

ЗАВИСИМОСТЬ СПЕКТРОВ И ЭФФЕКТИВНОСТИ СВЕТОДИОДОВ БЕЛОГО СВЕЧЕНИЯ НА ОСНОВЕ ГЕТЕРОСТРУКТУР ТИПА InGaN/AlGaN/GaN, ПОКРЫТЫХ РАЗЛИЧНЫМИ ЛЮМИНОФОРАМИ, ОТ ТЕМПЕРАТУРЫ

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Исследования зависимости спектров электролюминесценции и эффективности светодиодов белого свечения от температуры нагрева T необходимы для понимания относительной роли свойств светодиодов синего свечения, возбуждающих люминофоры, и свойств разных люминофоров [1, 2], а также их взаимодействия. Зависимость свойств светодиодов от температуры T также связана с нагревом светодиодов при больших токах. Это связано с важнейшей проблемой падения квантового выхода излучения с увеличением тока.

Исследовались светодиоды белого свечения ИРС-50 с кристаллами МК-24 на кремниевых подкристалльных платах. Корпус светодиодов изготовлен из дюралюминия Д-16, линза – из оптического поликарбоната. Полость линзы заполнена силиконовым гелем SilGel 612. В качестве компаунда люминофорной смеси использован силикон LS-6257. Была выбрана серия светодиодов на основе кристаллов синего свечения [3] со следующими слоями гетероструктуры: n-GaN – 4 мкм; 10 периодов буферной сверхрешетки InGaN/GaN – 0,1 мкм; 8 периодов активной области – ~0,5 мкм (барьер/яма – 1/2); 2 периода нелегированной сверхрешетки u-AlGaN/u-GaN; слой p-GaN – ~0,1 мкм. Образцы различались двумя люминофорами с одинаковой длиной волны возбуждения (≈ 460 нм): фирмы Intematix, Y4750 [(SrBaMg₂)₂SiO₄:Eu²⁺] и НИИ «Платан», ФЛЖ-21 [(Gd_xY_{1-x})₃Al₅O₁₂:Ce³⁺].

Регистрация спектров проводилась при комнатной температуре в диапазоне токов 1 – 350 мА. Спектральное разрешение не хуже 0,1 нм.

Показано, что различие спектров светодиодов белого свечения с разными люминофорами (Y4750 и ФЛЖ-21) обусловлено как свойствами самих люминофоров (спектр ФЛЖ-21 неоднородно уширен в длинноволновую сторону), так и разным поглощением излучения синей линии кристаллов этими люминофорами: люминофор ФЛЖ-21 сильнее поглощает синее излучение, что приводит к увеличению показателя коротковолнового спада синей линии.

Интегральная интенсивность излучения светодиодов белого свечения уменьшается с увеличением температуры в интервале от 0 до +60 °С приблизительно с коэффициентом 0,55 – 0,33 %/°С. Большая часть падения интенсивности обусловлена падением интенсивности излучения люминофора. Пик интенсивности светодиода, соответствующий излучению люминофора, смещается на 1 – 2 нм.

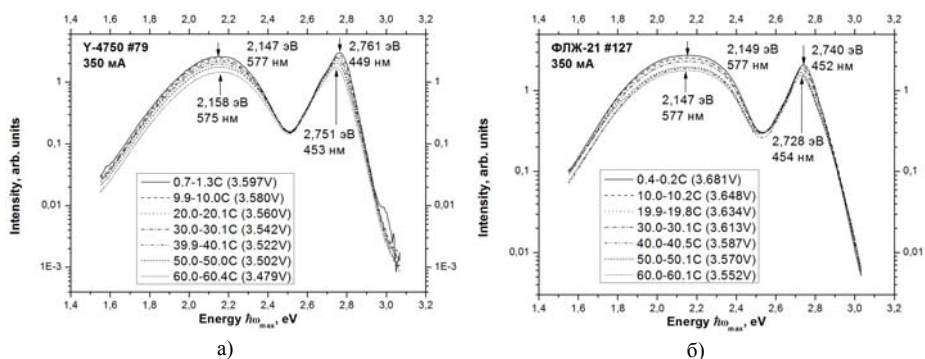


Рис. 1. Спектры электролюминесценции светодиодов с люминофором: а) Intematix Y4750 (SrBaMg₂)₂SiO₄:Eu²⁺; б) НИИ «Платан» ФЛЖ-21 (Gd_xY_{1-x})₃Al₅O₁₂:Ce³⁺ при изменении температуры.

