# HL 44: Quantum dots and wires: preparation and characterization II

Time: Thursday 16:45–18:30 Location: EW 201

HL 44.1 Thu 16:45 EW 201

**Investigation of MOVPE InN quantum dot growth by variation of temperature , V/III ratio and ammonia stabilisation flow** — •Simon Ploch, Christian Meissner, Markus Pristovsek, and Michael Kneissl — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, EW6-1, D-10623 Berlin, Germany

Despite their unique electronic and optical properties very little attention has been devoted to the growth of InN- nanostructures. Because of its bandgap in the range of 0.7 eV InN is an interesting candidate for lasers and LED emitting in the infrared spectral range. So far most InN quantum dots are grown in MBE. To prevent the formation of metalic Indium, very high V/III ratios in the range of 300,000 were used in the InN growth. We present our growth studies of InN quantum dots on GaN investigated by in-situ spectroscopic ellipsometry. As allready shown, we were abel to realize 8-10 ML high 3D structures with a mean hight of 1.7 nm, a mean diameter of 16.5 nm and a density of 2.1011 /cm* . The InN QDs were grown in a N2 atmosphere at 100 mbar, with a V/III ratio of 15,000, the time was 60s. By increasing the V/III ratio from 5,000 to 20,000 we observed a decrease of the growth rate, which can be explained by layer desorption due to reactive hydrogen from ammonia. It should be noted that we were able to obtain high cristaline quality InN QD at low V/III ratios in the range of 5,000 which corespondes with a short growth time compareable to InAs QD growth conditions. An ammonia stabilisation flow shows benefit effects on the InN quantum dot composition due

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**InN Nanocolumns - Electrical Properties and Site-Selective Growth** — •Christian Denker, Friederich Limbach, Soenke Huels, Florian Werner, Joerg Malindretos, and Angela Rizzi — IV. Physikalisches Institut, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany

The possible applications of Indium Nitride semiconductor nanocolumns in novel optoelectronic and photovoltaic devices as well as the fundamental material properties are better assessed on single nano-objects. In addition, selective growth of nanocolumns in a regular array is pursued with the aim of reducing ensemble masking effects in the measurements and facilitating further processing.

In the past we fabricated self-organised InN nanowires with a length of up to 2 $\mu$m and an aspect ratio up to 1:40 by molecular beam epitaxy (MBE). Single nanocolumns are contacted by e-beam lithography for measurements in a 4-point configuration. The resulting U-I curves will be presented.

For catalyst-free selective nucleation of the nanocolumns patterning of the natively oxidized Si(111) substrate is needed. As the standard process of SiN or SiO masking has not yet been successfully used in the MBE of InN, a new technique was applied. We show that the nucleation of InN can be inhibited by depositing a thin carbon layer, e.g. through e-beam exposure in a scanning electron microscope. This method will be optimised to grow arrays of well separated InN nanocolumns.

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**Catalyst-free and catalyst-induced growth of GaN nanowires by molecular beam epitaxy** — •Caroline Chèze[1], Lutz Geelhaar[1], Walter Weber[1], Henning Riechert[1], Philomela Komninou[2], Thomas Kehagias[2], and Theodoros Karakostas[2] — [1]Qimonda and NaMLaB, Dresden, Germany — [2]Aristotle University of Thessaloniki, Thessaloniki, Greece

GaN nanowires (NWs) were grown by molecular beam epitaxy with and without catalyst under very similar conditions, enabling a direct comparison of their growth mechanisms. The type of substrate determines whether a catalyst is necessary to induce the formation of NWs. On sapphire, NWs grow only when Ni seeds are deposited on the substrate before GaN-growth. Particles found at the NW-tips suggest that NWs form in a way similar to the vapour-liquid-solid mechanism. In contrast, on Si NWs form in a self-induced way without any catalyst. To elucidate the growth mechanisms, the incorporation rate of Ga was monitored in situ by line-of-sight quadrupole mass spectrometry. In all cases, growth starts with a reduced incorporation rate, i.e. nucleation is delayed. However, the growth rate saturates after different delays for the two different ways of NW-formation. At a growth temperature of 780°C, the nucleation phase is on Si at least five times longer than on sapphire (>3000 s vs. about 600 s). Thus, the external catalyst Ni strongly facilitates the formation of NWs. Based on these observations, we will discuss the possible growth mechanisms leading to the formation of NWs either by the catalyst-free (on Si) or by the catalyst-induced (on sapphire) approach.

