}N$ active layer (6).

Figure 2 represents a light-emitting diode heterostructure, grown on a langasit substrate. A profile of changing bandgap energy in different heterostructure layers is also shown. Unlike the structure represented in Figure 1 in the offered structure the n-$In_XGa_{1-X}N$ layer (4) and the p-GaN layer (8) are not grown. The p-GaN layer (8) is a wave guiding layer which is most effectively used in laser diodes, not in light-emitting diodes. For growth of a light-emitting diode heterostructure a langasit substrate (1) having the *a*-plane orientation and perfect surface treatment (Ra <0,5nm) is loaded into a reactor of an OMVPE apparatus in very clean nitrogen atmosphere conditions. After blowing through the reactor by pure nitrogen hydrogen pressure in the reactor decreases to an operating level nearby 70Torr . Then the graphite susceptor with the substrate are heated up to 1050°C. After heating during 15min at hydrogen flow rate of 15litre/min ammonia with flow rate of 5litre/min is supplied into the reactor. In this condition the process is sustained for 5 minutes. After that high-frequency heating power is decreased and within 6 minutes the temperature of the susceptor is stabilized at the level 530°C.

Then, to grow up a GaN buffer layer (2) trimethylgallium (TMG), as the source gas, with flow rate of $4*10^{-5}$ mol/min is supplied through separate injection nozzle into the reactor for 50 seconds. As a result, the GaN buffer layer with thickness of 15 nm is grown. After that, the susceptor temperature is very rapidly risen up to 1030°C and TMG with silane (SiH_4) used as a donor impurity source is supplied into the reactor with flow rate of $7*10^{-5}$mol/min. The TMG+SiH_4 gas mixture has flow rate of experimentally selected value to have a doping level of the GaN layer about $2*10^{18}cm^{-3}$. The GaN layer (3) with thickness about 3.2 microns grows for 35 minutes . Then the trimethylaluminum (TMAl) is supplied as a source gas, and its flow rate linearly increases from 0 to $1*10^{-5}$mol/min during 5 minutes. As a result, the n-$Al_xGa_{1-x}N$ ($x<0.15$) (5) layer with thickness of 0.5 microns and with a gradient of aluminum content is grown. After that, supplying TMG, TMAl and SiH_4 is stopped, the susceptor temperature has been very rapidly reduced down to 860°C during 5 minutes. Now, submission of TMG and trimethylindium (TMI) is switched on and growth of $In_xGa_{1-x}N/In_yGa_{1-y}N$ layers (6) forming a multiply quantum wells structure occurs by periodically switching TMI flow rates between $7*10^{-6}$ mol/min and $3*10^{-5}$mol/min. Duration of TMI submission with the higher flow rate takes of 3 seconds and with the lower flow rate of 16 seconds. Then the susceptor temperature rises up to 1030°C during 5 minutes and TMG + TMAL flows are supplied into the reactor again. During growth of AlGaN (9) and GaN (10) layers bis(cyclopentadienyl)magnesium (Cp_2Mg) as a source of acceptor impurity is supplied into the reactor. The Cp_2Mg flow rate must be high enough to obtain the acceptor concentration of the order $3*10^{18}cm^{-3}$ for providing low specific resistance of the p-GaN contact layer (10).

In Figure 3 a design of an emitter for an white light-emitting diode is represented. The emitter consists of a heterostructure radiating in dark blue part of spectrum whose layers (2)-(10), according to the invention, are grown on *a*-langasite substrate by selective OMVPE epitaxy. The langasite composition is described by formula $La_{3-x-y}Ce_xPr_yGa_5SiO_{14}$. There are specially prepared recesses in the substrate for selective heterostructure epitaxy.Before the final operation of separating a wafer into chips there are made a number of technological operations: photolithography, removal of layers (6), (9) and (10) from part of the selectively grown heterostructure by etching, deposition of the reflecting coating (11) consisting of thin layers of nickel and gold, and deposition of the ohmic contact (12) layer consisting of the tin-gold alloy which is needed for the subsequent mounting the emitter on the base of a light-emitting diode. Absorption of the dark blue radiation of the heterostructure excites yellow photoluminescence in the substrate, caused by presence of Ce and Pr in langasite. Effective transformation of part of dark blue radiation into yellow is provided with absence of air interlayer between the selectively grown heterostructure and langasite surrounding it from the all directions . As a result, due to mixture of dark blue and yellow radiation the emitter generates white light.

