SVT Associates, Inc.

Application Note

High Growth Rate RF Nitrogen Source

Abstract

The operation of a new high growth rate RF Plasma Source is described which has achieved a record 6 µm/hr growth rate. The growth process is monitored in real time with an optical reflectance instrument. Optical characterization of the GaN samples grown at high rates show excellent luminescence properties similar to those grown at lower rates.

Nov. 1998, Note No. 1001

Introduction

Interest in the group III (Al, Ga, In) nitrides and their ternary and quaternary alloys has increased dramatically with the recent progress in developing blue semiconductor lasers. Other devices such as high temperature, high power electronics and solar blind UV detectors are being developed in this wide band gap material system. While much of the growth of group III nitrides has been done with metal-organic chemical vapor deposition (MOCVD), recent progress has been made in molecular beam epitaxy (MBE) of these materials. The advancement of MBE in nitride growth is due in part to the improvement of nitrogen sources. In this application note, we describe our results to increase the growth rate of GaN using a new RF nitrogen plasma source. Growth rates of 6 µm/hr were achieved. Growth rate data measured in-situ using optical reflectance will be presented. Optical characterization of the films grown at higher rates show excellent properties similar to films grown at 0.5 µm/hr.

Experimental

The standard RF Source, Model RF 4.5, which mounts on a 4.5" CFF is shown in Figure 1. A smaller version which mounts on a 2.75" CFF is also available. The RF source creates a plasma of nitrogen with the use of a RF field. RF energy (200 to 550 W) is fed into the gun through a water cooled copper coil. A pyrolytic boron nitride (PBN) tube with a changeable aperture is centered between the RF coils. Nitrogen is introduced to the tube with a leak valve and a plasma is created within the tube. An optical port located at the rear of the source allows monitoring of the plasma emission characteristics. Figure 2 shows the intensity vs. wavelength spectra taken with the standard source for nitrogen, oxygen and hydrogen.

Figure 1. SVT Associates 4.5" (114 mm) OD CFF RF Source shown with matching network. A smaller version which mounts on a 2.75" (70 mm) OD CFF is also available.

To increase the growth rate we developed an advanced RF Source, Model RF 4.52. The growth rate data presented was done on sapphire (0001) substrates. A low temperature AlN buffer layer was grown after nitridation of the sapphire surface. This was annealed at 800 °C and GaN growth initiated. The GaN growth temperature ranged between 700 and 800°C. Elemental Ga and Al were supplied from effusion cells. The RF source to sample distance was 4 inches and the system was pumped with a CTI 8 cryopump. A leak valve was used to regulate the flow of nitrogen into the system.

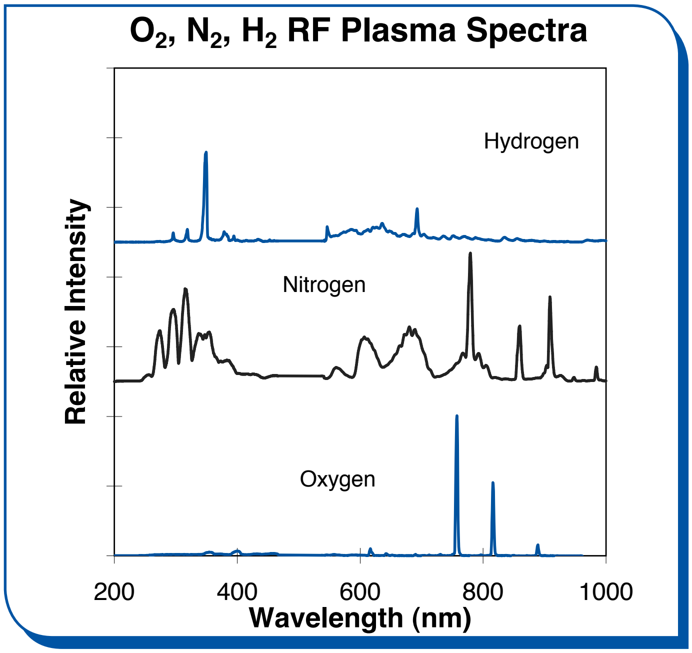

Figure 2. Intensity vs wavelength emission curves taken with the standard SVT Associates model 4.5 RF source for nitrogen, oxygen and hydrogen.

The growth rate data was taken in-situ using optical reflectance. In this method, light is reflected off the growing surface at a specific wavelength. Periodic variation of the reflected signal is observed due to the optical interference between the GaN and the sapphire surface. The quarter wave thickness (peak to valley in the reflected signal) is given by nd = ¼ where n is the index of refraction at the measured wavelength, d is the physical thickness and l is the wavelength of reflected light. A value of 62.5 nm was used for the peak to valley thickness in these measurements using a He-Ne laser for the light source at 632 nm. An example of the reflected signal is shown in Figure 3. The period in this example corresponds to 125 nm peak to peak. This corresponds to a 5 µm/hr growth rate.

