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 rate[3] 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 ofREDACTED 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).

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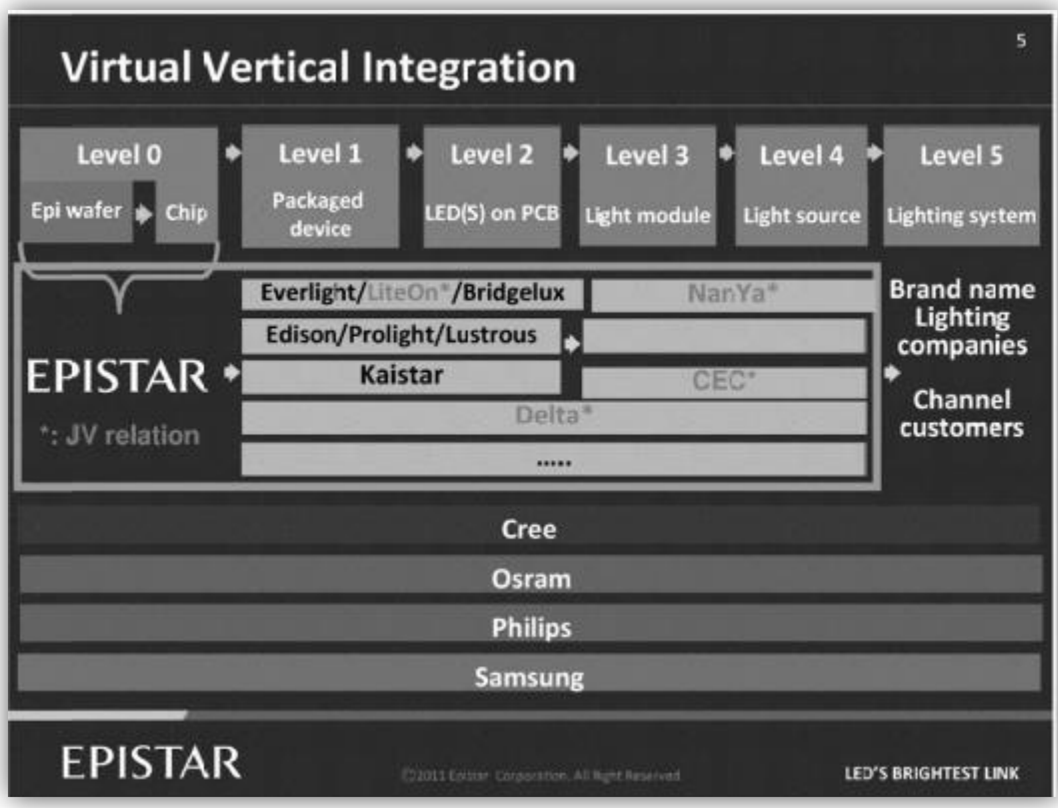
[5] This information can be found in the deposition transcript of Men-Chun Kuo ("Kuo Deposition") at 128:17-134:12. The Kuo Deposition was taken on May 1, 2014 in Hsinchu, Taiwan.

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

[7]

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REDACTED

:[8]

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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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[10]

[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 faciliate 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 rate[12] 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,

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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]

Moustakas

[11] Patent Number: 5,686,738

[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

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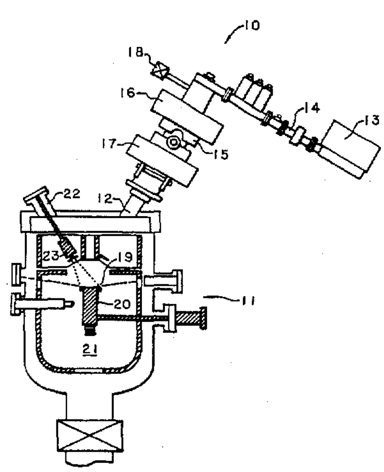
Primary Examiner—Jerome Jackson
Attorney, Agent, or Firm—Baker & Botts, L.L.P.