Форма синей линии в кристалле существенно меняется, как с длинноволновой (со стороны люминофора), так и с коротковолновой стороны. Знаменатель в показателе экспоненциального спада коротковолновой части пропорционален температуре $E_1 = m \cdot kT$, но величина коэффициента m существенно больше единицы, $m = 2,2 \div 9,0$. Это можно объяснить влиянием поглощения излучения кристалла люминофором.

При малых токах < 4 мА преобладает падение напряжения на параллельном сопротивлении светодиода R_{Π} и вольтамперные характеристики на этом участке линейны. Значение параллельного сопротивления увеличивается с ростом T и не зависит от типа люминофора. С увеличением T КПД и световая отдача в области максимума зависимости КПД от тока уменьшается на 2,5% для светодиодов с люминофором Y4750 и на 8% для светодиодов с люминофором ФЛЖ-21.

Показано, что с увеличением T координаты цветности светодиодов белого свечения сдвигаются в область холодного свечения $(0,374; 0,39) - (0,357; 0,345)$ вследствие уменьшения относительной доли излучения люминофора. Соответственно сдвигается коррелированная цветовая температура 4070 – 4506.

Светодиоды с люминофором Y4750 лучше для цветового восприятия человеческим глазом, в то время как светодиоды с люминофором ФЛЖ-21 имеют большие индексы цветопередачи и цветовую температуру. Повышение T приводит к сдвигу коррелированной цветовой температуры вследствие падения относительной роли люминофора.

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DEPENDENCE OF SPECTRA AND EFFICIENCY OF WHITE LIGHT-EMITTING DIODES BASED ON InGaN/AlGaIn/GaN HETEROSTRUCTURES COVERED BY VARIOUS PHOSPHORS ON TEMPERATURE

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Researching dependence of electroluminescence spectra and efficiency of white light-emitting diodes on heating temperature are necessary for understanding a relative role of blue light-emitting diodes properties exciting phosphors and properties of different phosphors and also their interactions. White light-emitting diodes based on identical blue-emitting crystals covered by two various phosphors [(SrBaMg₂)₂SiO₄:Eu²⁺, (Gd_xY_{1-x})₃Al₅O₁₂:Ce³⁺] with identical excitation wavelength (≈ 460 nm) were investigated. Spectra distinction of white light-emitting diodes with different phosphors is caused both phosphors properties (spectra FLJ-21 is inhomogeneously broadened to the long-wave side) and different absorption of blue-emitting crystals by these phosphors: phosphor FLJ-21 absorbs blue-emitting more strongly that leads to increasing short-wave decay index of blue line. Radiation intensity of white light-emitting diodes decreases with increasing temperature from 0 to +60 °C with factor 0,55 – 0,33 %/ °C. Temperature increasing leads to efficiency droop and also to shift of tristimulus values to cold luminescence region.

