

**IN THE UNITED STATES DISTRICT COURT
DISTRICT OF MASSACHUSETTS**

TRUSTEES OF BOSTON UNIVERSITY,

Plaintiff,

VS.

EPISTAR CORPORATION,

Defendant.

Civil Action No. 12-cv-12326-PBS

LEAVE TO FILE GRANTED ON

OCTOBER 10, 2014 PER DKT #883

**~~PROPOSED~~ FIRST AMENDED AND SUPPLEMENTAL
COMPLAINT FOR PATENT INFRINGEMENT
AND JURY DEMAND AGAINST EPISTAR CORPORATION**

Plaintiff Trustees of Boston University, by and through its undersigned attorneys, hereby plead the following amended and supplemental claims of patent infringement against Epistar Corporation (“Epistar”) based on newly discovered evidence and acts that have occurred since this lawsuit was originally filed.

I. PARTIES

1. Plaintiff Trustees of Boston University (“Boston University” or “BU”) is a non-profit educational institution with its principal place of business at One Silber Way, Boston, Massachusetts 02215. Boston University is one of the largest private universities in the United States and one of the largest employers in Boston, with more than 10,000 faculty and staff and more than 33,000 students. It conducts a diverse range of interdisciplinary, collaborative and innovative research across a broad spectrum of academic departments, programs, centers and institutes, including research in the field of electrical and computer engineering. Boston University professors have won five Nobel Prizes and have been awarded hundreds of United States Patents, including U.S. Patent No. 5,686,738 (the “738 patent”).

2. Defendant Epistar Corporation (“Epistar”) is a Taiwanese entity located at 5 Li-hsin 5th Road, Science Park, Hsinchu, Taiwan 300. Epistar has appeared in this Action and is represented by counsel.

II. JURISDICTION AND VENUE

3. This is an action for patent infringement arising under the patent laws of the United States of America, Title 35 of the United States Code. This Court has subject matter jurisdiction over the matters pleaded herein under 28 U.S.C. §§ 1331 and 1338(a) in that this is a civil action arising out of the patent laws of the United States of America.

4. Epistar regularly and deliberately engages in and continue to engage in activities that result in using, selling, offering for sale, and/or importing infringing products and products made by infringing processes in and/or into the United States, the Commonwealth of Massachusetts and this judicial district. These activities violate Boston University’s United States patent rights under the ’738 patent pled herein. This Court has personal jurisdiction over Epistar because, among other things, they have appeared in this action and thereby waived any jurisdictional challenges, patent infringement is a cause of action arising under the laws of the United States, and Defendants conduct business in the United States and the Commonwealth of Massachusetts such that they enjoy the privileges and protections of federal and Massachusetts law.

5. Venue is proper in the District of Massachusetts pursuant to 28 U.S.C. §§ 1391(b), (c) and (d) and 1400(b).

III. INFRINGEMENT OF UNITED STATES PATENT

6. Boston University is the owner of all rights, title and interest in and under United States Patent 5,686,738 (“’738 patent”), titled “Highly Insulating Monocrystalline Gallium Nitride

Thin Films,” which issued on November 11, 1997. A true and correct copy of the ’738 patent is attached hereto as **Exhibit A**. The ’738 patent is valid and enforceable.

7. All requirements under 35 U.S.C. § 287 have been satisfied with respect to the ’738 patent.

IV. COUNT I: DIRECT INFRINGEMENT OF U.S. PATENT NO. 5,686,738

8. Boston University incorporates by reference all paragraphs above as though fully repeated herein.

9. Epistar has been and continues to directly infringe the ’738 patent by making, using, offering for sale, selling, and/or importing in or into the United States, without authority, its InGaN LEDs. A full list of Epistar’s InGaN LEDs is attached hereto as **Exhibit B**.¹ Epistar’s InGaN LEDs practice claims 1, 2, 7, 9, 10, 15, 18, 19 and 20 of the ’738 patent as shown in Dkt. Nos. 75, 162, 168, 177, 183, 210. Even more specifically, Epistar sells hundreds of millions of dollars of its infringing InGaN LED products directly to Bridgelux, Inc. in the United States in violation of 35 U.S.C. § 271(a). Epistar also sells its infringing InGaN LED products directly into the U.S. to at least the following U.S. companies in further violation of 35 U.S.C. § 271(a):²

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¹ Epistar did not disclose a full list of its InGaN LED part numbers until February 14, 2014.

² This list may not be complete because it is based only discovery produced by Epistar as of May 15, 2014.

10. Epistar has at no time, either expressly or impliedly, been licensed under the '738 patent.

11. Epistar's direct infringement of the '738 patent has caused and will continue to cause substantial and irreparable damage to Boston University. Boston University is therefore entitled to an award of damages adequate to compensate for Epistar's infringement of the '738 patent; but in no event, less than a reasonable royalty for the use and/or sale of its invention by Epistar, together with interest and costs as fixed by the court under 35 U.S.C. § 284. Boston University estimates its damages for Epistar's direct infringement of the '738 patent as no less than \$REDACTED This figure is based on a 4% royalty rate³ of Epistar's admitted total U.S. InGaN LED sales for the period 2008-2014, as shown in the table below:⁴

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V. COUNT II: INDUCED INFRINGEMENT OF THE '738 PATENT

12. Boston University incorporates by reference all paragraphs above as though fully repeated herein.

13. Epistar induces infringement under § 271(b) by actively and knowingly aiding and abetting the direct infringement of Everlight Electronics Co., Ltd, Everlight Americas, Inc.

³ The deposition of Epistar's corporate representative revealed that Epistar pays a royalty rate of REDACTED for LED technology similar to the '738 patent.

⁴ These numbers are based on incomplete discovery from Epistar as of May 15, 2014.

(collectively “Everlight”), Lite-On Technology Corporation, and Lite-On Service USA, Inc. (collectively “Lite-On”).

14. Epistar, Everlight, and Lite-On have at no time, either expressly or impliedly, been licensed under the ’738 patent.

A. Epistar’s Knowledge of the ’738 Patent.

15. Epistar has had knowledge of the ’738 patent since 2007. Epistar’s corporate representative Men-Chun Kuo testified under oath at her deposition on May 1, 2014 ^{REDACTED}

Accordingly, Epistar hired a lawyer at Finnegan, Henderson, Farabow, Garrett & Dunner, LLP (“Finnegan”) to provide it with an infringement opinion. Epistar then sent an analysis of its ^{REDACTED} ^{REDACTED} to Finnegan. Finnegan never provided Epistar with a written infringement or invalidity opinion.⁵

16. In addition, Epistar met with Boston University’s licensee, Cree, on October 21, 2010 to discuss patents. At that meeting Cree presented a PowerPoint presentation that identified Epistar’s infringement of the ’738 patent.

B. Lite-On and Everlight’s Direct Infringement of the ’738 Patent.

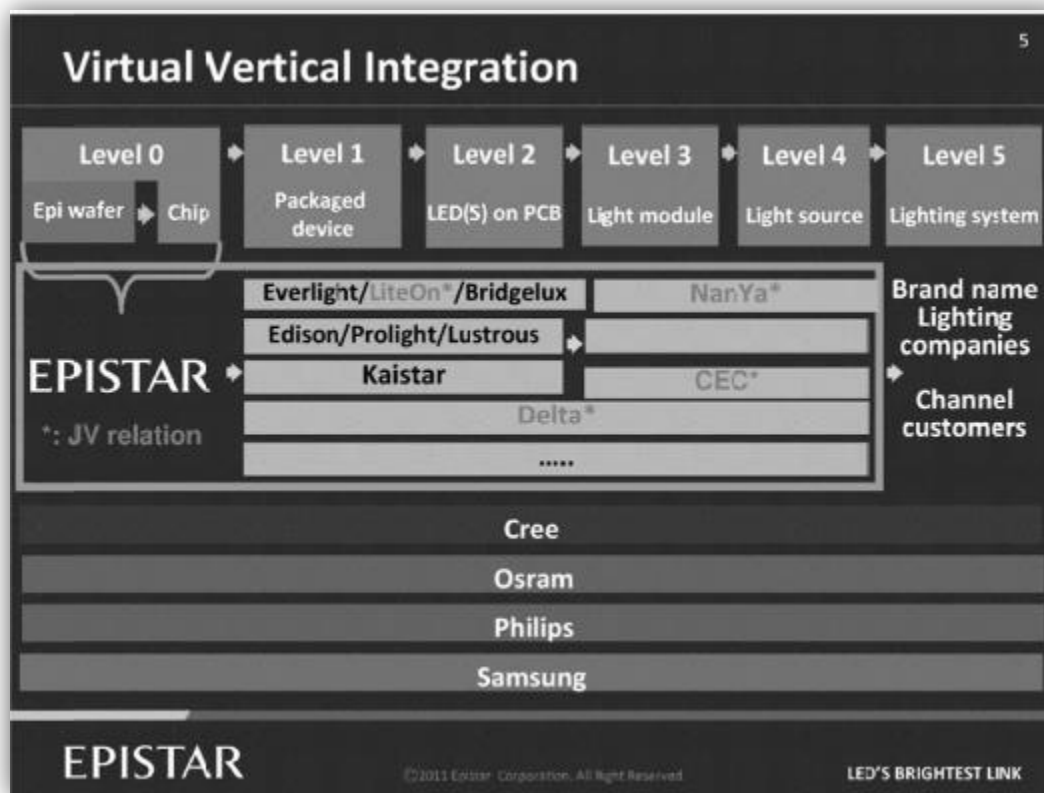
17. Lite-On directly infringes the ’738 patent by making, using, offering for sale, selling, and/or importing in or into the United States, without authority, products that contain Epistar’s infringing InGaN LEDs. Specifically, Lite-On Technology Corporation sells hundreds of millions of dollars of products containing Epistar’s infringing InGaN LED products directly to Lite-On, Inc. and Apple, Inc. in the United States in violation of 35 U.S.C. § 271(a).

⁵ This information can be found in the deposition transcript of Men-Chun Kuo (“Kuo Deposition”) at 128:17-134:12. The Kuo Deposition was taken on May 1, 2014 in Hsinchu, Taiwan.