[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



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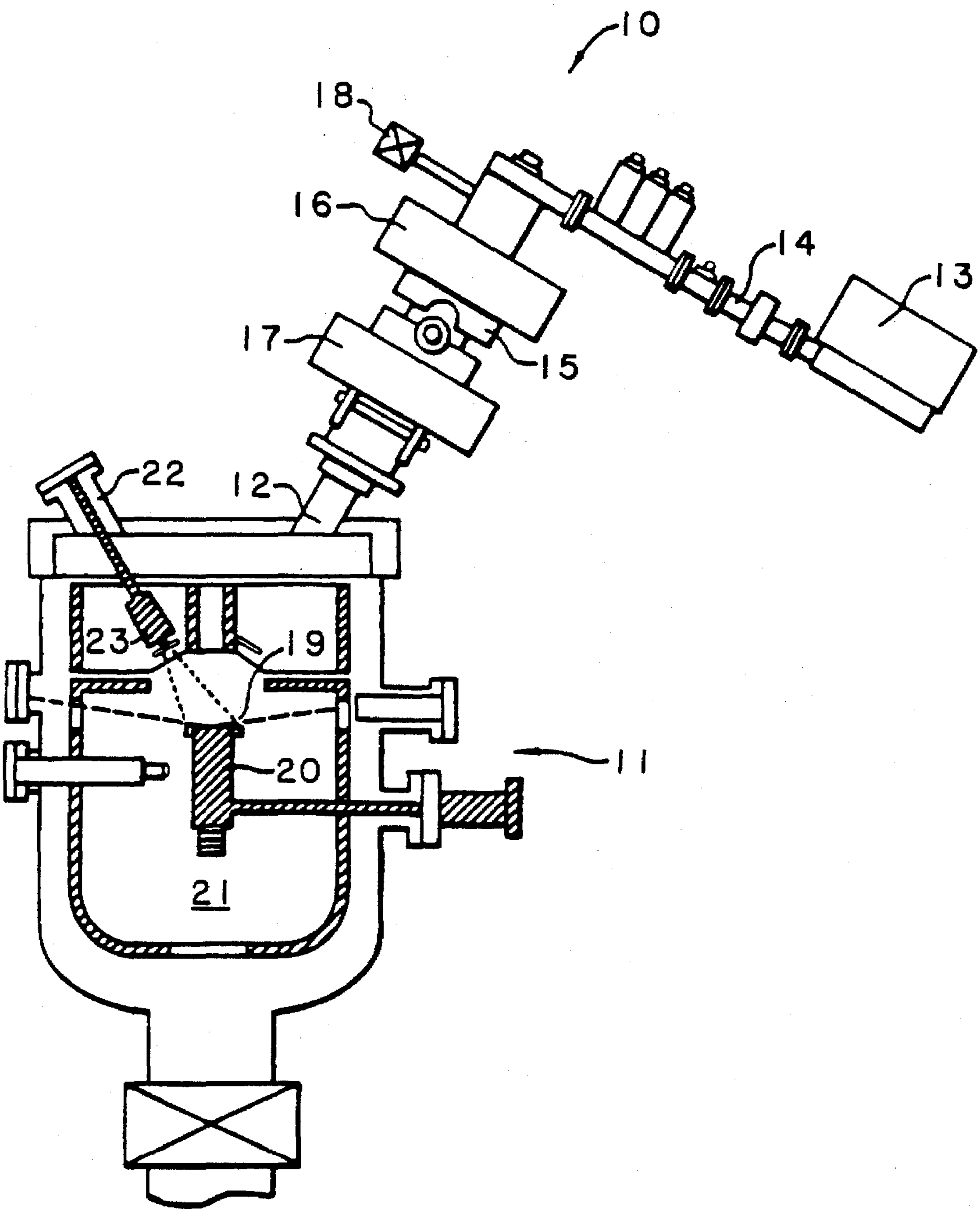

FIG. 1

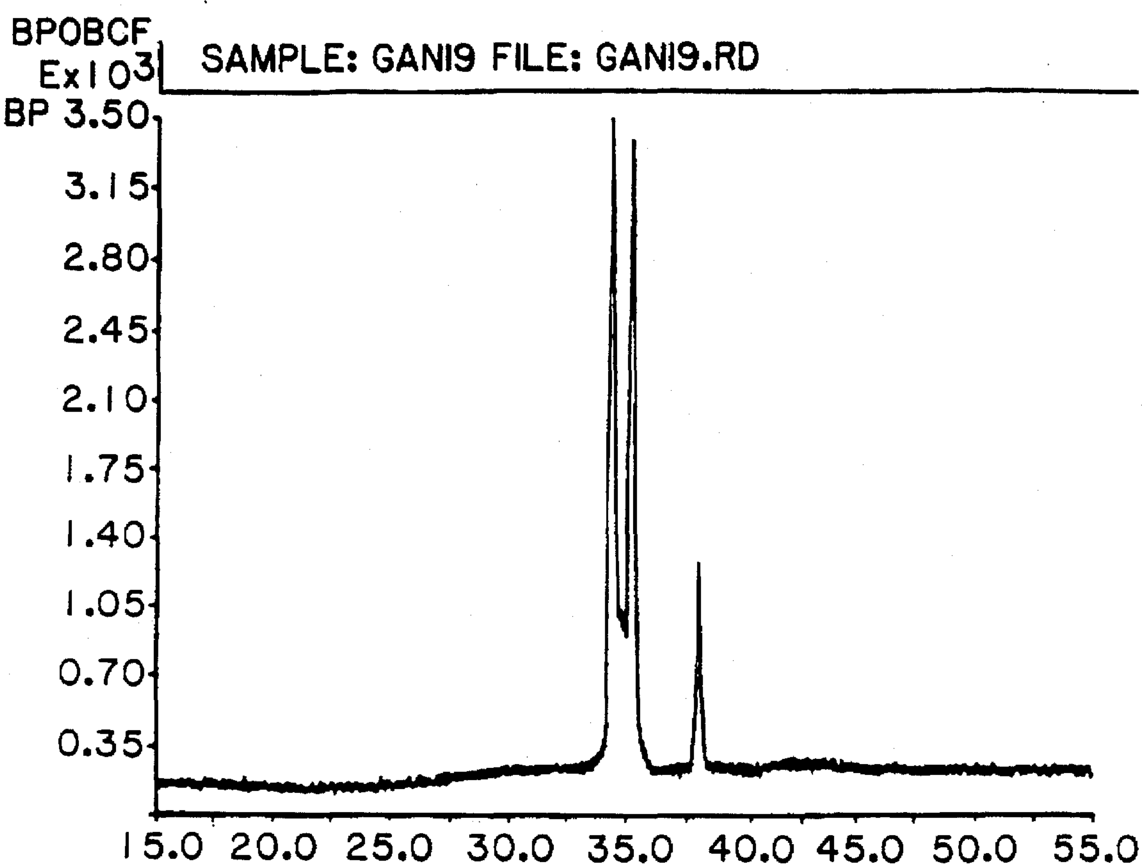
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FIG.2A