Research and development of structures and devices based on nitride semiconductors in Russia and in the world during last years <u>A.E. Yunovich</u>	12
Modeling of III-nitride materials technology: from bulk growth to device characteristics <u>R.A. Talalaev</u>	14
Optimization of III-N heterostructures growth by MOVPE via surface processes control <u>W.V. Lundin</u> , E.E. Zavarin, M.A. Sinit syn, A.E. Nikolaev, A.V.Sakharov, A.F. Tsatsulnikov, E.V. Yakovlev, R.A. Talalaev, A.V. Lobanova, A.S. Segal	15
Porous structure on GaN-sapphire interface improving LED light extraction efficiency <u>A.S. Pavluchenko</u> , D.A. Zakheim, D.A. Bauman	19
Effect of the growth conditions and reactor height on the AlGaIn growth rate and composition <u>E.V. Yakovlev</u> , A.V. Lobanova, J. Stellmach, Ö. Savaş, J. Schlegel, M. Pristovsek, M. Kneissl	21
3" 6H SiC wafers production for III-N epitaxy <u>Yu.N. Makarov</u> , D.P.Litvin, A.V. Vasiliev, A.S. Segal, S.S. Nagalyuk, H. Helava, M.I. Voronova, K.D. Scherbachov	23
Manufacture of aluminum nitride substrates <u>T.Yu. Chemekova</u> , O.V. Avdeev, S.S. Nagalyuk, E.N. Mokhov, Yu.N. Makarov	25
Sublimation growth of AlN crystals on SiC substrates <u>E.N.Mokhov</u>	27
Millimeter thickness range GaN layers grown by HVPE <u>A.S. Zubrilov</u> , Y.S. Lelikov, R.I. Gorbunov, N.I. Bochkareva, V.V. Voronenkov, Ph.E.Latyshev, Y.T. Rebane, A.I. Tsuk, Y.G. Shreter	29
Alloy components and impurities incorporation efficiency and defect formation during growth of III-N materials in the direction different from [0001] <u>A.Y.Polyakov</u> , A.V. Govorkov, N.B. Smirnov, H.Amano, S.J. Pearton, I-H. Lee, J. Hun, E.B. Yakimov, K.S. Zhuravlev, S.Yu. Karpov	31
Polarization of pl emission of nonpolar GaN layers and InGaIn/GaN MQW structures grown on LiAlO ₂ substrates <u>E. V. Lutsenko</u> , M. V. Rzhetski, V. N. Pavlovskii, G. P. Yablonskii, C. Mauder, H. Kalisch, M. Heuken, R. H. Jansen	35
Many-body effects in photoluminescence of GaN/AlN low-dimensional structures I.A. Aleksandrov, <u>K.S. Zhuravlev</u>	37
Diversity in nanostructural arrangement – source of problems in III-N device physics understanding A.A.Greshnov, A.L. Zakgeim, A.E. Chernyakov, E.I. Shabunina, <u>N.M.Shmidt</u> , E.B. Yakimov	39
Bridge over the “green valley”. Towards RGB white light source <u>A.F.Tsatsulnikov</u> , W.V.Lundin, A.V.Sakharov, E.E.Zavarin, S.O.Usov, A.E. Nikolaev, N.V.Kryzhanovskaya, M.A. Synitsin, V.S. Sizov, N.A. Cherkashin, A.E.Chernyakov, A.L.Zakgeim, M.N. Mizerov	41
Blue light emitting diode with the periodically structured p-contact <u>Yu. Kholopova</u> , M. Barabanenkov, S. Shapoval	45
Modeling of high-power light-emitting diodes: comparative analysis of advanced chip designs <u>S.Yu. Karpov</u> , K.A. Bulashevich, O.V. Khokhlev, M.V. Bogdanov, M.S. Ramm, I.Yu. Evstratov	47

Optimization of active region for GaN based LEDs <u>V.S.Sizov</u> , A. F. Tsatsulnikov, A.V.Sakharov , W.V.Lundin , E.E.Zavarin , A.E. Nikolaev	49
Studies of the effects of electron injection in III-nitride semiconductors <u>L. Chernyak</u>	51
Lattice dynamics of GaN/AlN and GaN/AlGaN superlattices: theory and experiment <u>V.Yu. Davydov</u> , M.B.Smirnov, Yu.E. Kitaev, A.N. Smirnov, M.A. Yagovkina, V.W.Lundin, E.E.Zavarin	55
Admittance spectroscopy – a powerful method for diagnostics of electronic structure of heterostructures with multiple quantum wells InGaN/GaN <u>O.V. Kucherova</u> , V.I. Zubkov	59
X-ray diffraction study of deformation state of multilayered structures InGaN/GaN <u>B.S. Yavich</u> , V.P. Kladko, A.V. Kuchuk, N.V. Safryuk, R.V. Konakova, V.F. Machulin, A.E. Belyaev	61
Large scale mcvd reactors for solid state lighting <u>F. Schulte</u> , L. Pauli, B. Schineller, and M. Heuken	63
Advancements in mcvd technology required to reduce LED manufacturing cost <u>A. Gurary</u> , M. Lamarra	64
Measurement of real wafer temperature during GaN growth on sapphire and SiC <u>M. Borasio</u> , K. Haberland, T. Schenk, F. Brunner, M. Weyers, J.-T. Zettler	66
Optimization of light and electrophysical characteristics of GaN-based LED structures <u>A.A.Naidin</u> , A.F.Ivanov, E.V.Ershov, S.A.Krukov, O.A.Rogachkov, O.I.Rogachkov	68
Problems of degradation, reability and stability of parameters of LED's as light sources <u>F.I. Manyakhin</u>	70
Problems of perception LED lighting human vision and develop of standards and norms for LED lighting <u>E.V. Dolin</u> , L.M. Teksheva, Y.G. Tkachuk	74
Laboratory «LIST» is the independent certified test center, first in Russia in the field of studying degradation process and metrology of semiconductors radiation <u>S.G.Nikiforov</u> , A.L. Arkhipov	76
High-power RGB LED light source with color smart control for medical-biological apparatus <u>A.V.Aladov</u> , S.B.Biryuchinskiy, SW.V.Demin, A.L.Zakgeim, G.Y.Klishin, M.N.Mizerov, K.V.Stelingovskiy, A.E.Chernyakov, A.F.Chumachenko	78
Modern effective phosphors for solid state lighting <u>N.P. Soshchin</u>	80
Patent history of white light-emitting diodes with converters <u>N.P. Soshchin</u>	84
Phosphors for white LEDs <u>R.B. Jabbarov</u> , N.N. Musayeva, S.H. Abdullaeva, A.E Yunovich, F. Scholz, T. Wunderer, P. Benalloul, C. Barthou	86
Green light-emitting diode based on phosphor, excited by violet radiation from InGaAlN p-n-heterostructures <u>N.P.Soshcin</u> , <u>L.M.Kogan</u> , N.A.Galchina, J.A.Portnyagin	88