18. Everlight directly infringes the '738 patent by making, using, offering for sale, selling, and/or importing in or into the United States, without authority, products that contain Epistar's infringing InGaN LEDs. Specifically, Everlight Electronics Co., Ltd sells hundreds of millions of dollars of products containing Epistar's infringing InGaN LED products directly to Everlight Americas, Inc. in the United States in violation of 35 U.S.C. § 271(a).

C. Epistar's Affirmative Acts that Induce the Direct Infringement of Everlight and Lite-On.

19. Epistar markets itself as vertically integrated with Everlight and Lite-On.⁶



20. In addition, Epistar collaborates with Lite-On to facilitate Lite-On's ability to sell products containing Epistar's infringing InGaN LEDs to U.S. companies in violation of 35 U.S.C. § 271(a). For example, the document bates labeled EPI0033090-3135 is an email chain

⁶ Dkt. 449 at 4.

between Epistar and Lite-On REDACTED

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⁷ EPI0033116. This email chain was produced on March 24, 2014.

⁸ EPI0033090. This email chain was produced on March 24, 2014.

21. These emails demonstrate that Epistar and Lite-On work collaboratively in order to facilitate Lite-On's ability to make infringing sales to U.S. customers.

22. Epistar also indemnifies Lite-On against liability for patent infringement for the Epistar InGaN LED products Lite-On sells.⁹ This indemnification encourages Lite-On to continue to sell Epistar's InGaN LEDs, which infringe the '738 patent, into the U.S. in violation of 35 U.S.C. § 271(a).

23. Epistar also collaborates with Everlight to facilitate Everlight's ability to sell products containing Epistar's infringing InGaN LEDs to U.S. companies in violation of 35 U.S.C. § 271(a). For example, the document bates labeled ELT0030792-842 is an email and attachment
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⁹ Boston University first learned that Epistar was indemnifying Lite-On during the Kuo Deposition that took place on May 1, 2014 in Hsinchu, Taiwan. The relevant testimony can be found in the transcript of that deposition on pages 96:13-97:10.

¹⁰ This document was produced March 24, 2014.

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24. This email and PowerPoint demonstrates that Epistar and Everlight work collaboratively to facilitate Everlight's ability to make infringing sales to U.S. customers.

25. Epistar also indemnifies Everlight against liability for patent infringement for the Epistar InGaN LED products Everlight sells.¹¹ This indemnification encourages Everlight to continue to sell Epistar's InGaN LEDs, which infringe the '738 patent, into the U.S. in violation of 35 U.S.C. § 271(a). Epistar did not produce its agreement to indemnify Everlight, EPI0649834-37, until April 18, 2014.

26. Epistar knew, or should have known, that the acts described above would result in Everlight and Lite-On's direct infringement of the '738 patent. Epistar knew of the '738 patent. Epistar knew Cree believed Epistar's InGaN LEDs infringed the '738 patent. Epistar could not obtain a written non-infringement opinion from Finnegan. Thus, Epistar knew, or should have known, that its acts would encourage Everlight and Lite-On to sell products containing Epistar's InGaN LEDs into the U.S. and that every such U.S. sale made by Everlight and Lite-On would be an act of direct infringement of the '738 patent.

27. Epistar's specific intent to encourage Everlight and Lite-On to directly infringe the '738 patent may be reasonably inferred from the specific acts discussed above coupled with Epistar's knowledge of the '738 patent.

28. Epistar's indirect infringement of the '738 patent has caused and will continue to cause substantial and irreparable damage to Boston University. Boston University is therefore entitled to an award of damages adequate to compensate for Epistar's infringement of the '738 patent; but in no event, less than a reasonable royalty for the use and/or sale of its invention made by Epistar, together with interest and costs as fixed by the court under 35 U.S.C. § 284.

¹¹ Boston University first learned that Epistar was indemnifying Everlight during the Kuo Deposition that took place on May 1, 2014 in Hsinchu, Taiwan. The relevant testimony can be found in the transcript of that deposition on pages 85:20-25, 92:7-12.

Boston University estimates its damages for Epistar's indirect infringement of the '738 patent to be no less than REDACTED. This figure is based on a 4% royalty rate¹² of Everlight's and Lite-On's admitted total direct U.S. InGaN LED sales for the period 2008-2014, as shown in the table below:¹³

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VI. COUNT III: WILLFUL INFRINGEMENT OF '738 PATENT

29. Boston University incorporates by reference all paragraphs above as though fully repeated herein.

30. Epistar has been willfully infringing the '738 patent since 2007. Epistar has had actual knowledge of the '738 patent since 2007. Epistar continues to have actual knowledge of or a deliberate disregard for the '738 Patent and its coverage of Epistar's infringing InGaN LEDs, but has nonetheless continued to infringe the '738 patent by selling its InGaN LEDs directly to companies located in the U.S. and by inducing infringement by actively and knowingly aiding and abetting the direct infringement of Everlight and Lite-On as set forth above. A cursory review by Epistar of its InGaN LEDs and the claims of the '738 patent would have alerted Epistar to the need to obtain a license from Boston University. Instead, Epistar has advanced increasingly specious defenses and procedural claims in this forum.

¹² The deposition of Epistar's corporate representative revealed that Epistar pays a royalty rate of REDACTED for LED technology similar to the '738 patent.

¹³ These numbers are based on incomplete discovery from Lite-On and Everlight as of May 15, 2014.

¹⁴ Estimated.

31. Since Boston University instituted this lawsuit, Epistar has failed in multiple challenges to the validity of the '738 Patent. Epistar, Everlight and Lite-On sought to initiate *inter partes* review before the Patent Trial and Appeal Board. Unlike more than 90% of IPR applicants, their joint IPR application was denied in full. The PTAB found their motion for reconsideration of the IPR denial to be entirely without merit. Early in this action, Everlight sought to challenge the Rule 11 investigation performed by Boston University, and failed. Epistar has filed a Rule 11 Motion on the same basis as Everlight's previous failed attempt to claim Boston University's case has no basis and claimed without support that one product out of more than 130 Epistar products that infringe the '738 patent is not actually Epistar's. Epistar's Rule 11 motion was denied.

32. In addition, certain claim terms at issue at this Court's *Markman* hearing had previously been determined by other district courts to have the meanings ascribed to them in this case by Boston University. Under those meanings, Epistar's InGaN LEDs clearly infringe the '738 patent. Thus, both the IPR bases proffered by Epistar and the claim constructions they advocated are not objectively reasonable.

33. After the inception of this suit, Epistar developed and deployed a new line of infringing InGaN LED products, the REDACTED that were specifically designed to use a gallium nitride buffer layer. Epistar first tried to use an aluminum nitride buffer layer in the REDACTED but switched to a gallium nitride to improve the manufacturing yield rate:¹⁵

¹⁵ These excerpts are from the deposition transcript of Wen-Hsiang Lin at 54:12-55:11. Mr. Wen was deposed as Epistar's corporate representative on May 2, 2014 in Hsinchu, Taiwan.

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34. Epistar, Everlight and Lite-On continue to manufacture, market, sell, import and use GaN LEDs that infringe the '738 Patent despite an objectively high likelihood that their actions infringe the patent.

35. Despite an objectively high likelihood that its actions infringe the '738 patent Epistar continues making, selling, or offering to sell its InGaN LEDs. Boston University should receive enhanced damages up to three times the amount of its actual damages for the Defendants' willful infringement under 35 U.S.C. § 284. Boston University estimates its enhanced damages total for Epistar's willful infringement of the '738 patent, based on incomplete disclosures provided to date, to be no less than \$REDACTED

VII. PRAYER FOR RELIEF

WHEREFORE, Boston University respectfully requests that judgment be entered in its favor and against Defendants and respectfully request that the Court grant the following relief:

- (a) Declare that the '738 patent is exclusively owned by Plaintiff Trustees of Boston University;
- (b) Declare that the '738 patent is valid and enforceable;
- (c) Declare that defendant Epistar is liable for past and present direct infringement of the '738 patent;
- (d) Declare that Epistar is liable for inducing infringement of the '738 patent;
- (e) Award damages to the Trustees of Boston University to which it is entitled for Epistar's infringement of the '738 patents
- (f) Award Boston University treble damages for Epistar's willful infringement;
- (g) That Boston University be awarded any other supplemental damages and interest on all damages, including, but not limited to attorney fees available under 35 U.S.C. § 285.
- (h) That Boston University be awarded such other and further relief as this Court may deem just and proper, including but not limited to equitable relief and all remedies available at law.

VIII. DEMAND FOR JURY TRIAL

Pursuant to Federal Rule of Civil Procedure 38(b), Boston University hereby demands a trial by jury on all issues triable to a jury.

Dated: Monday, May 19, 2014

Respectfully submitted,
TRUSTEES OF BOSTON UNIVERSITY

By its attorneys,

/s/ Michael W. Shore

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CERTIFICATE OF SERVICE

The undersigned certifies that the forgoing document, which was filed through the ECF system, will be sent electronically to the registered participants as identified on the Notice of Electronic Filing.

/s/ Erik Paul Belt

Erik Paul Belt

EXHIBIT A



US005686738A

United States Patent [19][11] **Patent Number:** **5,686,738****Moustakas**[45] **Date of Patent:** **Nov. 11, 1997**[54] **HIGHLY INSULATING MONOCRYSTALLINE GALLIUM NITRIDE THIN FILMS**[75] **Inventor:** **Theodore D. Moustakas**, Dover, Mass.[73] **Assignee:** **Trustees of Boston University**, Boston, Mass.[21] **Appl. No.:** **372,113**[22] **Filed:** **Jan. 13, 1995****Related U.S. Application Data**

[63] Continuation of Ser. No. 113,964, Aug. 30, 1993, Pat. No. 5,385,862, which is a continuation of Ser. No. 670,692, Mar. 18, 1991, abandoned.