In Figure 4 a typical design of a white light-emitting diode (prototype) is represented in which a dark blue color emitter (13) is used covered by usual Yttrium-Aluminum-Garnet phosphor (14).

Industrial applicability

A^3N-heterostructures on *a*-plane langasite substrates grown by the method proposed in the invention have lower density of defects than structures by usual methods and have no microcracks. The dislocation density in heterostructures represented in the Figure 2 may have values less than $5*10^7 cm^{-2}$. Emitters have white color of light with chromatic coordinates X=0.31, Y=0.31.

[1] SU № 635813, 07. 08. 1978.

[2] US № 5998925, 07. 12. 1999.

[3] M. Craven at el, Dislocation reduction in non-polar gallium nitride thin films, PCT/US03/11177, 15.04.2003.

[4] Sh. Nakamura, Growth and device strategies for AlGaN-based UV emitters, UCSB,2004.

CLAIMS

1. A method of growing non-polar epitaxial heterostructures for light-emitting diodes producing white emission and lasers, on the basis of compounds and alloys in AlGaInN system, comprising the step of vapor-phase deposition of one or multiple heterostructures layers described by the formula $Al_xGa_{1-x}N(0< x \leq 1)$, wherein the step of growing A^3N structures using (a)-langasite ($La_3Ga_5SiO_{14}$) substrates is applied for the purposes of reducing the density of defects and mechanical stresses in heterostructures.

2 The method of claim 1, wherein as substrates for growing A^3N structures $La_{3-x-y}Ce_xPr_yGa_5SiO_{14}$ (x=0,1÷3%, y=0,01÷1%) langasite substrates are used, that allows to transform a part of dark blue radiation of the heterostructure into a yellow photoluminescence of the substrate.

3. The method of claim 1, wherein as substrates for growing non-polar A^3N structures for monochromatic green and ultraviolet radiation devices *a*-plane langasite substrates are used.

4. The method of claim 1, wherein as substrates for growing non-polar A^3N structures for transformation of ultraviolet radiatioh into visible radiation, including white light, *a*-plane langasite ($La_3Ga_5SiO_{14}$) substrates doped by suitable phosphors are used.

5. The method of claim 1, wherein the thickness of the langasite substrate does not exceed 80 microns.

6. The method of claim 1, wherein Ce-doped and Pr-doped langasite buffer layers deposited on the materials of the group comprising any of Si, Al_2O_3, Ge or similar materials, are used as substrates.

7. The method of claim 1, wherein the step of growing A^3N structures is followed by the step of growing an additional phosphor langasite layer on the surface of A^3N.