High -power light-emitting diodes of the white luminescence with light feedback up to 100 lm/W and modules on their basis N.A.Galchina, A.L.Gofshtejn-Gardt, <u>L.M.Kogan</u> , I.T.Rassohin, N.P.Soshcin	90
AlGa _N -based heterostructures for deep ultraviolet optoelectronics grown by plasma-assisted molecular beam epitaxy <u>V.N. Jmerik</u> , A.M. Mizerov, T.V. Shubina, A.A. Sitnikova, M.A. Yagovkina, P.S. Kop'ev, E.V. Lutsenko, N.P. Tarasyuk, A.V. Danilchuk, N.V. Rzhetskii, G.P. Yablonskii, S.V. Ivanov	92
Growth of high quality AlN layers by ammonia molecular-beam epitaxy <u>T.V. Malin</u> , A.V. Tihonov, A.P. Vasilenko, K.S. Zhuravlev	96
Growth of Al _x Ga _{1-x} N layers (0<x<1) with different polarities by plasma-assisted molecular beam epitaxy <u>A.M. Mizerov</u> , V.N. Jmerik, P.S. Kop'ev and S.V. Ivanov	97
The influence of sapphire substrate orientation on crystalline quality of GaN films grown by hydride vapor phase epitaxy A.A. Donskov, L.I. Dyakonov, A.V. Govorkov, Yu.P. Kozlova, S.S. Malakhov, A.V. Markov, <u>M.V. Mezhenyi</u> , V.F. Pavlov, A.Y. Polyakov, V.I. Ratushnyi, N.B. Smirnov, T.G. Yugova	99
Ways to suppress parasitic deposition in vertical HVPE reactors for growth gallium nitride substrates <u>Y.T. Rebane</u> , N.I. Bochkareva, V.V. Voronenkov, R.I. Gorgunov, Ph.E.Latyshev, Y.S. Lelikov, A.S. Zubrilov, A.I. Tsuk, Y.G. Shreter	101
HVPE technology and reactor to produce GaN substrate materials <u>A. Usikov</u> , N. Singh, V. Soukhoveev, O. Kovalenkov, A. Syrkin, V. Ivantsov, T. Cornish, B. Scanlan, and L. Leung	103
High-power blue InGa _N LEDs – ways to increase efficiency <u>D.A.Zakheim</u> , A.S.Pavluchenko, D.A.Bauman	105
Tunneling mechanism of efficiency droop in GaN light-emitting diodes <u>N.I. Bochkareva</u> , V.V. Voronenkov, R.I. Gorbunov, , A.S. Zubrilov, Y.S. Lelikov, F.E. Latyshev, Y.T.Rebane, A.I. Tsuk, Y.G. Shreter	107
Auger recombination contribution to the efficiency droop of blue InGa _N MQW based LEDs B.Ya. Ber, <u>A.A. Greshnov</u> , A.L. Zakheim, G.G. Zegrya, D.Yu. Kazanzev, Z.N. Sokolova, A.S. Pavluchenko, A.E. Chernyakov, N.M. Shmidt, E.B. Yakimov	109
Overview of the nitride transistor technology development in JSC «SVETLANA-ROST» A.E.Byrnaz, A.L. Dudin, A.V. Naidenov, S.V. Kokin, D.M.Krasovitsky, M.V.Pavlenko, <u>S.I.Petrov</u> , I.S. Tkachenko, V.P.Chaly	111
Impact of epitaxial structure design for nitride transistor on its properties A.E.Byrnaz, A.L. Dudin, A.V. Naidenov, S.V. Kokin, D.M.Krasovitsky, M.V.Pavlenko, <u>S.I.Petrov</u> , I.S. Tkachenko, V.P.Chaly	113
Development of growth technology of AlN(AlGa _N)/n-SiC templates and transistor heterostructures on it using MBE A.E.Byrnaz, A.L. Dudin, A.V. Naidenov, S.V. Kokin, D.M.Krasovitsky, M.V.Pavlenko, <u>S.I.Petrov</u> , I.S. Tkachenko, V.P.Chaly	115
InAlN/GaN and (AlN/GaN)/Ga _N heterostructures with 2-D electron gas <u>A.V.Sakharov</u> , W.V.lundin, A.E. Nikolaev, E.E.Zaverin, M.A.Sinitsin, M.A. Yagovkina, A.F.Tsatsulnikov	117
Quasi-monolithic ultra wideband microwave power amplifier on heterostructures AlGa _N /Ga _N <u>B.V.Kalinin</u> , V.G.Guk, V.P.Chaly, A.N.Pikhtin	119