[51] **Int. Cl.⁶** **H01L 33/00; H01L 29/20**[52] **U.S. Cl.** **257/103; 257/94; 257/79; 257/615**[58] **Field of Search** **257/103, 94, 79, 257/615**[56] **References Cited****U.S. PATENT DOCUMENTS**

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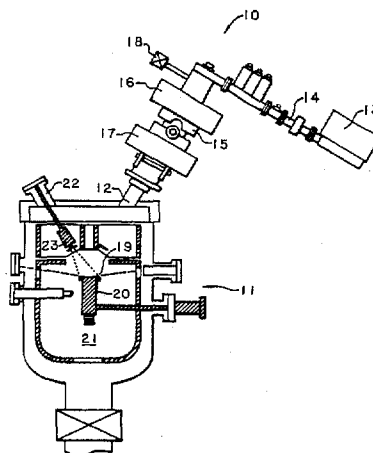
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(List continued on next page.)

Primary Examiner—Jerome Jackson**Attorney, Agent, or Firm**—Baker & Botts, L.L.P.[57] **ABSTRACT**

This invention relates to a method of preparing highly insulating GaN single crystal films in a molecular beam epitaxial growth chamber. A single crystal substrate is provided with the appropriate lattice match for the desired crystal structure of GaN. A molecular beam source of Ga and source of activated atomic and ionic nitrogen are provided within the growth chamber. The desired film is deposited by exposing the substrate to Ga and nitrogen sources in a two step growth process using a low temperature nucleation step and a high temperature growth step. The low temperature process is carried out at 100-400° C. and the high temperature process is carried out at 600-900° C. The preferred source of activated nitrogen is an electron cyclotron resonance microwave plasma.

21 Claims, 4 Drawing Sheets

5,686,738

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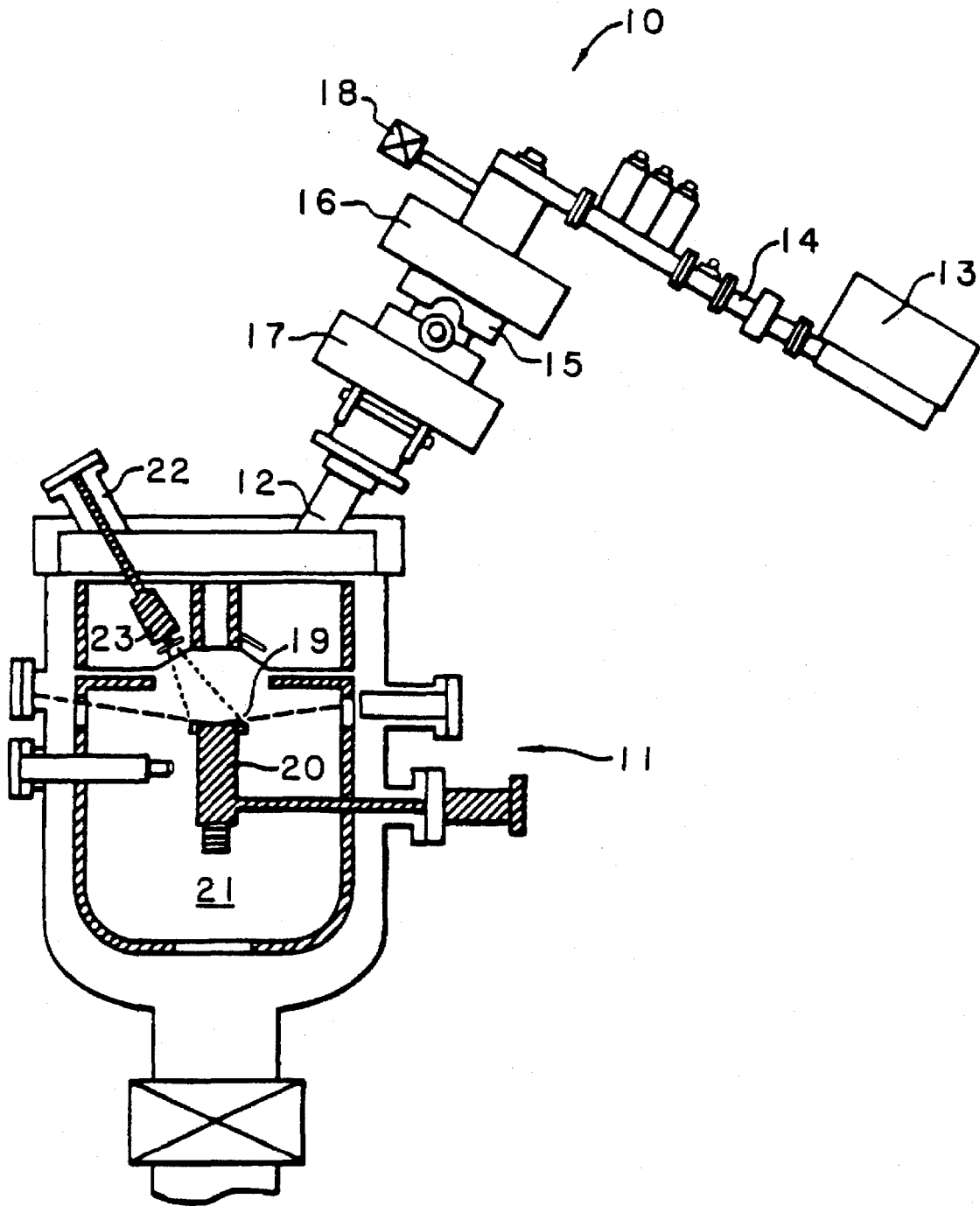


FIG. 1

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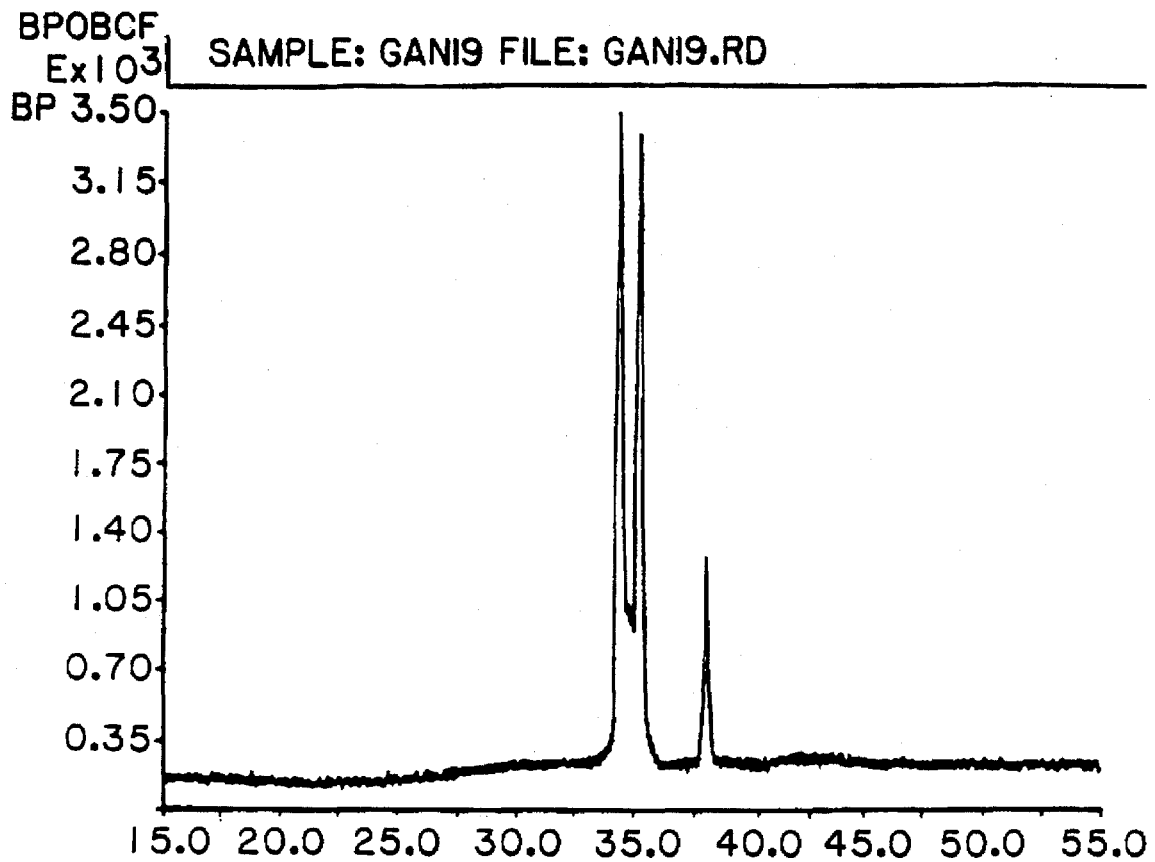


FIG.2A

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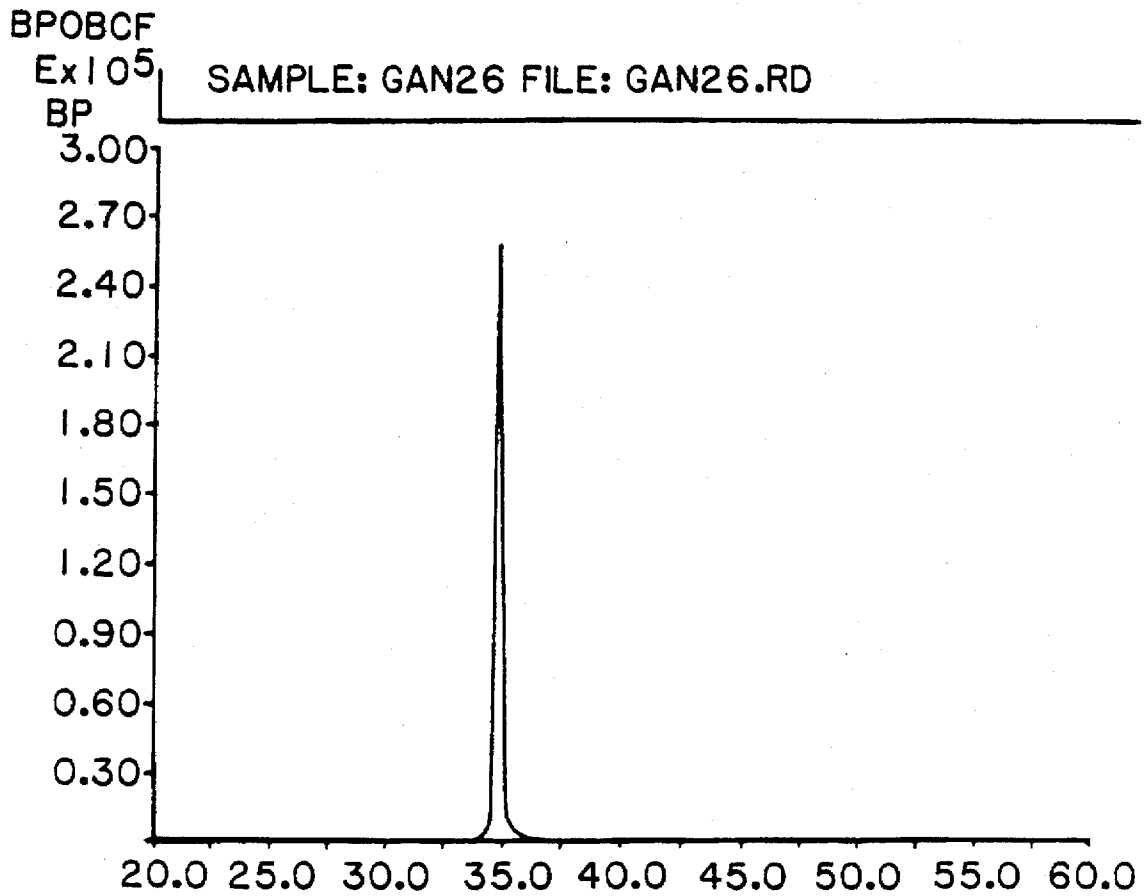