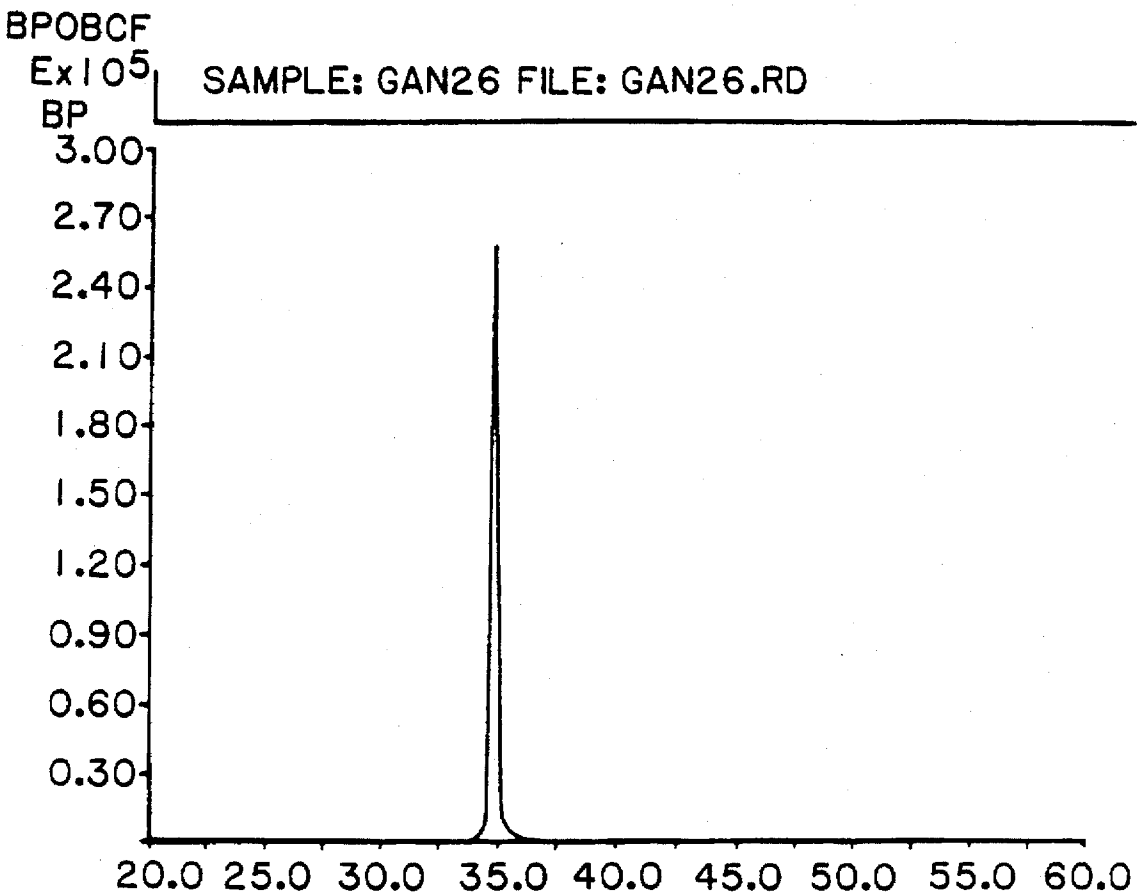
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FIG.2B