Microwave transistors at heterosystem AlGaIn/GaN with specific output power 3 W/mm Yu. Matveev, D. Amelin, E. Enyushkina, A. Kuznetsov, E. Ovcharenko, A. Lisitskii, A. Pavlov, A. Trofimov, <u>N. Shchavruk</u>	121
Preliminary studies of GaN as a detector of α -particles and thermal neutrons <u>A.Y. Polyakov</u> , N.B. Smirnov, A.V. Govorkov, I.L. Gazizov, V.M. Zalyetin, E.A. Kozhukhova, A.V. Markov, N.G. Kolin, A.V. Korulin, D.I. Merkurisov, V.M. Boiko, S.J. Pearton, I-H. Lee	123
Ultraviolet MSM-photodetectors on AlGaIn heterostructures S.V. Averin, <u>P.I. Kuznetsov</u> , V.A. Zhitov, N.V. Alkeev, A.A. Dorofeev, N.B. Gladisheva	125
Planar vacuum-semiconductor photodetector with semitransparance photocathode p-GaN(Cs,O)/AlN/C-Al ₂ O ₃ V.V. Bakin, S.N. Kosolobov, H.E. Scheibler, <u>A.S. Terekhov</u> , V.N. Jmerik, A.M. Mizerov, S.V. Ivanov	127
Use of dimethylethylamine alane as Al precursor in nitride MOCVD <u>A.E. Baranov</u> , V.S. Sizov, E.E. Zavarin, V.W. Lundin, M.A. Sinitzyn, A.V. Sakharov, S.O. Usov, A.E. Nikolaev, A.F. Tsatsulnikov	129
The interference fringes in the electroreflectance spectra from InGaIn/AlGaIn/GaN heterostructures L.P. Avakyants, <u>P.Yu. Bokov</u> , A.V. Chervyakov	131
GaN films on Si substrates with Ge buffer layer <u>Yu.N. Buzynin</u> , O.I. Khrykin, V.G. Shengurov, M.N. Drozdov, Yu.N. Drozdov, S.A. Denisov	133
Effect of growth parameters on stress in HVPE GaN films <u>R.I. Gorbunov</u> , N.I. Bochkareva, V.V. Voronenkov, Ph.E. Latyshev, Y.S. Lelikov, A.S. Zubrilov, A.I. Tsuk, Y.G. Shreter	135
Linear polarized photoluminescence from ensembles of GaN quantum dots imbedded in AlN matrix I.A. Aleksandrov, <u>K.S. Zhuravlev</u> , P.-O. Holtz	137
Growth and advanced characterization of InAlN/GaN distributed bragg reflectors <u>E.E. Zavarin</u> , W.V. Lundin, M.A. Sinitzyn, A.V. Sakharov, S.O. Usov, A.E. Nikolaev, S.I. Troshkov, M.A. Yagovkina, E.V. Yakovlev, R.A. Talalaev, D.V. Davydov, A.V. Lobanova, N.A. Cherkashin, M.J. Hytch, P.N. Brunkov, A.F. Tsatsulnikov	139
Investigation of optical and structural properties of InAlN/GaN distributed bragg reflectors <u>S.O. Usov</u> , E.E. Zavarin, A. F. Tsatsul'nikov, V.V. Lundin, A.V. Sakharov, A.E. Nikolaev, M. A. Sinitzyn, N.V. Kryzhanovskaya, S.I. Troshkov, N.N. Ledentsov	141
Features of high-power InGaIn LEDs operating in wide temperature-current range <u>A.L. Zakgeim</u> , D.A. Zakgeim, M.N. Mizerov, A.S. Pavlyuchenko, A.E. Chernyakov	143
High-power light-emitting diodes with ultra-violet radiation <u>L.M. Kogan</u> , N.A. Galchina, A.A. Kolesnikov, J.A. Portnjagin, I.T. Rassohin	145
GaN epitaxial films grown by HVPE on polycrystalline cvd diamond substrates using surface nanostructuring with TiN Or anodic Al oxide A.A. Donskov, L.I. Dyakonov, A.V. Govorkov, <u>Yu.P. Kozlova</u> , S.S. Malakhov, A.V. Markov, M.V. Mezhennyi, V.F. Pavlov, A.Y. Polyakov, N.B. Smirnov, T.G. Yugova, M.P. Duhnovsky, A.K. Ratnikova, Yu.Yu. Fyodorov, V.I. Ratushnyi, O.Yu. Kudryashov, I.A. Leontyev	147
Optical and structural properties of InGaIn/GaN Short period superlattice for light emitting diodes active region <u>N.V. Kryzhanovskaya</u> , V.V. Lundin, A.E. Nikolaev, A.F. Tsatsul'nikov, A.V. Sakharov, N.A. Cherkachin, M. J. Hytch, G.A. Valkovskiy, M.A. Yagovkina, S.O. Usov	149