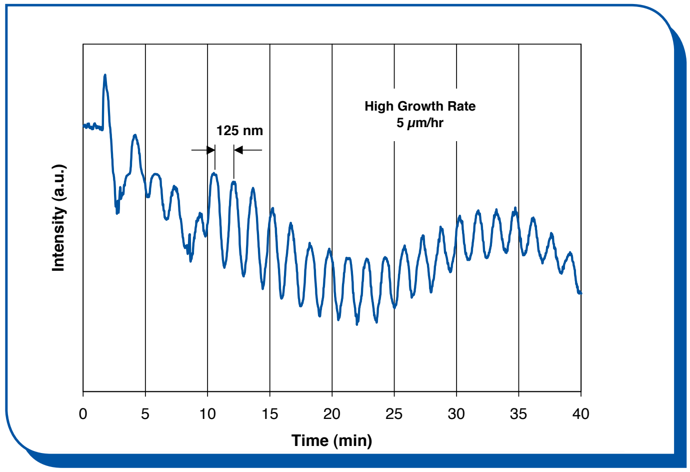

Figure 3. Interference oscillations measured as a function of time to determine the growth rate of GaN in-situ.

Results and Discussion

The high growth rate RF source was characterized by measuring the growth rate under fixed conditions of RF power and nitrogen flow. The growth rate was then measured as a function of Ga cell temperature. Figure 4 shows the measured growth rate for two different nitrogen flow rates at a fixed RF power of 500 W. The data shows a growth rate of 6 µm/hr was achieved for a RF power of 500 W, nitrogen pressure of $5x10^{-4}$ Torr and Ga cell temperature of 1,170 °C. A maximum growth of 4 µm/hr was achieved at 500 Watts, nitrogen pressure of $1x10^{-4}$ Torr, and a Ga cell temperature of 1,140 °C.

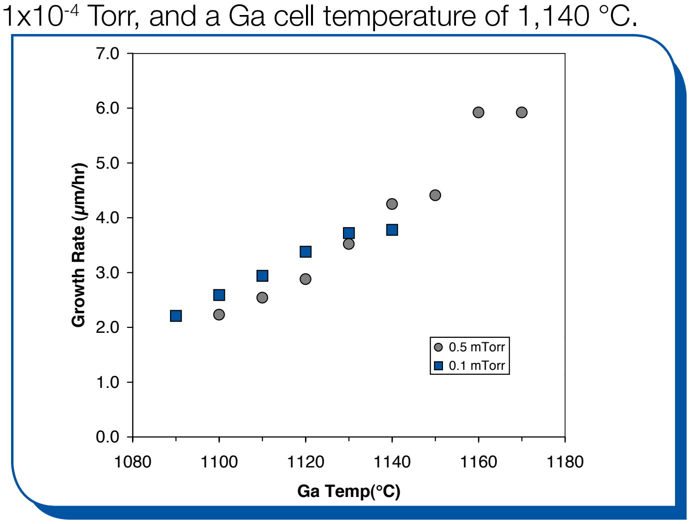

Figure 4. Measured growth rate of GaN as a function of Ga cell temperature. The RF power was fixed at 500 W for these experiments. The squares are data from a nitrogen pressure of $1x10^{-4}$ Torr, the circles are for a nitrogen pressure of $5x10^{-4}$ Torr. A maximum growth rate of 6 µm/hr is achieved.

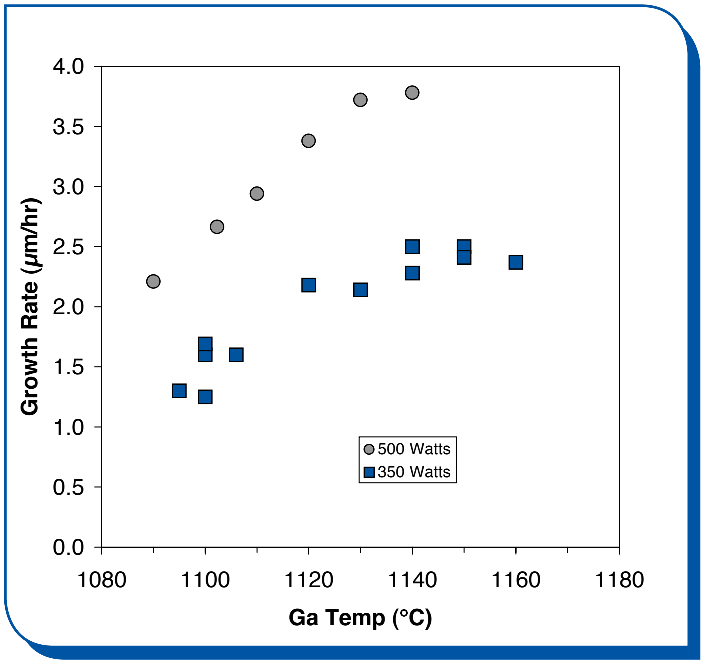

Figure 5. Measured growth rate at a fixed nitrogen pressure of $1x10^{-4}$ Torr for two different RF power values.