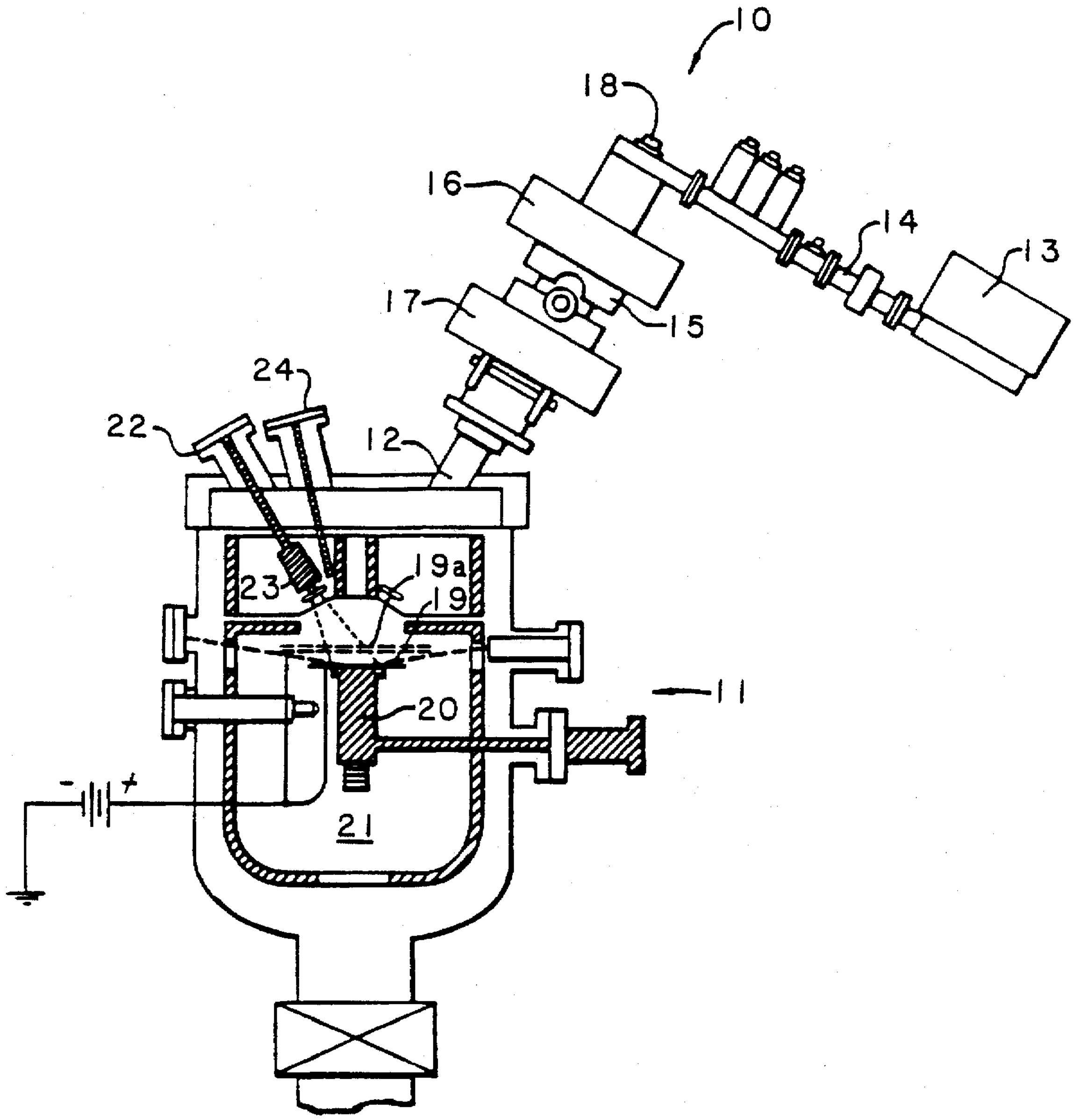

FIG.3

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 5.2×10^3 cm^{-3}, the mobility is 330 $cm^2V^{-1}s^{-1}$ and the resistivity is 3.6×10^{12} Ω-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 firms 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 1×10^{19} cm^{-3} and 50–100 $cm^2V^{-1}s^{-1}$, 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 Ω-cm and relatively low carrier concentrations and mobilities (10^{14} cm^{-3} and 1–10 $cm^2V^{-1}s^{-1}$, 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

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°–400° C. and the high temperature growth step is preferably carried out in the temperature range of 600°–900° 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 $2.0–5.0\times10^{-7}$ torr. There is preferably an overpressure of nitrogen in the growth chamber, more preferably in the range of $10^{-3}–10^{-5}$ 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°–900° C. in the presence of activated nitrogen. Subsequent treatment at higher temperatures, preferably 600°–900° 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.

Practice of this invention affords near-intrinsic GaN films with resistivities of up to 10^{10} ohms-cm and mobilities of 100 $cm^2V^{-1}s^{-1}$ 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. 2*a* is a an X-ray diffraction pattern from a GaN film on (11–20) sapphire grown from a one-step process.