Effect of surface contamination on HVPE epitaxial growth of gallium nitride <u>Ph.E.Latyshev</u> , N.I. Bochkareva, V.V. Voronenkov, R.I. Gorbunov, Y.S. Lelikov, A.S. Zubrilov, A.M. Nemets, S.N. Petrov, Y.T. Rebane, A.I. Tsuk, Y.G. Shreter	151
Laser action and optical gain in InGaN/GaN MQWs grown on Si under optical pumping by femtosecond pulses <u>E. V. Lutsenko</u> , A. V. Danilchuk, V. Z. Zubialevich, V. N. Pavlovskii, G. P. Yablonskii, Y. Dikme, B. Schineller, M. Heuken, L. Rahimzadeh Khoshro, H. Kalisch, R. H. Jansen, M. B. Danailov, A. A. Demidovich	153
Properties of thick GaN films grown by HVPE on GaN templates with TiN masks A.A. Donskov, L.I. Dyakonov, M.P. Duchnovskiy, A.V. Govorkov, Yu.P. Kozlova, <u>S.S. Malakhov</u> , A.V. Markov, M.V. Mezhenyi, V.F. Pavlov, A.Y. Polyakov, V.I. Ratushnyi, N.B. Smirnov, T.G. Yugova	155
Diffusion model of light extraction from LED chips <u>Y.T.Rebane</u> , R.I. Gorbunov, N.I. Bochkareva, A.S. Zubrilov, V.V. Voronenkov, Y.S. Lelikov, F.E. Latyshev, A.I. Tsyuk, Y.G. Shreter	157
InGaN/AlGaN heterostructures for near-UV LEDs <u>M.M. Rozhavskaia</u> , V.S. Sizov, E.E. Zavarin, V.V. Lundin	159
Use of InAlN layers for optical confinement <u>A.V. Sakharov</u> , E.E. Zavarin, M.A. Sinitsyn, W.V. Lundin, N.Yu.Gordeev, A.F. Tsatsulnikov	161
Low-temperature kinetics of III-N MOVPE growth W.V. Lundin, E.E. Zavarin, M.A. Sinitsyn, A.V. Sakharov, A.E. Nikolaev, <u>A.S. Segal</u> , E.V. Yakovlev, O.V. Bord	163
Reflective contacts ITO/Ag for high-power flip-chip AlGaInN-based LEDs <u>I.P.Smirnova</u> , L.K.Markov, E.M.Arakcheeva, M.M.Kulagina, D.A.Zakheim, M.M.Kukushkin	165
Frequency and temperature dependences of capacitance –voltage characteristics in InGaN/GaN multiple quantum well light-emitting structures <u>O.A. Soltanovich</u> , N.M. Schmidt, E.B. Yakimov	167
Synthesis and optimization of oxyanion-based phosphors parameters for white LEDs <u>N.P. Soshchin</u> , V.N.Litshmanova, V.A.Bolshukhin, E.A.Kirillov	169
The optimization of luminous flux of high-power white LED with silicate phosphor <u>A.V. Feopentov</u> , L.M. Vtyurina	171
Electroluminescence ripples of blue and green LEDs at low forward bias voltages <u>Y.V. Trofimov</u> , V.I. Tsvirko	173
Comparative analysis of thermal and current spreading in high-power InGaN LEDs with flip-chip and vertical structure A.L.Zakgeim, M.N.Mizerov, <u>A.E.Chernyakov</u>	175
Influence of changing parameters of active region and buffer superlattice on spectra and efficiency of blue InGaN/GaN light-emitting diodes <u>A.V.Chuyas</u> , B.S.Yavich	177
Low – frequency noise in light emitting structures based on InGaN/GaN MQW <u>E.I. Shabunina</u> , N.M. Schmidt, A.E. Chernyakov, P.V. Petrov, M.E. Levinshtein, N.S. Averkiev	179
Aluminum nitride on silicon: conception of intermediate SiC layer, technology of HVPE V. N. Bessolov, Yu.V.Zhilyaev, E.V.Konenkova, S.A.Kukushkin, A.V.Osipov, N.A.Feoktistov, <u>S.Sharofidinov</u> , M.P. Shcheglov	181