FIG.2B

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HIGHLY INSULATING MONOCRYSTALLINE GALLIUM NITRIDE THIN FILMS

This application is a continuation of application Ser. No. 08/113,964, filed Aug. 30, 1993, now U.S. Pat. No. 5,538, 862, entitled "A METHOD FOR THE PREPARATION AND DOPING OF HIGHLY INSULATING MONOCRYSTALLINE GALLIUM NITRIDE THIN FILMS", which is a continuation of application Ser. No. 07/670,692, filed Mar. 18, 1991, which is abandoned.

BACKGROUND OF THE INVENTION

This invention relates to a method of preparing monocrystalline gallium nitride thin films by electron cyclotron resonance microwave plasma assisted molecular beam epitaxy (ECR-assisted MBE). The invention further relates to a method for the preparation of n-type or p-type gallium nitride (GaN) films.

Efforts have been made to prepare monocrystalline GaN because of its potentially useful electrical and optical properties. GaN is a potential source of inexpensive and compact solid-state blue lasers. The band gap for GaN is approximately 3.4 eV, which means that it can emit light on the edge of the UV-visible region. For intrinsic GaN, the carrier concentration, n_i , is $5.2 \times 10^3 \text{ cm}^{-3}$, the mobility is $330 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$ and the resistivity is $3.6 \times 10^{12} \text{ } \Omega \cdot \text{cm}$.

Despite the desirability of a monocrystalline GaN film, its development has been hampered by the many problems encountered during the growth process. Previous attempts to prepare monocrystalline GaN films have resulted in n-type films with high carrier concentration. The n-type characteristic is attributed to nitrogen vacancies in the crystal structure which are incorporated into the lattice during growth of the film. Hence, the film is unintentionally doped with nitrogen vacancies during growth. Nitrogen vacancies affect the electrical and optical properties of the film.

ECR-assisted metalorganic vapor phase epitaxy gave GaN films that were highly conductive and unintentionally doped n-type (S. Zembutsu and T. Sasaki *J. Cryst. Growth* 77, 25–26 (1986)). Carrier concentrations and mobilities were in the range of $1 \times 10^{19} \text{ cm}^{-3}$ and $50\text{--}100 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$, respectively. Efforts to dope the film p-type were not successful. The carrier concentration was reduced by compensation, that is, the effect of a donor impurity is "neutralized" by the addition of an acceptor impurity.

Highly resistive films were prepared by sputtering using an ultra-pure gallium target in a nitrogen atmosphere. The films were characterized n-type and the high resistivity was attributed to the polycrystalline nature of the films (E. Lakshmi, et al. *Thin Solid Films* 74, 77 (1977)).

In reactive ion molecular beam epitaxy, gallium was supplied from a standard effusion cell and nitrogen was supplied by way of an ionized beam. Monocrystalline films were characterized n-type, but higher resistivities of $10^6 \text{ } \Omega \cdot \text{cm}$ and relatively low carrier concentrations and mobilities (10^{14} cm^{-3} and $1\text{--}10 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$, respectively) were obtained (R. C. Powell, et al. in "Diamond, Silicon Carbide and Related Wide Bandgap Semiconductors" Vol. 162, edited by J. T. Glass, R. Messier and N. Fujimori (Material Research Society, Pittsburgh, 1990) pp.525–530).

The only reported p-type GaN was a Mg-doped GaN treated after growth with low energy electron beam irradiation. P-type conduction was accomplished by compensation of n-type GaN (H. Areario et al. *Jap. J Appl. Phys.* 28(12), L2112–L2114 (1989)).

Current methods of preparing GaN do not permit control of nitrogen vacancies within the lattice. Thus it has not been

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possible to prepare intrinsic GaN. Additionally, it is desirable to control the doping process in GaN films, thereby enabling the production of p-n junctions. The present invention presents a method to prepare near-intrinsic monocrystalline GaN films and to selectively dope these films n- or p-type.

SUMMARY OF THE INVENTION

The method according to this invention for preparing highly insulating near-intrinsic monocrystalline GaN films uses ECR-assisted MBE. In a preferred embodiment, a molecular beam source of Ga and an activated nitrogen source is provided within an MBE growth chamber. The desired substrate is exposed to Ga and activated nitrogen. A film is epitaxially grown in a two step process comprising a low temperature nucleation step and a high temperature growth step. The nucleation step preferably occurs by exposure of the substrate to gallium and a nitrogen plasma at a temperature in the range of $100^\circ\text{--}400^\circ \text{ C}$. and the high temperature growth step is preferably carried out in the temperature range of $600^\circ\text{--}900^\circ \text{ C}$. Preferred substrates include, but are not limited to, (100) and (111) silicon and (0001), (11-20) and (1-102) sapphire, (111) and (100) gallium arsenide, magnesium oxide, zinc oxide and silicon carbide. The preferred source of activated nitrogen species is a nitrogen plasma which can be generated by electron cyclotron resonance microwave plasma or a hot tungsten filament or other conventional methods.

In a preferred embodiment, the nitrogen plasma pressure and Ga flux pressure are controlled, thus preventing the bearing of metallic gallium on the film surface and the forming of nitrogen vacancies within the lattice. The Ga flux is preferably in the range of $2.0\text{--}5.0 \times 10^{-7}$ torr. There is preferably an overpressure of nitrogen in the growth chamber, more preferably in the range of $10^{-3}\text{--}10^{-5}$ torr.

In yet another preferred embodiment, the low temperature nucleation step includes exposure of the substrate to Ga and nitrogen for a period of time in the range of 3–15 minutes. A film with a thickness of 200–500 Å is deposited, which is amorphous at the low temperatures of the nucleation step. The amorphous film can be crystallized by heating at $600^\circ\text{--}900^\circ \text{ C}$. in the presence of activated nitrogen. Subsequent treatment at higher temperatures, preferably $600^\circ\text{--}900^\circ \text{ C}$., results in the epitaxial growth of monocrystalline near-intrinsic GaN film. Preferred thickness of the growth layer is in the range of 0.5–10 μm .

In another aspect of this invention, the monocrystalline GaN film is preferentially doped n- or p-type. To generate a p-type semiconductor, the MBE growth chamber is equipped with Ga, activated nitrogen and acceptor sources. Acceptor sources include Group II elements such as Be, Zn, Cd, and Ca. The substrate is bombarded with electrons either by applying a positive bias to the substrate surface or a metal grid placed directly in front of the substrate. Conditions for low and high temperature deposition are as described above. Exposing the substrate to Ga, nitrogen and acceptor sources results in a doped GaN film, whereby the acceptor takes on an electron and is incorporated into the lattice as a negatively charged species. A charged acceptor species requires less energy to incorporate into the GaN lattice than a neutral acceptor. To dope the material n-type the substrate is bombarded with positive ions by biasing either the substrate or the grid negatively. Thus, the donor impurities incorporate into the GaN in their charged state. This requires less energy than to incorporate a neutral donor species. Suitable donors include Groups IV and VI elements.

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Practice of this invention affords near-intrinsic GaN films with resistivities of up to 10^{10} ohms-cm and mobilities of $100 \text{ cm}^2 \text{V}^{-1} \text{s}^{-1}$ at 200°C . P-type and n-type semiconductors can be selectively prepared simply by choice of surface or grid bias and impurity source. It is possible to efficiently manufacture p-n junctions using the methods of this invention,

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a cross-sectional view of an ECR-assisted MBE growth chamber.

FIG. 2a is an X-ray diffraction pattern from a GaN film on (11-20) sapphire grown from a one-step process.

FIG. 2b is an X-ray diffraction pattern from a GaN film on (11-20) sapphire grown from a two-step process.

FIG. 3 is a schematic illustration of the method for doping GaN films.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The unintentional doping of GaN has been attributed to the formation of nitrogen vacancies in the GaN lattice. GaN decomposes (and loses nitrogen) at about 650°C ., well below the processing temperatures of the above processes ($>10000^\circ \text{C}$.). Therefore, the growth process itself provides sufficient thermal energy for vacancy formation. Growth processes at lower temperatures should reduce the number of nitrogen vacancies in the lattice, prevent the unintentional n-type doping of the GaN lattice and result in intrinsic GaN.

The practice of the present invention forms GaN at significantly lower processing temperatures using an activated nitrogen source. An ECR microwave nitrogen plasma is the preferred activated nitrogen source. A two step heating process permits the formation of monocrystalline GaN at lower processing temperatures.