FIG. 2*b* is a 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° 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 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. 2*a*) and a two-step process (FIG. 2*b*). The two peaks at ca. 2θ=35° of FIG. 2*a* are attributed to a defective GaN crystal. FIG. 2*b* 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} Ω-cm). The mobility of this material is 10 $cm^2V^{-1}s^{-1}$, 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 **19*a*** directly in front of it is positively biased. FIG. 3 shows both substrate **19** and grid **19*a*** connected to a voltage source. In practice of this invention, either substrate **19** or grid **19*a*** would be positively biased. Electrons are therefore attracted to the substrate surface, while positive ions such as

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 aresenide, (100) gallium aresenide, 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 aresenide. (100) gallium aresenide, 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.

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 aresenide, (100) gallium aresenide, magnesium oxide, zinc oxide and silicon carbide;

a non-single crystalline buffer layer, comprising a fast 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 aresenide, (100) gallium aresenide, 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 aresenide, (100) gallium aresenide, 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 $\mathbf{10^8}$ 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 10^8 Ω·cm to about 10^{12} 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 aresenide, (100) gallium aresenide, 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 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 aresenide, (100) gallium aresenide, 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 aresenide, (100) gallium aresenide, 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) silicon, (0001) sapphire, (11–20) sapphire, (1–102) sapphire, (111) gallium aresenide, (100) gallium aresenide, 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 aresenide, (100) gallium aresenide, 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 aresenide, (100) gallium aresenide, 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.

* * * * *

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-CEBLL07
4T40DF-R-8	ES-CABHV45P	ES-CADBV20F	ES-CEBH713	ES-CEBLL07A
4T40EF-R	ES-CABHV54B	ES-CADBV20G	ES-CEBH912	ES-CEBLL07C
5G11HC-QR-AU	ES-CABLAC55	ES-CADBV20K	ES-CEBHJ08A	ES-CEBLL08A
5G11HC-R-AU	ES-CABLAC55B	ES-CADBV20L	ES-CEBHJ09A	ES-CEBLL08B
5G13DC	ES-CABLAF40	ES-CADBV20Q	ES-CEBHJ12	ES-CEBLL08C
5G13HC-QR-AU	ES-CABLV09B	ES-CADBV20R	ES-CEBHL07	ES-CEBLL10
5G13HC-R-AU	ES-CABLV10A	ES-CADBV20S	ES-CEBHL07A	ES-CEBLM07
5T11AC-R-AU	ES-CABLV11C	ES-CADBV22A	ES-CEBHL07C	ES-CEBLM07A
5T13GC-QR-AU	ES-CABLV14C	ES-CADBV23F	ES-CEBHL08A	ES-CEBLM08A
5T13GC-R-AU	ES-CABLV14F	ES-CADBV24B	ES-CEBHL08B	ES-CEBLM08B
5T14CC-R-AU	ES-CABLV14H	ES-CADBV24G	ES-CEBHL08C	ES-CEBLM09
5T15AC-QR-AU	ES-CABLV15M	ES-CADBV24H	ES-CEBHM07	ES-CEBLM10A
5T24AC-R-AU	ES-CABLV17A	ES-CADBV24J	ES-CEBHM07A	ES-CEBLM12A
5T30AC-R-AU	ES-CABLV18	ES-CADBV24K	ES-CEBHM08A	ES-CEBLM12B
5T40BC-R-AU	ES-CABLV18C	ES-CADBV24Q	ES-CEBHM08B	ES-CEBLM13
5T40BF	ES-CABLV20G	ES-CADBV24R	ES-CEBHM09	ES-CEBLV05A
5T40DF-R	ES-CABLV20K	ES-CADBV25A	ES-CEBHM10A	ES-CEBLV08A
5T40DF-R-4	ES-CABLV20L	ES-CADBV26A	ES-CEBHM12A	ES-CEBLV08B
5T40DF-R-8	ES-CABLV20R	ES-CADBV27A	ES-CEBHM12B	ES-CEBLV08C
9T40AF-R-4	ES-CABLV20S	ES-CADBV30A	ES-CEBHM13	ES-CEBLV09A
9T40AF-R-8	ES-CABLV23F	ES-CADBV33B	ES-CEBHV05A	ES-CEBLV09F
B2708SB1E7L1	ES-CABLV24B	ES-CADBV33C	ES-CEBHV08A	ES-CEBLV09G
ES-AABLHF40	ES-CABLV24G	ES-CADBV35	ES-CEBHV08B	ES-CEBLV09K
ES-AABLHG38	ES-CABLV24H	ES-CADBV35A	ES-CEBHV08C	ES-CEBLV10A
ES-AABLHG38B	ES-CABLV24J	ES-CADBV38	ES-CEBHV09F	ES-CEBLV10B
ES-AABLHG38C	ES-CABLV24K	ES-CADBV45B	ES-CEBHV10A	ES-CEBLV10C
ES-AABLHG50	ES-CABLV24R	ES-CADBV45C	ES-CEBHV10B	ES-CEBLV10D
ES-AABLHG85	ES-CABLV25A	ES-CADBV45F	ES-CEBHV10F	ES-CEBLV10F
ES-AABLHV45	ES-CABLV27A	ES-CADBV45H	ES-CEBHV10J	ES-CEBLV10G
ES-AABLHV45B	ES-CABLV30A	ES-CADBV45J	ES-CEBHV10R	ES-CEBLV10H
ES-AADBHF40	ES-CABLV33B	ES-CADBV45K	ES-CEBHV10S	ES-CEBLV10J
ES-AADBHG38	ES-CABLV33C	ES-CADBV45P	ES-CEBHV10Z	ES-CEBLV10K
ES-AADBHG38B	ES-CABLV35	ES-CADBV45Q	ES-CEBHV13	ES-CEBLV10Q
ES-AADBHG38C	ES-CABLV35A	ES-CADBV50	ES-CEBHV15	ES-CEBLV10R
ES-AADBHG50	ES-CABLV38	ES-CADBV54B	ES-CEBHV15A-M	ES-CEBLV10S

