Recent Japanese Patents: Gallium Nitride and Related Materials

Several Japanese patents granted in 1998 in the field of GaN & related materials recently became available for the first time in English. The following is a summary of relevant items from January through March.

Contacts

JP10084167 / 19980 3 31 / **Toshiba**
Method of forming top & bottom contacts on a GaN-on-sapphire device.

JP10065215 / 19980 3 06 / **Toyoda Gosei**
Electrode design to reduce ESD sensitivity.

JP10012567 / 1998 01 16 / **Toyoda Gosei**
Method to reduce the resistance of the electrodes.

Contacts, n-type

JP10084135 / 19980 3 31 / **Nichia Chem**
JP10065216 / 19980 3 06 / **Toyoda Gosei**
JP10022494 / 1998 01 23 / **Sony**
JP10004210 / 1998 01 06 / **Toyoda Gosei**

Contacts, p-type

JP10084160 / 19980 3 31 / **Toshiba**
JP10084159 / 19980 3 31 / **Matsushita**
JP10070082 / 19980 3 10 / **Sony**
JP10065212 / 19980 3 06 / **Toshiba**
JP10056206 / 1998 02 24 / **Toshiba**
JP10051070 / 1998 02 20 / **Fujitsu**
JP10051030 / 1998 02 20 / **Toyoda Gosei**
JP10041254 / 1998 02 13 / **Sony**

Device Design

JP10084165 / 19980 3 31 / **Sharp**
GaN device on SiC substrate with a high quality re-growth boundary surface.

JP10051028 / 1998 02 20 / **Toshiba**
Zn- and Mg-doped clads to restrain shift of emitted light wavelength.

JP10041545 / 1998 02 13 / **Toyoda Gosei**
Superlattice active layer.

JP10041232 / 1998 02 13 / **Showa Denko**
Low temp. buffer layer.

JP10022586 / 1998 01 23 / **Sony**
Device with p-type & n-type InGaN light absorbing layers.

JP10012922 / 1998 01 16 / **Toyoda Gosei**
Strained superlattice emission layer.

Device Design, Lasers

JP10065271 / 19980 3 06 / **Toshiba**
Design of InGaAlN barrier layer of a quantum well structure.

JP10056236 / 1998 02 24 / **Toyota**
Confinement layer for SQW laser.

JP10051074 / 1998 02 20 / **Fujitsu**
Low temp. buffer layer for laser.

JP10041581 / 1998 02 13 / **Nichia Chem**
Design of a MQW laser structure.

JP10032367 / 1998 02 03 / **Fujitsu**
c-plane or (0001) plane GaN grown on sapphire substrate with d-plane as its main surface.

A First Look at AlGaN/GaN HBTs

Researchers from the University of California Santa Barbara ~~recently~~ demonstrated the first AlGaN/GaN HBTs. In this special report, they describe some of their findings.

LEE MCCARTHY, PETER KOZODOY, MARK RODWELL, STEVE DENBAARS, AND UMESH MISHRA
UNIVERSITY OF CALIFORNIA SANTA BARBARA
ECE DEPARTMENT
SANTA BARBARA, CA

There is a growing consensus that a significant market for sophisticated high power semiconductor devices will emerge in the near future. And even though GaN-based electronics are still in their infancy, it is becoming clear that they have excellent prospects in this area.

The wide bandgap of GaN, which makes the now-familiar blue LEDs and lasers possible, is also advantageous for high power electronics applications. Another advantage, high predicted electron velocities, makes GaN an attractive solution for communications systems, radar, and high frequency switching power supplies.

The intense interest in GaN electronics is further fueled by recent reports of AlGaN/GaN HEMTs exhibiting record high power, high frequency operation. These impressive results are encouraging to bipolar research because HBTs potentially have several inherent advantages over FETs, including better linearity, more uniform threshold voltages and higher current densities.

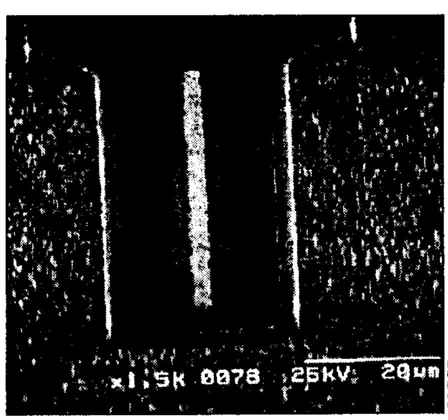

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***Figure 1.** An SEM photograph of the GaN/AlGaN HBT*

Unfortunately, difficulties with this emerging technology, particularly with the p-type material, have hampered research into GaN based bipolar transistors. Although GaN optical bipolar devices such as LEDs, photodetectors, and (very soon) laser diodes are already commercially available, until recently little progress had been seen in the area of bipolar electronics. Unlike these optical devices, bipolar transistors require lateral current through p-type material, exacerbating the drawbacks associated with the high resistivity of Mg doped GaN.

But in May of this year our research group demonstrated the first AlGaN/GaN HBT. In this article, we describe some of our findings.

AlGaN/GaN HBT Strucutre

A SEM photograph of the device is shown in Figure 1. The devices were grown by MOCVD on sapphire substrates, and utilize an AlGaN/GaN heterojunction for the base/emitter diode. A

Recent III-Nitride Japanese Patents

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Epitaxial Growth, cont.