Figure 5 shows the measured growth rate as a function of Ga cell temperature at a fixed nitrogen pressure of $1x10^{-4}$ Torr for two different RF power values. One can see that increasing the RF power increases significantly the growth rate under these conditions.

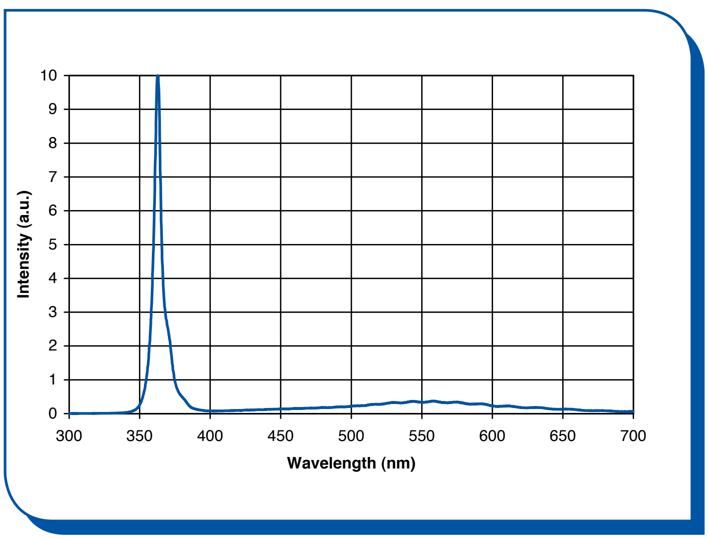

Figure 6. Cathodoluminescence spectrum at room temperature of GaN grown at 1.6 µm/hr. A FWHM of 5.77 nm is measured.

Characterization of the film properties is currently being done. Preliminary optical measurements indicate that very similar material quality can be achieved at the faster growth rates. Figure 6 shows the cathodoluminescence spectrum (CL) taken from a sample grown at 1.6 µm/hr. Figure 7 shows the cathodoluminescence spectrum taken from a sample grown at 4 µm/hr. A very sharp FWHM of <6 nm is obtained for both. In both samples, the yellow emission level at 550 nm is quite small. In general, the cathodoluminescence correlates with photoluminescence (PL) measurements.

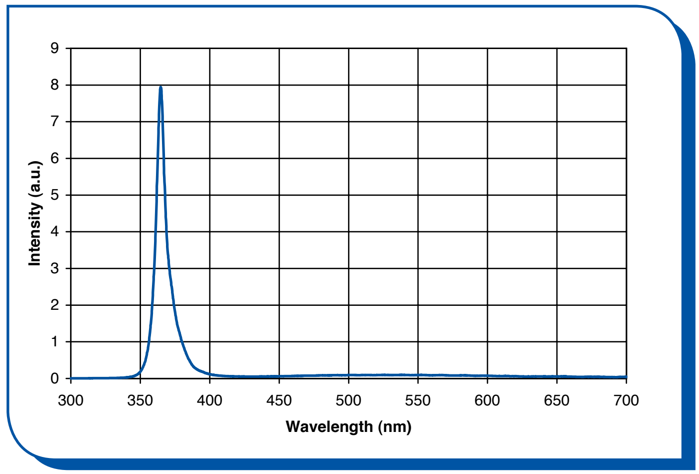

Figure 7. Cathodoluminescence spectrum at room temperature of GaN grown at 4 µm/hr rate. A FWHM of 5.83 nm is measured.

Summary

The growth rate characteristics of a new RF source was described as a function of nitrogen flow and RF power. Using in-situ optical reflectance, the maximum growth rate measured was 6 µm/hr. Optical characterization of the films grown at higher rates show excellent properties similar to films grown at 1.6 µm/hr.

RF Plasma Source Maintenance and Upgrades

SVT Associates offers several levels of service and upgrades for our RF Plasma Source including:

1. Inspection and cleaning
2. Refurbishment including PBN and/or coil replacement
3. Upgrading of standard Model RF 4.5 source to high growth rate design

For typical operating conditions we recommend an inspection and cleaning on a yearly basis and refurbishment every two years. Please check with SVT Associates for more details, pricing information, and scheduling.

INFORMATION REQUEST

For more detailed information about any of our products or services, please copy this form, fill it out and fax or mail it to us at the address listed below.

- ☐ Model RF 4.5 Plasma Source
- ☐ Model RF 2.75 Plasma Source
- ☐ RF Source Inspection
- ☐ RF Source Refurbishment
- ☐ RF Source High Growth Rate Upgrade
- ☐ Effusion Cell
- ☐ Compact E-Beam Evaporator
- ☐ RHEED and Cathodoluminescence (CL) Software
- ☐ In-Situ 4000 Temperature and Thickness Monitor
- ☐ Nitride and III-V MBE Systems
- ☐ SiGe MBE Systems
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