Exhibit B – List of Epistar InGaN LED Part Numbers

ES-CEBLV10Y
ES-CEBLV10Z
ES-CEBLV11A
ES-CEBLV11B
ES-CEBLV11C
ES-CEBLV12A
ES-CEBLV13
ES-CEBLV13A
ES-CEBLV14A
ES-CEBLV15
ES-CEBLV15A-M
ES-CEBLV15M
ES-CEBLV17A
ES-CEBLV18A-M
ES-CEBLV19A
ES-CEBLV20
ES-CEBLV20A
ES-CEBLV20P
ES-CEBLV22
ES-CEBLV23A
ES-CEBLV23B
ES-CEBLV24
ES-CEBLV24A-M
ES-CEBLV27A
ES-CEBLV30
ES-CEBLV30A-M
ES-CEBLV31
ES-CEBLV40
ES-CEBLV40A-M
ES-CEBLV45
ES-CEBLV45A
ES-CEBM712
ES-CEBMM10A
ES-CEDB710A
ES-CEDB712C
ES-CEDBAE47
ES-CEDBJ08A
ES-CEDBJ09A
ES-CEDBJ12
ES-CEDBL07
ES-CEDBL07A
ES-CEDBM08A
ES-CEDBM09
ES-CEDBM10A
ES-CEDBM12A
ES-CEDBM13
ES-CEDBV08A
ES-CEDBV08B
ES-CEDBV08C
ES-CEDBV09F
ES-CEDBV09G
ES-CEDBV09K
ES-CEDBV09R
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ES-CEDBV10C
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ES-CEDBV13
ES-CEDBV14A
ES-CEDBV15
ES-CEDBV15A-M
ES-CEDBV17A
ES-CEDBV18A-M
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ES-CEDBV20P
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ES-CEDBV22B
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ES-CEDBV23C
ES-CEDBV24
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ES-CEDBV27A
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ES-CEDBV31
ES-CEDBV40A-M
ES-CEDBV45
ES-CEGH712
ES-CEGH712A
ES-CEGH912
ES-CEGHJ08A
ES-CEGHJ09A
ES-CEGHL07A
ES-CEGHL07C
ES-CEGHL08A
ES-CEGHL08B
ES-CEGHM08B
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ES-CEGHV10B
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ES-CEGHV18A-M
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ES-CEGHV30F
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ES-CEGRV15A-M
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ES-CELVV23A
ES-CELVV23B
ES-CELVV23C
ES-CELVV24C
ES-CELVV24F
ES-CELVV27A
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ES-CEUV930
ES-CEUVM15
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ES-CFBHM13
ES-CFDBV05A
ES-CGBHM10A
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ES-EABHF23B
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ES-EABHF50
ES-EABHF50B
ES-EABHF60
ES-EABHF60B
ES-EABLAC36B
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ES-EABLFD21A
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ES-EADBAC36C
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ES-EADBF11C
ES-EADBF11F
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ES-EADBF14B
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ES-EADBF22B
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ES-EADBF26H
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ES-EADBFD21A
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ES-EADBFV38
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ES-EALVF21A
ES-EALVF22A
ES-EALVF23B
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ES-EALVF26F
ES-EALVF26H
ES-EALVF28A
ES-EASVF26A
ES-EASVF45
ES-EEBHF08A
ES-EEBHF10A
ES-EEBHF10C
ES-EEBHM09B
ES-EEBHV10P
ES-EEBLF05A
ES-EEBLF08A
ES-EEBLF08C
ES-EEBLF09A
ES-EEBLF09F
ES-EEBLF10A
ES-EEBLF10C