The ECR-MBE system used in this invention is shown in FIG. 1. An ECR-system 10 was integrated with an MBE system 11 by attaching the ECR system 10 to an effusion pert 12. The ECR system includes a microwave generator 13, a waveguide 14, a high vacuum plasma chamber 15, and two electromagnets 16 and 17. The microwaves at 2.43 GHz are created in the microwave generator 13 and travel down the rectangular waveguide 14. The microwave power (100–500 W) passes from the waveguide 14 into the plasma chamber 15. Nitrogen flows into the plasma chamber 15 through a mass flow controller 18. The mass flow controller 18 maintains an adjustable constant flow rate. The plasma chamber 15 is surrounded by the two electromagnets 16 and 17. The upper magnet 16 is powered by a 2 kW power supply (not shown) and the lower magnet 17 is powered by a 5 kW power supply (not shown). Positioning of the electromagnets in this way results in a more intense and stable plasma.

The upper electromagnet 16 sets the free electrons in the chamber 15 into cyclotron orbits. The cyclotron frequency is dependent upon the strength of the magnetic field and the electron charge-to-mass ratio. Since all the electrons assume cyclotron orbits, the energy lost in random motion and collisions is reduced. Additionally, the plasma will be confined to the center of the chamber 15. The magnetic field is adjusted such that the frequency of oscillation of the microwaves is exactly equal to the cyclotron frequency of the electrons. N_2 is then introduced into the chamber through the mass flow controller 18 and is decomposed to high energy atomic and ionic nitrogen species by impact with the high

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energy electrons. The lower electromagnet 17 then guides the ions through the effusion pert 12 towards a substrate 19 which is positioned on a continuous azimuthal rotation (C.A.R.) unit 20 in a growth chamber 21 of the MBE system 11. The C.A.R. 20 can be rotated between 0 and 120 rpm. On certain substrates, GaN films grow in the wurtzitic structure and on others in the zincblende structure. Such substrates include for example sapphire (GaN in wurtzitic structure) and Si(100) (GaN in the zincblende structure). Gallium flux is generated in a Knudsen effusion cell 22.

In a typical process, the substrate 19 was sputter-etched by the nitrogen plasma at 600°C . The substrate was cooled down to 270°C . in the presence of the nitrogen plasma. A Ga shutter 23 was then opened to deposit the initial buffer layer of GaN. The use of an activated nitrogen source permitted the deposition of GaN at this low temperature. The buffer layer was allowed to nucleate over ten minutes and then the Ga shutter 23 was closed to stop the nucleation of the film. The substrate was then brought slowly to 600°C . at the rate of 4°C . every 15 seconds in the presence of the nitrogen plasma. The nitrogen overpressure also helped reduced the formation of nitrogen vacancies.

Once at 600°C ., the substrate 19 was kept at this temperature for 30 minutes in the presence of nitrogen plasma to ensure that the GaN buffer layer had crystallized. The Ga shutter 23 was opened once again to grow the GaN monocrystalline film. The thickness of the film was about 1 μm , although in theory there is no limitation to film thickness. Nitrogen pressure and gallium flux are kept constant during the entire process.

The two step growth process allows for the nucleation of a buffer layer. The buffer layer is grown at a temperature in the range of 100° – 400°C . Because the temperature is low, the probability of nitrogen vacancy formation is reduced. As the temperature increases to 600°C ., the amorphous film crystallizes. Any further growth takes place on the crystallized GaN buffer layer. The films grown by this two step process are superior to those grown by a one step growth process.

FIG. 2 shows the X-ray diffraction (XRD) pattern of a GaN film grown on the α -plane of sapphire (11-20) in a one-step process (FIG. 2a) and a two-step process (FIG. 2b). The two peaks at ca. $2\theta=35^\circ$ of FIG. 2a are attributed to a defective GaN crystal. FIG. 2b has a single peak indicating a film of better quality. This is because the majority of the film grows on the top of the GaN buffer and does not see the underlying substrate. The growth layer of GaN "recognizes" the GaN buffer layer and on which it can grow without defects. The buffer is the only part of the film which is highly defective.

Films grown by the method described above were highly resistive at room temperature ($10^{10} \Omega\text{-cm}$). The mobility of this material is $10 \text{ cm}^2 \text{V}^{-1} \text{s}^{-1}$, a reasonable value compared to the theoretic mobility of intrinsic GaN 330 which is $\Omega\text{-cm}^{-3}$.

GaN films are doped n-type or p-type by incorporating the proper impurities in their charged state. This is because the energy to incorporate a charged impurity into the lattice is lower than the energy needed to incorporate a neutral impurity. FIG. 3 is a schematic illustration of the doping of a charged acceptor into the GaN lattice. The substrate 19 or a grid 19a directly in front of it is positively biased. FIG. 3 shows both substrate 19 and grid 19a connected to a voltage source. In practice of this invention, either substrate 19 or grid 19a would be positively biased. Electrons are therefore attracted to the substrate surface, while positive ions such as

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N⁺ are repelled. The growth process is carried out as described above with addition of an acceptor source 24 so that Ga, nitrogen and acceptor are deposited on the electron-rich surface of the substrate. As the acceptor atom approaches the surface, it takes on an electron and is incorporated into the lattice as a negative species, the energy of incorporation being lower than that of the neutral acceptor species. The same procedure is used to dope the GaN lattice with donor impurities, except that a negative bias is used on the substrate or the grid. Alternately, a charged surface can be generated by bombarding the substrate with electrons or positive ions. Electron guns and ion guns, respectively, are conventional sources of these species.

Suitable acceptor species include, but are not limited to, zinc, magnesium, beryllium, and calcium. Suitable donor species include, but are not limited to, silicon, germanium, oxygen, selenium and sulfur.

What is claimed is:

1. A semiconductor device comprising:

a substrate, said substrate consisting of a material selected from the group consisting of (100) Silicon, (111) silicon, (0001) sapphire, (11-20) sapphire, (1-102) sapphire, (111) gallium arsenide, (100) gallium arsenide, magnesium oxide, zinc oxide and silicon carbide;

a non-single crystalline buffer layer having a thickness of about 30 Å to about 500 Å, comprising a first material grown on said substrate, the first material consisting essentially of gallium nitride; and

a first growth layer grown on the buffer layer, the first growth layer comprising gallium nitride and a first dopant material.

2. The semiconductor device of claim 1 further comprising:

a second growth layer grown on the first growth layer, the second growth layer comprising gallium nitride and a second dopant material.

3. The semiconductor device of claim 1 wherein the buffer layer is grown at a first temperature and wherein the first growth layer is grown at a second temperature higher than the first temperature.

4. The semiconductor device of claim 3 wherein the first temperature is in the range of about 100° C. to about 400° C.

5. The semiconductor device of claim 3 wherein the second temperature is in the range of about 600° C. to about 900° C.

6. The semiconductor device of claim 1 wherein the buffer layer is grown by exposing the substrate to gallium and nitrogen at the first temperature for about 3 to about 15 minutes.

7. The semiconductor device of claim 1 wherein the first dopant material is a donor.

8. A semiconductor device comprising:

a substrate, said substrate consisting of a material selected from the group consisting of (100) silicon, (111) silicon, (0001) sapphire, (11-20) sapphire, (1-102) sapphire, (111) gallium arsenide, (100) gallium arsenide, magnesium oxide, zinc oxide and silicon carbide;

a non-single crystalline buffer layer, comprising a first material grown on said substrate, the first material consisting essentially of gallium nitride;

a first growth layer grown on the buffer layer, the first growth layer comprising gallium nitride and an acceptor dopant material;

a second growth layer grown on the first growth layer, the second growth layer comprising gallium nitride and a donor dopant material.

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9. A semiconductor device comprising:

a substrate, said substrate consisting of a material selected from the group consisting of (100) silicon, (111) silicon, (0001) sapphire, (11-20) sapphire, (1-102) sapphire, (111) gallium arsenide, (100) gallium arsenide, magnesium oxide, zinc oxide and silicon carbide;

a non-single crystalline buffer layer, comprising a first material grown on said substrate, the first material consisting essentially of gallium nitride;

a first growth layer grown on the buffer layer, the first growth layer comprising gallium nitride and a first dopant material;

a second growth layer grown on the first growth layer, the second growth layer comprising gallium nitride and a second dopant material; and

wherein the first growth layer comprises a first conductivity type and the second growth layer comprises the opposite conductivity type.

10. The semiconductor device of claim 9 wherein the first conductivity type is n-type.

11. A semiconductor device comprising:

a substrate, said substrate consisting of a material selected from the group consisting of (100) silicon, (111) silicon, (0001) sapphire, (11-20) sapphire, (1-102) sapphire, (111) gallium arsenide, (100) gallium arsenide, magnesium oxide, zinc oxide and silicon carbide;

a non-single crystalline buffer layer, comprising a first material grown on said substrate, the first material consisting essentially of gallium nitride;

a first growth layer grown on the buffer layer, the first growth layer comprising gallium nitride and a first dopant material;

wherein the buffer layer is a recrystallized, partially amorphous layer.

12. The semiconductor device of claim 3 wherein the buffer layer is a recrystallized, partially amorphous layer.

13. A semiconductor device comprising:

a substrate, said substrate consisting of a material selected from the group consisting of (100) silicon, (111) silicon, (0001) sapphire, (11-20) sapphire, (1-102) sapphire, (111) gallium arsenide, (100) gallium arsenide, magnesium oxide, zinc oxide and silicon carbide;

a non-single crystalline buffer layer, comprising a first material grown on said substrate, the first material comprising gallium nitride; and

a near intrinsic gallium nitride layer grown on the buffer layer and having a resistivity of greater than 10⁸ Ω-cm. at room temperature.

14. The semiconductor device of claim 13, wherein the near intrinsic gallium nitride layer has a resistivity in the range of about 10⁸ Ω-cm to about 10¹² Ω-cm at room temperature.

15. A semiconductor device having an activated p-type layer comprising:

a substrate, said substrate consisting of a material selected from the group consisting of (100) silicon, (111) silicon, (0001) sapphire, (11-20) sapphire, (1-102) sapphire, (111) gallium arsenide, (100) gallium arsenide, magnesium oxide, zinc oxide and silicon carbide;

a non-single crystalline buffer layer having a thickness of about 30 Å to about 500 Å comprising a first material grown on said substrate, the first material consisting essentially of gallium nitride; and

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an activated p-type growth layer comprising gallium nitride and an acceptor dopant material formed without the use of a post-growth activation step.

