DEPARTMENT *of* PHYSICS *and* ASTRONOMY
THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

Condensed Matter / Materials Seminar

11/08/2007: Dr Tanya Paskov, Kyma Technology, Inc., Raleigh, NC

HVPE Growth of III-Nitrides: Principles, Applications, and Development Status

Time: 3:30PM
Place: Room 258 Phillips Hall

The great commercialization potential of III-nitride semiconductor devices for applications in visible and UV optoelectronics and high power electronics requires development of highly perfect crystalline device layers. The highest quality device layers require high quality native substrates, which Kyma and its competitors are racing to develop.

Hydride vapour phase epitaxy (HVPE) and the closely related technique, halide vapour phase epitaxy, have played important roles in the early development of III-V compound semiconductors, including arsenides, phosphides and nitrides. The first open-tube HVPE reactor was developed at RCA laboratories in the early 1960s to grow GaAs films on germanium substrates. Since then, the HVPE technique has been used to prepare different semiconductor materials, which has enabled the study of their fundamental properties as well the fabrication of devices. In 1967 this techniques was employed for growing the first GaN material and led to characterization of many important physical properties. Although the technique for GaN was largely abandoned for more than 20 years in favour of low-dimensional structure development by more precise epitaxial growth techniques of MOCVD and MBE, during last 5-6 years the research interest in the HVPE technique has been renewed due to commercial demand for a native GaN substrate. HVPE results are currently ahead of competing bulk GaN growth approaches such as various modifications of sublimation growth or liquid phase solutions, which either require very complicated facilities or are still limited by relatively low growth rates. In contrast, HVPE has the following main advantages: (i) The HVPE growth of GaN is based on two-step chemical reaction between metal (Ga, Al, In), HCl and ammonia at temperatures of 1000-1100 °C and atmospheric pressure and thus being relatively simple and cheap; (ii) The technique is very efficient, as being capable of very high growth rates up to 200 μm/h; (iii) The third advantage and probably the most important one is related to the ability of the HVPE to grow very high-quality material.

As a result of present high research activity in the HVPE growth of GaN some remarkable achievements have been reported. Thick (~300 μm), large-area (2 inches) HVPE GaN layers removed from sapphire were demonstrated by several research groups to have a low threading dislocation density ($<10^6$ cm^{-2}), low free-carrier concentrations ($<10^{16}$ cm^{-3}) and high optical quality (band-edge dominated room temperature absorption and photoluminescence), that could serve as high quality substrates. Moreover, growth of boules with heights up to 1cm has been demonstrated by a couple of leading companies in this field including Kyma Technologies. Such a boule dimension enables substrates of desired orientation to be sliced and polished.

However, the availability of this material is still very limited in the market, although announcements were made several years ago. There are still many challenges to be overcome, like non-uniform distributions of dislocations, impurity incorporation, native defect generation, and stress along the film thickness; many questions to be answered, like understanding of bending and cracking; and still there is a need for modifications of the reactors and optimisations of the growth procedures.

In this talk I will briefly review the basic principles of the HVPE growth technique, its development and applicability for nitrides; will summarise the recent achievements and the most important problems, hampering the reproducible production of large-area GaN substrates; and then will give examples for some approaches towards overcoming the present challenges.