JP10041544 / 1998 02 13 / **Toyoda Gosei**
Pyrolyzed ammonia as N source.

JP10032349 / 1998 02 03 / **Sony**
GaInN/GaN quantum well structure grown at varying temperatures.

JP10032348 / 1998 02 03 / **Toyoda Gosei**
Growth of SQW or MQW structure using two separate heating stages.

JP10022224 / 1998 01 23 / **Showa Denko**
Buffer layers.

JP10012923 / 1998 01 16 / **Sanyo**
Growth method involving variable temperatures.

JP10012555 / 1998 01 16 / **Sharp**
Optimization of gas flow rate and its gradient.

Epitaxial Growth, Doping

JP10041549 / 1998 02 13 / **Toshiba**
N type buffer layer with graded doping level.

JP10017400 / 1998 01 20 / **Sumitomo Electric**
Method for Mg doping.

JP10012624 / 1998 01 16 / **Sony**
Thermal processing method that increases p-type carrier concentration.

JP10004211 / 1998 01 06 / **Sony**
OMVPE growth of p-type material.

Epitaxial Growth, Substrates For

JP10075018 / 19980 3 17 / **Matsushita Electric**
SiC substrate for MOVPE growth.

JP10074980 / 19980 3 17 / **Sumitomo Electric**
Aluminum nitride single crystal substrate.

JP10072299 / 19980 3 17 / **Sony**
Yttrium-aluminum-perovskite as a substrate material.

JP10070079 / 19980 3 10 / **Matsushita Electric**
Removal of Si substrate after growth of SiC and GaN layers.

JP10065214 / 19980 3 06 / **Toyoda Gosei**
Sapphire substrate with zinc oxide buffer layers.

JP10051073 / 1998 02 20 / **Fujitsu**
ZnO substrate with low temp. buffer layer.

JP10041586 / 1998 02 13 / **Sony**
Structure grown on sapphire and bonded to GaP substrate.

JP10041547 / 1998 02 13 / **NEC**
Hexagonal system SiC substrate with wurtzite nitride structure.

JP10041312 / 1998 02 13 / **New Japan Radio**
Formation of GaN layer on Ga-rich surface of a GaAs substrate.

JP10032365 / 1998 02 03 / **NEC**
N-type Si (110) substrate

JP10022568 / 1998 01 23 / **Hitachi**
SiC substrate with nitrided insulating layer.

JP10022526 / 1998 01 23 / **Sanyo Electric**
n-type 6H-SiC substrate

JP10012924 / 1998 01 16 / **Sony**
$YAlO_3$ substrate or other material having a perovskite structure.

JP10007496 / 1998 01 13 / **Hitachi Cabl**
GaN bulk growth method.

DC current gain (I_C/I_B) of three and an output conductance too low to measure from the common emitter curves. Devices with 3μm x 20μm emitters were capable of supporting over 1mA of collector current. However, due to current crowding effects, the current density in these devices is unknown. Base contact problems are thought to be responsible for a collector current offset in the common emitter configuration, but these offset voltages are expected to drop significantly when the contacts are improved.

High recombination rates in the base of the transistor are thought to be the cause of the low current gain of these devices. Although the high resistivity of the p-type material makes thinner base layers undesirable, it is believed that small fractions of Al graded into the base region will introduce a bandgap gradient, providing large quasi-fields and driving injected electrons across the neutral base before they can recombine. A 10% grade of Al in the base, for example, is expected to introduce an energy drop in the conduction band on the order of 10 kT or 250 meV at room temperature. This would lead to a quasi-field of approximately 10 kV/cm across a 200 nm base.

In addition to incorporating Al grading in the base of these transistors, future work will include self-aligned submicron lithography and the fabrication of devices compatible with AC testing. Further on the horizon are plans to develop a process to remove the devices from their sapphire substrates, flip-chip bond them to carrier wafers, and employ Schottky collector IC technology as is currently done with ultra-high speed HBTs in other III-V material systems.

Although still in its infancy, with continuing improvements in GaN material and processing technology, the HBT promises to become an integral part of the GaN electronics industry.

This work was supported by the ONR.

Nitride News Briefs

On September 30 **Fujitsu Laboratories** announced that its researchers had succeeded in fabricating a **room-temperature CW laser diode**. The GaN/AlGaN device, grown by MOCVD, is based on a SiC-substrate. The 408nm device was said to have threshold current and voltage of 115mA and 10.5V, respectively, and a threshold current density of 7 kA/cm2, the device continues to operate at temperatures up to 40°C. The company is expected to make a full report at a major conference this fall.

The MITI-affiliated **Japan Research and Development Center for Metals** (JRCM) has launched a project to **develop a blue or UV LED** which will be able to achieve an energy efficiency level about two times higher than that of fluorescent lamps. A total of 12 corporations, including Japan Energy, Sumitomo Electric, and Omron, one industry organization and two universities, Yamaguchi and Mie Universities, will participate in the five-year, ¥5 billion yen ($34.8 mil) project. The objectives are: basic research on physical properties; development of a dedicated LED substrate; improvements in LED production technology; and the production of a light source device.