16. A semiconductor device comprising:

a substrate, said substrate consisting of a material selected from the group consisting of (100) silicon, (0001) silicon, (0001) sapphire, (11-20) sapphire, (1-102) sapphire, (111) gallium arsenide, (100) gallium arsenide, magnesium oxide, zinc oxide and silicon carbide;

a non-single crystalline buffer layer having a thickness of about 30 Å to about 500 Å grown on the substrate and comprising a first material consisting essentially of a Group III nitride grown at a temperature of about 100° C. to about 400° C. from a molecular Group III source and an activated nitrogen source in a molecular beam epitaxial growth chamber; and

a first growth layer grown on the buffer layer and comprising gallium nitride and a first dopant material, the first growth layer being grown at a temperature of at least about 600° C. from a molecular gallium source and an activated nitrogen source in a molecular beam epitaxial growth chamber.

17. The semiconductor device of claim 16 wherein the Group III nitride is gallium nitride.

18. A semiconductor device comprising:

a substrate, said substrate consisting of a material selected from the group consisting of (100) silicon, (111) silicon, (0001) sapphire, (11-20) sapphire, (1-102) sapphire, (111) gallium arsenide, (100) gallium arsenide, magnesium oxide, zinc oxide and silicon carbide;

a non-single crystalline buffer layer having a first thickness, comprising a first material grown on said substrate, the first material consisting essentially of gallium nitride; and

a growth layer grown on the buffer layer having a second thickness which is at least ten times greater than the first thickness, the growth layer comprising gallium nitride and a first dopant material.

19. A semiconductor device comprising:

a substrate, said substrate consisting of a material selected from the group consisting of (100) silicon, (111)

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silicon, (0001) sapphire, (11-20) sapphire, (1-102) sapphire, (111) gallium arsenide, (100) gallium arsenide, magnesium oxide, zinc oxide and silicon carbide;

a non-single crystalline buffer layer, comprising a first material grown on said substrate, the first material consisting essentially of gallium nitride; and

a growth layer grown on the buffer layer, the growth layer comprising gallium nitride and a first dopant material.

20. A semiconductor device having an activated p-type layer comprising:

a substrate, said substrate consisting of a material selected from the group consisting of (100) silicon, (111) silicon, (0001) sapphire, (11-20) sapphire, (1-102) sapphire, (111) gallium arsenide, (100) gallium arsenide, magnesium oxide, zinc oxide and silicon carbide;

a non-single crystalline buffer layer, comprising a material grown on said substrate, the material consisting essentially of gallium nitride; and

an activated p-type growth layer comprising gallium nitride and a dopant material formed without the use of a post-growth activation step.

21. A semiconductor device comprising:

a substrate, said substrate consisting of a material selected from the group consisting of (100) silicon, (111) silicon, (0001) sapphire, (11-20) sapphire, (1-102) sapphire, (111) gallium arsenide, (100) gallium arsenide, magnesium oxide, zinc oxide and silicon carbide;

a non-single crystalline buffer layer grown on the substrate and comprising a material consisting essentially of a Group III nitride grown at a temperature of about 100° C. to about 400° C. from a molecular Group III source and an activated nitrogen source in a molecular beam epitaxial growth chamber; and

a growth layer grown on the buffer layer and comprising gallium nitride and a first dopant material, the growth layer being grown at a temperature of at least about 600° C. from a molecular gallium source and an activated nitrogen source in a molecular beam epitaxial growth chamber.

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EXHIBIT B

Exhibit B – List of Epistar InGaN LED Part Numbers

4711HC-QR-AU	ES-AADBHG85	ES-CABLV45B	ES-CAGHV15M	ES-CEBHV15B
4711HC-R-AU	ES-AADBHV45	ES-CABLV45C	ES-CAGHV24A	ES-CEBHV18A-M
4713DC	ES-AADBHV45B	ES-CABLV45F	ES-CAGHV31	ES-CEBHV19A
4713DC(Z)	ES-AEBHHD10A	ES-CABLV45H	ES-CAGHV35	ES-CEBHV20
4713DC-AU	ES-AEBLHD10A	ES-CABLV45J	ES-CAGHV45A	ES-CEBHV20A
4713HC-QR-AU	ES-AEGHHD10A	ES-CABLV45K	ES-CAGHV45L	ES-CEBHV23A
4713HC-R-AU	ES-BNSA114	ES-CABLV45P	ES-CAGLV35	ES-CEBHV24
4T11AC-R-AU	ES-BNSA116	ES-CABLV45Q	ES-CALVV18B	ES-CEBHV24A-M
4T13GC-QR-AU	ES-BNSA11A	ES-CABLV50	ES-CALVV20L	ES-CEBHV27A
4T13GC-R-AU	ES-CABEV45H	ES-CABLV54B	ES-CALVV20Q	ES-CEBHV30
4T14CC-R-AU	ES-CABHV09B	ES-CADBAC55	ES-CALVV20R	ES-CEBHV30F
4T15AC-QR-AU	ES-CABHV14F	ES-CADBAC55B	ES-CALVV24Q	ES-CEBHV40
4T15AC-R-AU	ES-CABHV15M	ES-CADBAF40	ES-CALVV25A	ES-CEBHV40A-M
4T18AC-R-AU	ES-CABHV18	ES-CADBV09B	ES-CEBE710A	ES-CEBHV45
4T24AC-R-AU	ES-CABHV24B	ES-CADBV11C	ES-CEBE712	ES-CEBL710A
4T30AC-R-AU	ES-CABHV24H	ES-CADBV14C	ES-CEBE712C	ES-CEBL712
4T35AC-R-AU	ES-CABHV35	ES-CADBV14F	ES-CEBEM10A	ES-CEBL712C
4T35AC-TR-AU	ES-CABHV35A	ES-CADBV14H	ES-CEBEM12A	ES-CEBL713
4T40BC-R-AU	ES-CABHV38	ES-CADBV15M	ES-CEBEM13	ES-CEBL912
4T40BC-RE-AU	ES-CABHV45B	ES-CADBV17A	ES-CEBEV15	ES-CEBLAE47
4T40BF	ES-CABHV45C	ES-CADBV17B	ES-CEBH708	ES-CEBLJ08A
4T40CC-R-AU	ES-CABHV45F	ES-CADBV18	ES-CEBH710A	ES-CEBLJ09A
4T40DF-R	ES-CABHV45H	ES-CADBV18B	ES-CEBH712	ES-CEBLJ12
4T40DF-R-4	ES-CABHV45J	ES-CADBV18C	ES-CEBH712C	ES-CEBL07
4T40DF-R-8	ES-CABHV45P	ES-CADBV20F	ES-CEBH713	ES-CEBL07A
4T40EF-R	ES-CABHV54B	ES-CADBV20G	ES-CEBH912	ES-CEBL07C
5G11HC-QR-AU	ES-CABLAC55	ES-CADBV20K	ES-CEBHJ08A	ES-CEBL08A
5G11HC-R-AU	ES-CABLAC55B	ES-CADBV20L	ES-CEBHJ09A	ES-CEBL08B
5G13DC	ES-CABLAF40	ES-CADBV20Q	ES-CEBHJ12	ES-CEBL08C
5G13HC-QR-AU	ES-CABLV09B	ES-CADBV20R	ES-CEBHL07	ES-CEBL08C
5G13HC-R-AU	ES-CABLV10A	ES-CADBV20S	ES-CEBHL07A	ES-CEBL08C
5T11AC-R-AU	ES-CABLV11C	ES-CADBV22A	ES-CEBHL07C	ES-CEBL08C
5T13GC-QR-AU	ES-CABLV14C	ES-CADBV23F	ES-CEBHL08A	ES-CEBL08C
5T13GC-R-AU	ES-CABLV14F	ES-CADBV24B	ES-CEBHL08B	ES-CEBL08C
5T14CC-R-AU	ES-CABLV14H	ES-CADBV24G	ES-CEBHL08C	ES-CEBL08C
5T15AC-QR-AU	ES-CABLV15M	ES-CADBV24H	ES-CEBHM07	ES-CEBL08C
5T24AC-R-AU	ES-CABLV17A	ES-CADBV24J	ES-CEBHM07A	ES-CEBL08C
5T30AC-R-AU	ES-CABLV18	ES-CADBV24K	ES-CEBHM08A	ES-CEBL08C
5T40BC-R-AU	ES-CABLV18C	ES-CADBV24Q	ES-CEBHM08B	ES-CEBL08C
5T40BF	ES-CABLV20G	ES-CADBV24R	ES-CEBHM09	ES-CEBL08C
5T40DF-R	ES-CABLV20K	ES-CADBV25A	ES-CEBHM10A	ES-CEBL08C
5T40DF-R-4	ES-CABLV20L	ES-CADBV26A	ES-CEBHM12A	ES-CEBL08C
5T40DF-R-8	ES-CABLV20R	ES-CADBV27A	ES-CEBHM12B	ES-CEBL08C
9T40AF-R-4	ES-CABLV20S	ES-CADBV30A	ES-CEBHM13	ES-CEBL08C
9T40AF-R-8	ES-CABLV23F	ES-CADBV33B	ES-CEBHV05A	ES-CEBL08C
B2708SB1E7L1	ES-CABLV24B	ES-CADBV33C	ES-CEBHV08A	ES-CEBL08C
ES-AABLHF40	ES-CABLV24G	ES-CADBV35	ES-CEBHV08B	ES-CEBL08C
ES-AABLHG38	ES-CABLV24H	ES-CADBV35A	ES-CEBHV08C	ES-CEBL08C
ES-AABLHG38B	ES-CABLV24J	ES-CADBV38	ES-CEBHV09F	ES-CEBL08C
ES-AABLHG38C	ES-CABLV24K	ES-CADBV45B	ES-CEBHV10A	ES-CEBL08C
ES-AABLHG50	ES-CABLV24R	ES-CADBV45C	ES-CEBHV10B	ES-CEBL08C
ES-AABLHG85	ES-CABLV25A	ES-CADBV45F	ES-CEBHV10F	ES-CEBL08C
ES-AABLHV45	ES-CABLV27A	ES-CADBV45H	ES-CEBHV10J	ES-CEBL08C
ES-AABLHV45B	ES-CABLV30A	ES-CADBV45J	ES-CEBHV10R	ES-CEBL08C
ES-AADBHF40	ES-CABLV33B	ES-CADBV45K	ES-CEBHV10S	ES-CEBL08C
ES-AADBHG38	ES-CABLV33C	ES-CADBV45P	ES-CEBHV10Z	ES-CEBL08C
ES-AADBHG38B	ES-CABLV35	ES-CADBV45Q	ES-CEBHV13	ES-CEBL08C
ES-AADBHG38C	ES-CABLV35A	ES-CADBV50	ES-CEBHV15	ES-CEBL08C
ES-AADBHG50	ES-CABLV38	ES-CADBV54B	ES-CEBHV15A-M	ES-CEBL08C