8. The method of claim 1, wherein the thickness of the grown langasite layer does not exceed 3 microns.

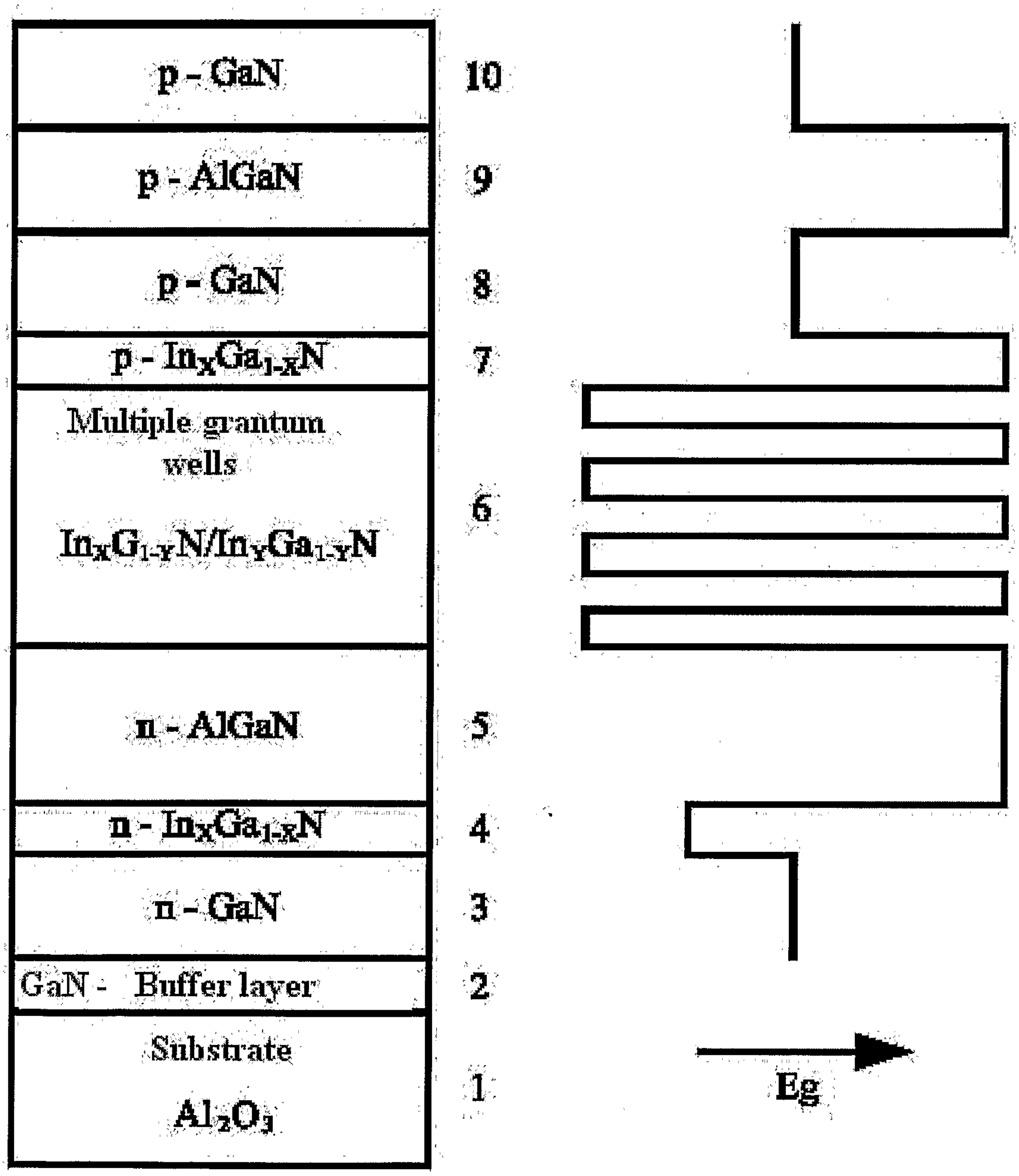

p - GaN
10
p - AlGaN
9
p - GaN
8
p - $In_XGa_{1-X}N$
7
Multiple grantum wells
$In_XG_{1-Y}N/In_YGa_{1-Y}N$
6
n - AlGaN
5
n - $In_XGa_{1-X}N$
4
n - GaN
3
GaN - Buffer layer
2
Substrate
Al_2O_3
1
Eg