Surface morphology features of GaN Layers grown on different orientation substrates A.A. Donskov, L.I. Dyakonov, Yu.P. Kozlova, C.C. Malahov, A.V. Markov, M.V. Mezennyi, V.F. Pavlov, <u>T.G. Yugova</u>	183
Measurements of excess carrier diffusion length in GaN <u>E.B. Yakimov</u>	185
Effect of irradiation in scanning electron microscope on the spectrum and intensity of cathodoluminescence of light emitting structures with multiple quantum wells InGaN/GaN P.S. Vergeles, N.M. Schmidt, <u>E.E. Yakimov</u> , E.B. Yakimov	187
Time – resolved high field photoconductivity of AlGaIn/GaN heterostructures <u>B. A. Danilchenko</u> , N.A. Tripachko, L.I. Shpinar, O.O. Voitsekhivska, E.A. Drok	189
Phosphors based on cubic boron nitride doped with rare earth ions <u>O.R. Abdullaev</u> , E.M. Shishonok, A.S. Yakunin, D.M. Zhigunov, P.V. Ivannikov, I.N. Odin, M.V. Chukichev, A.E. Yunovich	191
Synchrotron photoemission spectroscopy studies of n-AlGaIn and ultrathin Ba/n-AlGaIn interfaces <u>G.V. Benemanskaya</u> , M.N. Lapushkin, S.N. Timoshnev, V.N. Zhmerik	193
Post growth processing of GaN films in contact metallization areas <u>A.V. Bespalov</u> , O.L. Golikova	195
Application of HF reactor to nitride activation for obtaining Al ₂ O ₃ /AlN structures Safaraliev G.K., <u>Bilalov B.A.</u> , Gitikchiev M.A	197
Quantitative luminescence analysis of the parameters of light emitting diodes and lighting systems on their basis <u>D.S. Bobuchenko</u> , V.I. Tsvirko, Yu.V. Trofimov, V.V. Krasovskii, I.A. Khorunzhii, D.S. Domanevskii, R.D. Kakanakov	199
The ohmic and barrier contacts to n-GaN with diffusion barriers made by interstitial phases A.E. Belyaev, <u>N.S. Boltovets</u> , V.N. Ivanov, R.V. Konakova, V.P. Kladko, Ya. Ya. Kudryk, V.V. Milenin, V.N. Sheremet, Yu.N. Sveshnikov	201
Growth and characterization of transition metals silicide single crystals as possible substrates for gallium nitride epitaxial layers <u>A. Yu. Bunkin</u> , A.A. Povzner	203
Detection of defects in InGaIn/AlGaIn/GaN-heterostructures using true color and narrow-band color cathodoluminescence SEM-modes <u>P.V. Ivannikov</u> , A.I. Gabelchenko	205
Degradation of light-emitting diodes on the basis of heterostructures InGaIn/GaN At an irradiation fast neutrons <u>A.V. Gradoboev</u> , A.A. Vilisov, P.V. Rubanov, I.A. Asanov	207
Development of the technology of manufacturing of LED matrixes on the basis of heterostructures InGaIn/GaN/AlGaIn V.A. Burobin, A.M. Konovalov, <u>A.A. Gysev</u> , E.N. Enushkina, A.A. Efimov, A.L. Kuznetsov, Y.A. Matveev, A.Y. Pavlov, V.A. Romanko, A.A. Tkacheva	209
Investigation of indium concentration profile in InGaIn/GaN MQW of blue LED structures influence on optical properties <u>A.A. Arendarenko</u> , I.G. Ermoshin, U.N. Sveshnikov, I.N. Ciplenkov	211
Ionic-plasma processing of GaN-based diode structures <u>A.V. Zhelannov</u> , V.E. Oudaltsov	213
Spectra and I-V characteristics kinetics of blue LEDs S.S. Strelchenko, Y.P. Golovatiy, <u>P.S. Zakharov</u> , E.V. Prokolkin	214