Exhibit B – List of Epistar InGaN LED Part Numbers

ES-EEBLF11A
ES-EEBLF11H
ES-EEBLF11K
ES-EEBLF12A
ES-EEBLM09A
ES-EEBLM09B
ES-EEBLM22
ES-EEBLV09C
ES-EEBLV09H
ES-EEBLV09L
ES-EEBLV10P
ES-EEDBF05A
ES-EEDBF08A
ES-EEDBF08C
ES-EEDBF09A
ES-EEDBF09C
ES-EEDBF09F
ES-EEDBF10A
ES-EEDBF10C
ES-EEDBF11A
ES-EEDBF11H
ES-EEDBF11J
ES-EEDBF11K
ES-EEDBF12A
ES-EEDBF23A
ES-EEDBM09A
ES-EEDBM09B
ES-EEDBM10B
ES-EEDBM10F
ES-EEDBM22
ES-EEDBV09C
ES-EEDBV09H
ES-EEDBV09L
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ES-EQBL2NA
ES-EQBL2NC
ES-EQDB2NA
ES-EQDB2NC
ES-EQLV2NA
ES-EQSV2NA
ES-EUSA116
ES-EUSA11A
ES-FABLPE20A
ES-FABLPE45A
ES-FADBPE20A
ES-FADBPE38A
ES-FADBPE45A
ES-FEBHF40AA
ES-FEBL140AA
ES-FEBL540AA
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ES-FEGHF40AA
ES-FFBHM10C
ES-FFBLM10C
ES-FFBLM10D
ES-MMBHSP120
ES-MMBHSP121
ES-MMBHSP39A
ES-MMBHSP39B
ES-MMBHSP54A
ES-MMBHSP54B
ES-MMBHSP90A
ES-MMBHSP90B
ES-MMGHSP121
ES-MMGHSP39B
ES-MMGHSP54B
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ES-PADBF50
ES-PEBLF50
ES-QABLAC36C
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ES-SABLSN30
ES-SABLSN30A
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ES-WEBLM10A
ES-WEBLVNA
ES-WEDBVNA
ES-WEGHVNA
ES-WELVVNA
ES-WMBHM10A
ES-WMBLV10F
ES-WMBLV15
ES-WMBLV45B
ES-WQBAVNA
ES-WQBE3NA
ES-WQBEVNA
ES-WQBH2NA
ES-WQBH3NA
ES-WQBH3NC
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ES-WQLVVNA
ES-WQLVVNC
ES-WQUV3NA
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ES-WVBH712C
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ES-WXBHJ09A
ES-WXBHL07B
ES-WXBHM10A
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ES-WXBHSP121
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ES-WXBLV20L
ES-WXBLV22B
ES-WXBLV23C
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ES-WXBLV45H
ES-WXDBJ09A
ES-WXDBL07B
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ES-WXDBV10S
ES-WXDBV10Z
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ES-YABLAC55B
ES-YABLF11F
ES-YABLV14G
ES-YADBF11C
ES-YADBF11F
ES-YADBV24R
ES-YEBEL07A
ES-YEBEL07B
ES-YEBEM07
ES-YEBHF07A
ES-YEBHJ12
ES-YEBHL07A
ES-YEBHL07B
ES-YEBHL07C
ES-YEBHM07
ES-YEBHM07A
ES-YEBHV08A
ES-YEBLF05B
ES-YEBLF06A
ES-YEBLF07A
ES-YEBLF10A
ES-YEBLJ08A
ES-YEBLJ12
ES-YEBLL07A
ES-YEBLL07B
ES-YEBLL07C
ES-YEBLL07G
ES-YEBLM07
ES-YEBLM07A
ES-YEBLM08B
ES-YEBLV08A
ES-YEBLV10F
ES-YEBLV10J
ES-YEBLV10S
ES-YEDBF05B
ES-YEDBF06A
ES-YEDBF07A
ES-YEDBJ08A
ES-YEDBJ12
ES-YEDBL07A
ES-YEDBL07B
ES-YEDBL07C
ES-YEDBL07G
ES-YEDBM07
ES-YEDBV08A
ES-YEDBV10F
ES-YEDBV10J
ES-YEDBV10S
ES-YEDBV10W
ES-YEDBV23A
ES-YEGHL07A
ES-YEGHL07B
ES-YEGHL07C
ES-YEGHL07G
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ES-YEGLL07B
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ES-YEGLL07G
ES-YELVF05B
ES-YELVF07A
ES-YELVJ08A
ES-YELVL07A
ES-YELVL07B
ES-YELVL07C
ES-YELVL07G
ES-YELVV10F
ES-ZABLHV45
ES-ZABLV45C
ES-ZEBLL08A
ES-ZEBLV10F
ES-ZEBLV15
ES-ZEBLV23A
ES-ZEGHV15
ET-AED12PGG
ET-AEDANDB
ET-AEDANDBJ
ET-AEDANDBK
ET-AEDANDBL
ET-AEDANDBM
ET-AEDANDBN
ET-AEDANNB
ET-AEDANNBL
ET-AEDANNBM
ET-AEDANNBN
ET-AEDANNBO
ET-AEDANSB
ET-AEDANSBH
ET-AEDANSBI
ET-AEDANSBJ
ET-AEDANSBK
ET-AEDANSBL
ET-BIX24DB
ET-BIZ24DBC
ET-BIZ24NBE
ET-BIZ24NBE-
4GJ5B0
ET-CEY10DB
ET-CEY10DBD
ET-CEY10DBE
ET-CEY10DBF
ET-CEY10DBG
ET-CEY10DBH
ET-CEY10NB
ET-CEY10NBG
ET-CEY10PB
ET-CEY10PG
ET-CEY10PGE
ET-CEY10PGG
ET-CEY10SB