Fig.1

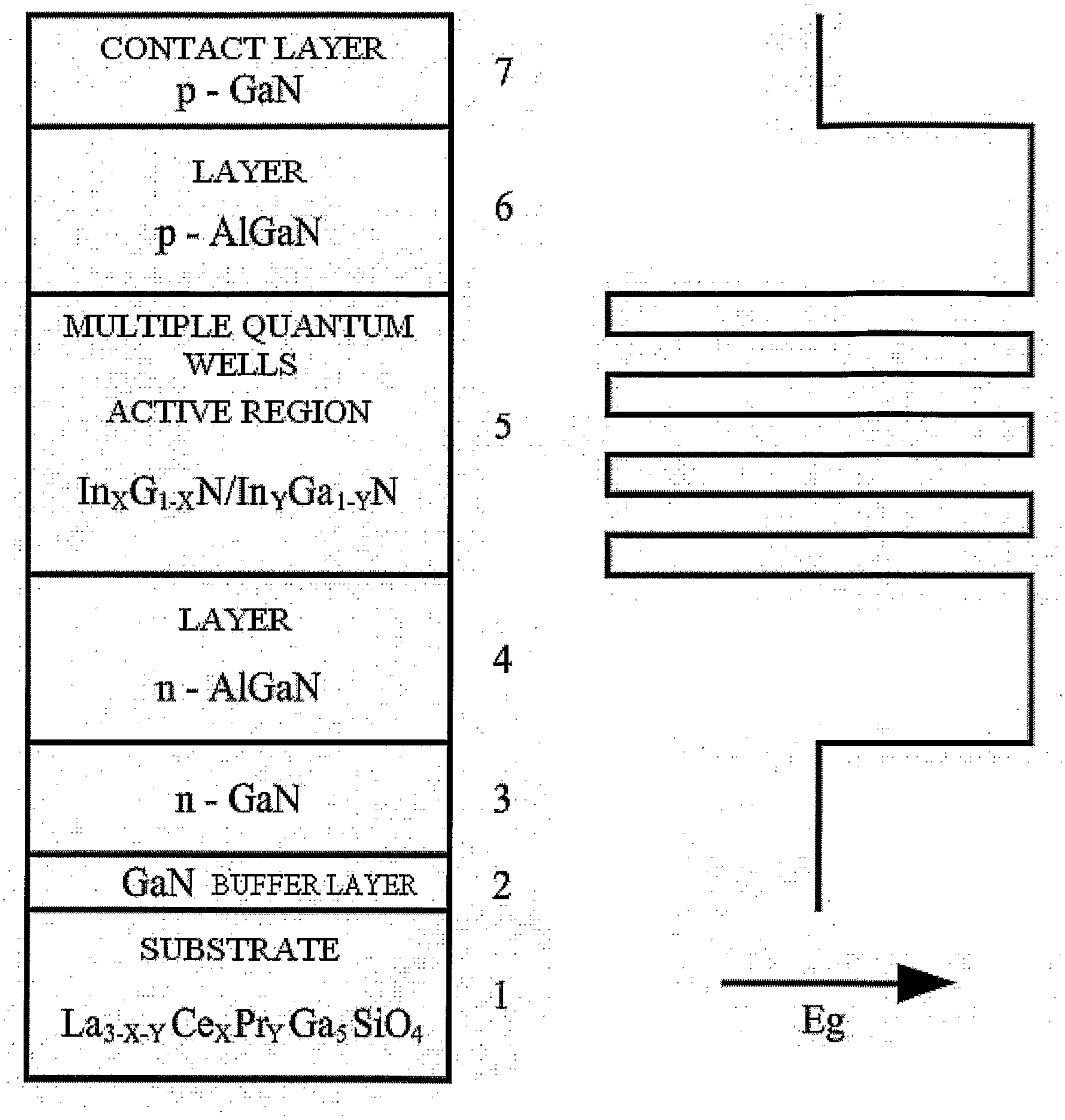

CONTACT LAYER
p - GaN
7
LAYER
p - AlGaN
6
MULTIPLE QUANTUM WELLS
ACTIVE REGION
$In_XG_{1-X}N/In_YGa_{1-Y}N$
5
LAYER
n - AlGaN
4
n - GaN
3
GaN BUFFER LAYER
2
SUBSTRATE
$La_{3-X-Y}Ce_XPr_YGa_5SiO_4$
1
Eg