Exhibit B – List of Epistar InGaN LED Part Numbers

ES-CEBLV10Y	ES-CEDBV10J	ES-CEGHV30	ES-EABLF20A	ES-EADBF22C
ES-CEBLV10Z	ES-CEDBV10K	ES-CEGHV30A-M	ES-EABLF20B	ES-EADBF22F
ES-CEBLV11A	ES-CEDBV10Q	ES-CEGHV30F	ES-EABLF20C	ES-EADBF23B
ES-CEBLV11B	ES-CEDBV10R	ES-CEGHV32A	ES-EABLF20G	ES-EADBF23C
ES-CEBLV11C	ES-CEDBV10S	ES-CEGHV40A-M	ES-EABLF20H	ES-EADBF23F
ES-CEBLV12A	ES-CEDBV10Y	ES-CEGHV42	ES-EABLF21B	ES-EADBF24
ES-CEBLV13	ES-CEDBV10Z	ES-CEGHV42A	ES-EABLF22A	ES-EADBF24C
ES-CEBLV13A	ES-CEDBV11A	ES-CEGHV45	ES-EABLF22C	ES-EADBF26A
ES-CEBLV14A	ES-CEDBV11B	ES-CEGL712	ES-EABLF22F	ES-EADBF26C
ES-CEBLV15	ES-CEDBV11C	ES-CEGL912	ES-EABLF23B	ES-EADBF26F
ES-CEBLV15A-M	ES-CEDBV12A	ES-CEGLJ08A	ES-EABLF23C	ES-EADBF26H
ES-CEBLV15M	ES-CEDBV13	ES-CEGLJ09A	ES-EABLF23F	ES-EADBF28A
ES-CEBLV17A	ES-CEDBV14A	ES-CEGLL08A	ES-EABLF24	ES-EADBF30A
ES-CEBLV18A-M	ES-CEDBV15	ES-CEGLL08B	ES-EABLF26A	ES-EADBF33
ES-CEBLV19A	ES-CEDBV15A-M	ES-CEGLM12A	ES-EABLF26G	ES-EADBF33A
ES-CEBLV20	ES-CEDBV17A	ES-CEGLM13	ES-EABLF30A	ES-EADBF45
ES-CEBLV20A	ES-CEDBV18A-M	ES-CEGLV15	ES-EABLF33	ES-EADBF45B
ES-CEBLV20P	ES-CEDBV20	ES-CEGLV15A-M	ES-EABLF33A	ES-EADBF45C
ES-CEBLV22	ES-CEDBV20A	ES-CEGRM09	ES-EABLF45	ES-EADBF45F
ES-CEBLV23A	ES-CEDBV20P	ES-CEGRV15	ES-EABLF45B	ES-EADBF45G
ES-CEBLV23B	ES-CEDBV22	ES-CEGRV15A-M	ES-EABLF45C	ES-EADBF50
ES-CEBLV24	ES-CEDBV22B	ES-CEGRV45	ES-EABLF45F	ES-EADBF50B
ES-CEBLV24A-M	ES-CEDBV23A	ES-CELVJ12	ES-EABLF45G	ES-EADBF60
ES-CEBLV27A	ES-CEDBV23B	ES-CELVV14A	ES-EABLF50	ES-EADBF60B
ES-CEBLV30	ES-CEDBV23C	ES-CELVV20	ES-EABLF50B	ES-EADBF60A
ES-CEBLV30A-M	ES-CEDBV24	ES-CELVV20P	ES-EABLF60	ES-EADBF60A
ES-CEBLV31	ES-CEDBV24A-M	ES-CELVV22B	ES-EABLF60B	ES-EADBF60A
ES-CEBLV40	ES-CEDBV24C	ES-CELVV23A	ES-EABLF60B	ES-EADBF60A
ES-CEBLV40A-M	ES-CEDBV24F	ES-CELVV23B	ES-EABLF60B	ES-EADBF60A
ES-CEBLV45	ES-CEDBV27A	ES-CELVV23C	ES-EABLF60B	ES-EADBF60A
ES-CEBLV45A	ES-CEDBV30	ES-CELVV24C	ES-EABLF60B	ES-EADBF60A
ES-CEBM712	ES-CEDBV31	ES-CELVV24F	ES-EABLF60B	ES-EADBF60A
ES-CEBMM10A	ES-CEDBV40A-M	ES-CELVV27A	ES-EABLF60B	ES-EADBF60A
ES-CEDB710A	ES-CEDBV45	ES-CESVM15	ES-EABLF60B	ES-EADBF60A
ES-CEDB712C	ES-CEGH712	ES-CESVM15 -M	ES-EABLF60B	ES-EADBF60A
ES-CEDBAE47	ES-CEGH712A	ES-CEUV930	ES-EABLF60B	ES-EADBF60A
ES-CEDBJ08A	ES-CEGH912	ES-CEUVM15	ES-EABLF60B	ES-EADBF60A
ES-CEDBJ09A	ES-CEGHJ08A	ES-CFBHM10A	ES-EABLF60B	ES-EADBF60A
ES-CEDBJ12	ES-CEGHJ09A	ES-CFBHM13	ES-EABLF60B	ES-EADBF60A
ES-CEDBL07	ES-CEGHL07A	ES-CFDBV05A	ES-EABLF60B	ES-EADBF60A
ES-CEDBL07A	ES-CEGHL07C	ES-CGBHM10A	ES-EABLF60B	ES-EADBF60A
ES-CEDBM08A	ES-CEGHL08A	ES-EABHF17A	ES-EABLF60B	ES-EADBF60A
ES-CEDBM09	ES-CEGHL08B	ES-EABHF23B	ES-EABLF60B	ES-EADBF60A
ES-CEDBM10A	ES-CEGHM08B	ES-EABHF45	ES-EABLF60B	ES-EADBF60A
ES-CEDBM12A	ES-CEGHM09	ES-EABHF45B	ES-EABLF60B	ES-EADBF60A
ES-CEDBM13	ES-CEGHM10A	ES-EABHF50	ES-EABLF60B	ES-EADBF60A
ES-CEDBV08A	ES-CEGHM12A	ES-EABHF50B	ES-EABLF60B	ES-EADBF60A
ES-CEDBV08B	ES-CEGHM13	ES-EABHF60	ES-EABLF60B	ES-EADBF60A
ES-CEDBV08C	ES-CEGHM13B	ES-EABHF60B	ES-EABLF60B	ES-EADBF60A
ES-CEDBV09F	ES-CEGHV05A	ES-EABLAC36B	ES-EABLF60B	ES-EADBF60A
ES-CEDBV09G	ES-CEGHV10B	ES-EABLAC36C	ES-EABLF60B	ES-EADBF60A
ES-CEDBV09K	ES-CEGHV13	ES-EABLF11B	ES-EABLF60B	ES-EADBF60A
ES-CEDBV09R	ES-CEGHV15	ES-EABLF11C	ES-EABLF60B	ES-EADBF60A
ES-CEDBV10A	ES-CEGHV15A-M	ES-EABLF11F	ES-EABLF60B	ES-EADBF60A
ES-CEDBV10C	ES-CEGHV15B	ES-EABLF11G	ES-EABLF60B	ES-EADBF60A
ES-CEDBV10D	ES-CEGHV18A-M	ES-EABLF14A	ES-EABLF60B	ES-EADBF60A
ES-CEDBV10F	ES-CEGHV20A	ES-EABLF14B	ES-EABLF60B	ES-EADBF60A
ES-CEDBV10G	ES-CEGHV24	ES-EABLF17A	ES-EABLF60B	ES-EADBF60A
ES-CEDBV10H	ES-CEGHV24A-M	ES-EABLF17B	ES-EABLF60B	ES-EADBF60A