Exhibit B – List of Epistar InGaN LED Part Numbers

ET-CEY10SBD
ET-CEY10SBE
ET-CEY10TG
ET-CEY10TGD
ET-DED14DB
ET-DED14DBG
ET-DED14DBH
ET-DED14DBI
ET-DED14DBJ
ET-DED14DBK
ET-DED14DBL
ET-DED14DBM
ET-DED14NB
ET-DED14NBI
ET-DED14NBJ
ET-DED14NBK
ET-DED14NBL
ET-DED14NBM
ET-DED14NBN
ET-DED14PB
ET-DED14PBL
ET-DED14PBM
ET-DED14PBN
ET-DED14PBO
ET-DED14SB
ET-DED14SBH
ET-DED14SBI
ET-DEY14SBC
ET-DEY14SBI
ET-EED12DB
ET-EED12DBG
ET-EED12DBH
ET-EED12DBI
ET-EED12DBJ
ET-EED12DBK
ET-EED12DBL
ET-EED12NB
ET-EED12NBI
ET-EED12NBJ
ET-EED12NBK
ET-EED12NBL
ET-EED12NBM
ET-EED12NBN
ET-EED12PB
ET-EED12PBM
ET-EED12PBN
ET-EED12SB
ET-EED12SBH
ET-EEY12DB
ET-EEY12DBE
ET-EEY12DBG
ET-EEY12DBH
ET-EEY12DBI
ET-EEY12NB
ET-EEY12SB
ET-EEY12SBE
ET-LED10PG
ET-LED14PGI
ET-LED14PGJ
ET-LED40CBPM
ET-LEXBJ4545B
ET-LEZBJ4545B
ET-LID24DBB
ET-LID24DBB-4GM570
ET-LID24DBC
ET-LID24DBC-4GM570
ET-LID24DBD-4GM570
ET-LID24NBB
ET-LID24NBB-4GM520
ET-LID24NBB-4GM570
ET-LID24NBC
ET-LID24NBC-4GM570
ET-LID24NBD
ET-LID24NBD-4GM570
ET-LID24PGC-4GJ570
ET-LID24PGD
ET-LID24PGD-4GJ570
ET-LID24PGD-4GJ590
ET-LID24SBD-4GM540
ET-LMD30PGB
ET-LMD30PGD-4GJ570
ET-LMD30PGE
ET-LMD30PGE-4GJ580
ET-LMD30PGE-4GJ5D0
ET-LPD40DBC
ET-LPD40DBC-4GM570
ET-LPD40DBD
ET-LPD40DBD-4GM570
ET-LPD40DBE-4GM570
ET-LPD40DBF
ET-LPD40DBF-4GM530
ET-LPD40NBB-4GM570
ET-LPD40NBC
ET-LPD40NBC-4GM570
ET-LPD40NBC-4GM5B0
ET-LPD40NBD
ET-LPD40NBD-4GM570
ET-LPD40NBE
ET-LPD40NBE-4GM570
ET-LPD40NBE-4GM5B0
ET-LPD40NBF-4GM570
ET-LPD40PBE-4GM570
ET-LPD40PGE
ET-LPD40PGE-4GJ530
ET-LPD40PGF-4GJ530
ET-LPD40PGG-4GJ540
ET-LPD40PGG-4GJ570
ET-LPD40PGG-4GJ590
ET-LPD40PGH
ET-LPD40PGH-4GJ570
ET-LPDBJ4545A
ET-LPDBJ4545B
ET-LPXBJ4545A
ET-LRD60NBD
ET-LRD60NBD-4GM560
ET-REYBR0812A
ET-RPDBJ4545A
ET-RPDBJ4545B
ET-RPDBJ4545C
HDCKF20EBW
IDAK909ABW
JDBKF23EBW
MKO3131C452-9
RDCHIP
RDCHIP-NC
RDWAFER
RECHIP
RECHIP-LEY
RECHIP-NC
REWAFER
REWAFER-NE
RGB-8-CHIPS-ARRAY
藍光磊晶片(UEC)