Fig. 2

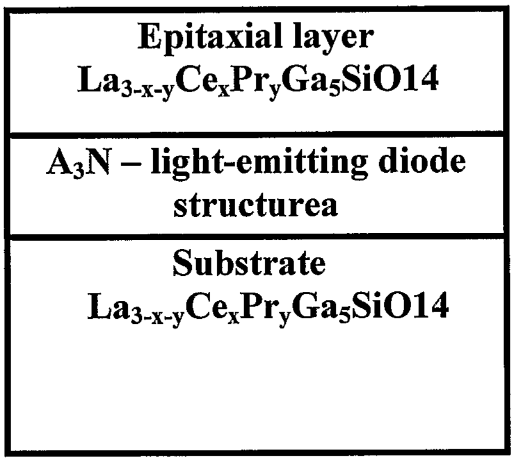

Epitaxial layer
$La_{3-x-y}Ce_xPr_yGa_5SiO14$
A_3N – light-emitting diode structurea
Substrate
$La_{3-x-y}Ce_xPr_yGa_5SiO14$

Fig.3

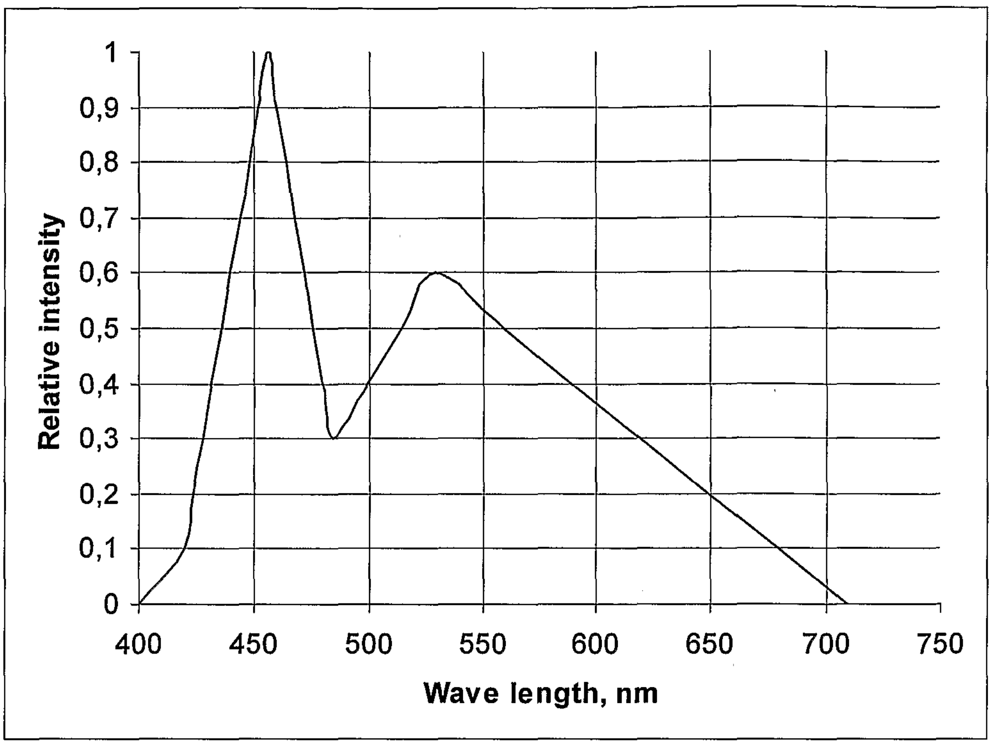

Relative intensity
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
400
450
500
550
600
650
700
750
Wave length, nm

Fig.4