Exhibit B – List of Epistar InGaN LED Part Numbers

ES-EEBLF11A	ES-FEGHF40AA	ES-WMBLV45B	ES-WXDBV10R	ES-YEGHL07A
ES-EEBLF11H	ES-FFBHM10C	ES-WQBAVNA	ES-WXDBV10S	ES-YEGHL07B
ES-EEBLF11K	ES-FFBLM10C	ES-WQBE3NA	ES-WXDBV10Z	ES-YEGHL07C
ES-EEBLF12A	ES-FFBLM10D	ES-WQBEVNA	ES-WXGHSP121	ES-YEGHL07G
ES-EEBLM09A	ES-MMBHSP120	ES-WQBH2NA	ES-WXGHV13	ES-YEGLL07A
ES-EEBLM09B	ES-MMBHSP121	ES-WQBH3NA	ES-WXGHV15	ES-YEGLL07B
ES-EEBLM22	ES-MMBHSP39A	ES-WQBH3NC	ES-WXGHV15B	ES-YEGLL07C
ES-EEBLV09C	ES-MMBHSP39B	ES-WQBHVNA	ES-WXLVL07B	ES-YEGLL07G
ES-EEBLV09H	ES-MMBHSP54A	ES-WQBHVNC	ES-WYUVM13A	ES-YELVF05B
ES-EEBLV09L	ES-MMBHSP54B	ES-WQBL2NA	ES-YABLAC55B	ES-YELVF07A
ES-EEBLV10P	ES-MMBHSP90A	ES-WQBL3NA	ES-YABLF11F	ES-YELVJ08A
ES-EEDBF05A	ES-MMBHSP90B	ES-WQBL3NC	ES-YABLV14G	ES-YELVL07A
ES-EEDBF08A	ES-MMGHSP121	ES-WQBLVNA	ES-YADBF11C	ES-YELVL07B
ES-EEDBF08C	ES-MMGHSP39B	ES-WQBLVNC	ES-YADBF11F	ES-YELVL07C
ES-EEDBF09A	ES-MMGHSP54B	ES-WQBM3NA	ES-YADBV24R	ES-YELVL07G
ES-EEDBF09C	ES-MMGHSP90B	ES-WQDB2NA	ES-YEBEL07A	ES-YELVV10F
ES-EEDBF09F	ES-PABLAC36B	ES-WQDB3NA	ES-YEBEL07B	ES-ZABLV45
ES-EEDBF10A	ES-PABLAC36C	ES-WQDB3NC	ES-YEBEM07	ES-ZABLV45C
ES-EEDBF10C	ES-PABLF45	ES-WQDBVNA	ES-YEBHF07A	ES-ZEBLL08A
ES-EEDBF11A	ES-PABLF50	ES-WQDBVNC	ES-YEBHJ12	ES-ZEBLV10F
ES-EEDBF11H	ES-PABLF60	ES-WQGH3NA	ES-YEBHL07A	ES-ZEBLV15
ES-EEDBF11J	ES-PADBF50	ES-WQGH3NC	ES-YEBHL07B	ES-ZEBLV23A
ES-EEDBF11K	ES-PEBLF50	ES-WQGHVNA	ES-YEBHL07C	ES-ZEGHV15
ES-EEDBF12A	ES-QABLAC36C	ES-WQGHVNC	ES-YEBHM07	ET-AED12PGG
ES-EEDBF23A	ES-SABHSN30	ES-WQGL3NA	ES-YEBHM07A	ET-AEDANDB
ES-EEDBM09A	ES-SABLSN30	ES-WQLV2NA	ES-YEBHV08A	ET-AEDANDBJ
ES-EEDBM09B	ES-SABLSN30A	ES-WQLV3NC	ES-YEBLF05B	ET-AEDANDBK
ES-EEDBM10B	ES-SABLSN45	ES-WQLVNA	ES-YEBLF06A	ET-AEDANDBL
ES-EEDBM10F	ES-SABLSN48	ES-WQLVVNC	ES-YEBLF07A	ET-AEDANDBM
ES-EEDBM22	ES-SABLSN50	ES-WQUV3NA	ES-YEBLF10A	ET-AEDANDBN
ES-EEDBV09C	ES-SADBSN30	ES-WVBH712	ES-YEBLJ08A	ET-AEDANNB
ES-EEDBV09H	ES-SADBSN30A	ES-WVBH712C	ES-YEBLJ12	ET-AEDANNBL
ES-EEDBV09L	ES-SADBSN45	ES-WXBEL07B	ES-YEBLL07A	ET-AEDANNBM
ES-EEDBV10P	ES-SADBSN48	ES-WXBHJ09A	ES-YEBLL07B	ET-AEDANNBN
ES-EELVF11A	ES-SADBSN50	ES-WXBHL07B	ES-YEBLL07C	ET-AEDANNBO
ES-EELVF23A	ES-SAYL814	ES-WXBHM10A	ES-YEBLL07G	ET-AEDANSB
ES-EQBA2NA	ES-SMGHPP1116A	ES-WXBHSP120	ES-YEBLM07	ET-AEDANSBH
ES-EQBE2NA	ES-TABLAC36B	ES-WXBHSP121	ES-YEBLM07A	ET-AEDANSBI
ES-EQBH2NA	ES-TABLAC36C	ES-WXBLJ08A	ES-YEBLM08B	ET-AEDANSBJ
ES-EQBL2NA	ES-TABLFV38	ES-WXBLJ09A	ES-YEBLV08A	ET-AEDANSBK
ES-EQBL2NC	ES-TABLFV38C	ES-WXBLL07B	ES-YEBLV10F	ET-AEDANSBL
ES-EQDB2NA	ES-TABLFV45	ES-WXBLV09F	ES-YEBLV10J	ET-BIX24DB
ES-EQDB2NC	ES-TADBAC36B	ES-WXBLV10F	ES-YEBLV10S	ET-BIZ24DBC
ES-EQLV2NA	ES-TADBAC36C	ES-WXBLV10J	ES-YEDBF05B	ET-BIZ24NBE
ES-EQSV2NA	ES-TADBFV38	ES-WXBLV10R	ES-YEDBF06A	ET-BIZ24NBE-
ES-EUSA116	ES-TADBFV38C	ES-WXBLV10S	ES-YEDBF07A	4GJ5B0
ES-EUSA11A	ES-TADBFV45	ES-WXBLV10Z	ES-YEDBJ08A	ET-CEY10DB
ES-FABLPE20A	ES-WEBHM10A	ES-WXBLV14A	ES-YEDBJ12	ET-CEY10DBD
ES-FABLPE45A	ES-WEBHVNA	ES-WXBLV15	ES-YEDBL07A	ET-CEY10DBE
ES-FADBPE20A	ES-WEBL3NA	ES-WXBLV20	ES-YEDBL07B	ET-CEY10DBF
ES-FADBPE38A	ES-WEBL9NA	ES-WXBLV20A	ES-YEDBL07C	ET-CEY10DBG
ES-FADBPE45A	ES-WEBLM10A	ES-WXBLV20L	ES-YEDBL07G	ET-CEY10DBH
ES-FEBHF40AA	ES-WEBLVNA	ES-WXBLV22B	ES-YEDBM07	ET-CEY10NB
ES-FEBL140AA	ES-WEDBVNA	ES-WXBLV23C	ES-YEDBV08A	ET-CEY10NBG
ES-FEBL540AA	ES-WEGHVNA	ES-WXBLV45C	ES-YEDBV10F	ET-CEY10PB
ES-FEBLC40AA	ES-WELVVNA	ES-WXBLV45H	ES-YEDBV10J	ET-CEY10PG
ES-FEBLG40AA	ES-WMBHM10A	ES-WXDBJ09A	ES-YEDBV10S	ET-CEY10PGE
ES-FEGH140AA	ES-WMBLV10F	ES-WXDBL07B	ES-YEDBV10W	ET-CEY10PGG
ES-FEGH640AA	ES-WMBLV15	ES-WXDBV10F	ES-YEDBV23A	ET-CEY10SB

Exhibit B – List of Epistar InGaN LED Part Numbers

ET-CEY10SBD	ET-LED40CBPM	ET-LPD40NBD-
ET-CEY10SBE	ET-LEXBJ4545B	4GM570
ET-CEY10TG	ET-LEZBJ4545B	ET-LPD40NBE
ET-CEY10TGD	ET-LID24DBB	ET-LPD40NBE-
ET-DED14DB	ET-LID24DBB-	4GM570
ET-DED14DBG	4GM570	ET-LPD40NBE-
ET-DED14DBH	ET-LID24DBC	4GM5B0
ET-DED14DBI	ET-LID24DBC-	ET-LPD40NBF-
ET-DED14DBJ	4GM570	4GM570
ET-DED14DBK	ET-LID24DBD-	ET-LPD40PBE-
ET-DED14DBL	4GM570	4GM570
ET-DED14DBM	ET-LID24NBB	ET-LPD40PGE
ET-DED14NB	ET-LID24NBB-	ET-LPD40PGE-
ET-DED14NBI	4GM520	4GJ530
ET-DED14NBJ	ET-LID24NBB-	ET-LPD40PGF-
ET-DED14NBK	4GM570	4GJ530
ET-DED14NBL	ET-LID24NBC	ET-LPD40PGG-
ET-DED14NBM	ET-LID24NBC-	4GJ540
ET-DED14NBN	4GM570	ET-LPD40PGG-
ET-DED14PB	ET-LID24NBD	4GJ570
ET-DED14PBL	ET-LID24NBD-	ET-LPD40PGG-
ET-DED14PBM	4GM570	4GJ590
ET-DED14PBN	ET-LID24PGC-	ET-LPD40PGH
ET-DED14PBO	4GJ570	ET-LPD40PGH-
ET-DED14SB	ET-LID24PGD	4GJ570
ET-DED14SBH	ET-LID24PGD-	ET-LPDBJ4545A
ET-DED14SBI	4GJ570	ET-LPDBJ4545B
ET-DEY14SBC	ET-LID24PGD-	ET-LPXBj4545A
ET-DEY14SBI	4GJ590	ET-LRD60NBD
ET-EED12DB	ET-LID24SBD-	ET-LRD60NBD-
ET-EED12DBG	4GM540	4GM560
ET-EED12DBH	ET-LMD30PGB	ET-REYBR0812A
ET-EED12DBI	ET-LMD30PGD-	ET-RPDBJ4545A
ET-EED12DBJ	4GJ570	ET-RPDBJ4545B
ET-EED12DBK	ET-LMD30PGE	ET-RPDBJ4545C
ET-EED12DBL	ET-LMD30PGE-	HDCKF20EBW
ET-EED12NB	4GJ580	IDAK909ABW
ET-EED12NBI	ET-LMD30PGE-	JDBKF23EBW
ET-EED12NBJ	4GJ5D0	MKO3131C452-9
ET-EED12NBK	ET-LPD40DBC	RDCHIP
ET-EED12NBL	ET-LPD40DBC-	RDCHIP-NC
ET-EED12NBM	4GM570	RDWAFER
ET-EED12NBN	ET-LPD40DBD	RECHIP
ET-EED12PB	ET-LPD40DBD-	RECHIP-LEY
ET-EED12PBM	4GM570	RECHIP-NC
ET-EED12PBN	ET-LPD40DBE-	REWAFER
ET-EED12SB	4GM570	REWAFER-NE
ET-EED12SBH	ET-LPD40DBF	RGB-8-CHIPS-
ET-EEY12DB	ET-LPD40DBF-	ARRAY
ET-EEY12DBE	4GM530	藍光磊晶片(UEC)
ET-EEY12DBG	ET-LPD40NBB-	
ET-EEY12DBH	4GM570	
ET-EEY12DBI	ET-LPD40NBC	
ET-EEY12NB	ET-LPD40NBC-	
ET-EEY12SB	4GM570	
ET-EEY12SBE	ET-LPD40NBC-	
ET-LED10PG	4GM5B0	
ET-LED14PGI	ET-LPD40NBD	
ET-LED14PGJ		