The features of the aluminum nitride film formation at the thermochemical nitridation of sapphire <u>Kh.Sh-o. Kaltaev</u> , N.S. Sidel'nikova, S.V. Nizgankovskiy, A.Y. Danko, M.A. Rom, M.V. Dobrotvorskaya	216
Structural and optical characteristics of aluminum nitride films obtained at the sapphire nitridation using gaseous reductants (CO, H ₂) N.S. Sidel'nikova, M.A. Rom, <u>Kh.Sh-o. Kaltaev</u> , S.V. Nizgankovskiy, A.Y. Danko	217
Porous InP as soft substrate for InN films J. A. Suchikova, <u>V.V. Kidalov</u> , G. A. Sukach	218
Submicron optical spectroscopy of spatial uniformities of InGaN/GaN structures <u>O.F. Kolomys</u> , V.V. Strelchuk, K.A. Avramenko, M.Ya. Valakh, E.V. Lutsenko, V.N. Pavlovskii, G.P. Yablonskii	220
Structural properties of AlN, GaN AND InN under pressure: ab initio calculations <u>A.V. Kosobutsky</u>	222
Anisotropic strains and defect structure in a- epitaxial layers InN and GaN on R-sapphire <u>R.N.Kyutt</u> , V.V.Ratnikov, M.P.Scheglov, V.Yu.Davydov, M.A.Yagovkina	224
Ultra bright blue and UV LEDs in astroparticle physics experiments <u>B.K. Lubsandorzhev</u> , Y.E. Vyatchin, B.A.Jr. Shaibonov	226
Donor doping of GaN by nuclear transmutations and the influence of radiation defects <u>A.Y.Polyakov</u> , N.B. Smirnov, A.V. Govorkov, A.V. Markov, N.G. Kolin, A.V. Korulin, D.I. Merkurisov, V.M. Boiko, S.J. Pearton	228
Scattering mechanism of 2DEG in MBE AlGaInP heterostructures <u>D.Yu. Protasov</u> , T.V. Malin, A.V. Tikhonov, K.S. Zhuravlev	230
InGaInP emitting diodes simulation <u>O.I. Rabinovich</u> , V.P. Sushkov, A.L. Arhipov	232
Non-local lateral redistribution of GaN near growth defect's fields under ion-beam irradiation A.V. Bespalov, O.L. Golikova, N.N. Novitski, <u>A.I. Stognij</u>	234
Actual energy efficient illumination technologies using power LED <u>V.G.Terekhov</u> , A.N.Turkin	236
TEM study of defects in Al _x Ga _{1-x} N layers A.V. Tikhonov, T.M. Malin, A.K. Gutakovskii, K.S. Zhuravlev, L. Dobos, B. Pecz	238
Assembling features of UV-emitting diodes <u>V.E.Oudaltsov</u> , G.V.Zaritskij, A.A.Pavlov, A.V.Zhelannov, A.A.Uvarova	240
Optimization of charge carriers injection to the active region of the blue InGaInP/GaN high power light-emitting diodes <u>S.O. Usov</u> , A.F. Tsatsul'nikov, V.W. Lundin, A.V. Sakharov, N.V. Kryzhanovskaya, A.E. Nikolaev, N.A. Cherkashin, N.N. Ledentsov	241
InN dielectric function from midinfrared to the visible range L.A. Falkovsky	243
Templates for nitride devices <u>Yu.N. Makarov</u> , T.Yu. Chemekova, I.S. Barash, A.D.Roenkov, S.Yu. Kurnikov, H. Helava	245
Dependence of spectra and efficiency of white light-emitting diodes based on InGaInP/GaN heterostructures covered by various phosphors on temperature <u>A.V.Chuyas</u> , A.V.Feopentov	247