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**Transmission Electron Microscopy investigation of self-organized InN nanocolumns** — •Henning Schuhmann[1], Christian Denker[1], Tore Niermann[2], Jörg Malindretos[1], Angela Rizzi[1], and Michael Seibt[1] — [1]IV. Physikalisches Institut, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany — [2]Now at: Institut für Optik und Atomare Physik, Technische Universität Berlin, D-10623 Berlin, Germany

Semiconductor InN Nanocolumns have electronic properties which makes them a promising candidate for novel photovoltaic devices.

Molecular-beam epitaxy (MBE) grown InN on Si(111) forming self organized InN nanocolumns with diameters down to 20 nm and lengths of up to 2 $\mu$m. These structures have been investigated by using energy dispersive X-Ray (EDX) scanning transmission electron microscopy showing an oxygen-rich layer coating the InN nanocolumns. High-resolution TEM of the interface between the nanocolumns and the Si substrate indicates the existing of an amorphous interlayer. Conventional techniques have been applied for cross-section TEM specimen preparation, in addition a Dual Beam Focused Ion Beam (FIB) has been used to prepare cross-section and plan-view specimens. The latter allows us to study single nanocolumns along the rod axis projection. This work was supported, within the EU FP6, by the ERANET project ”NanoSci-ERA: NanoScience in the Eropean Research Area”

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**Dependence of InGaN quantum dot formation on two-step growth parameters** — •Christian Tessarek, Stephan Figge, Detlef Hommel, Joachim Kalden, Kathrin Sebald, and Jürgen Gutowski — Institut für Festkörperphysik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen

InGaN is a potential candidate for the application in LED and lasers with emission in the blue-green spectral region. Compared to quantum wells (QWs) it is expected to have an improvement in the optical and electrical characteristics of a device by implementing InGaN quantum dots (QDs).

The overgrowth of Stranski-Krastanov-type QDs with a GaN-capping layer leads to the dissolution of the QD structures. Utilizing a two-step-growth-mode we succeeded to grow capped QDs. The first step in this growth is the deposition of a few monolayer thin $In_xGa_{1-x}N$ nucleation layer (NL) which is stabilized in a second step by growing a $In_yGa_{1-y}N$ formation layer (FL) with y<x. The resulting structure shows both QW as well as QD related luminescence as we proved by micro-photoluminescence (PL) measurements. To achieve sole QD luminescence the QW contribution has to be suppressed while not dissolving the QDs. For this reason we have investigated the effect of different gas fluxes during the growth of NL and FL on the QD and QW PL. Furthermore, we will present the impact of growth interruptions and growth temperatures on the PL-spectra. Finally, the growth on different AlGaN templates and the influence of strain is investigated.

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**Influence of growth time and $NH_3$ stabilisation flow on InN quantum dot formation by MOVPE** — •S. Ploch[1], C. Meissner[1,2], M. Pristovsek[1], and M. Kneissl[1] — [1]Institut für Festkörperphysik, TU Berlin, Hardenbergstr. 36, EW6-1, 10623 Berlin — [2]ISAS - Institute for Analytical Sciences, Albert-Einstein-Str. 9, 12489 Berlin

Despite their unique electronic and optical properties very little attention has so far been devoted to the growth of InN quantum dots (QDs). In the present study we have investigated the metalorganic vapour phase epitaxy (MOVPE) of InN QDs on GaN/sapphire by in-situ spectroscopic ellipsometry. Three-dimensional nanostructures with a mean hight of 1.7 nm (corresponding to 6 monolayers of InN), a mean diameter of 16.5 nm and a density of $2{\cdot}10^{11}\,cm^{-2}$ have been realized. In this case the InN QDs were grown for 60 s at a total reactor pressure of 100 mbar and a V/III ratio of 15,000. By decreasing the V/III ratio from 20,000 to the relatively low value of 5,000 we observed an increase of the total growth rate, which can be explained by reduced layer desorption due to the reaction of InN with atomic hydrogen from the ammonia pyrolysis. It should be noted that we were able to obtain high crystalline quality InN QDs even at low V/III ratios around 5,000 using an ammonia stabilisation flow. These growth conditions and times between 5 s and 60 s are very similar to growth of InAs QDs.

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**Charge Sensing in Carbon Nanotube Double Quantum Dots**
— H. O. H. Churchill[1], •D. Marcos[2], F. Kuemmeth[1], S. K. Watson[1,3], and C. Marcus[1] — [1]Department of Physics. Harvard University. Cambridge 02138. Massachusetts, USA — [2]Departamento de Teoría de la Materia Condensada. Instituto de Ciencia de Materiales de Madrid, CSIC, Cantoblanco 28049. Madrid, Spain — [3]Department of Physics. Middlebury College. Middlebury 05753. Vermont, USA

Recent advances in fabrication techniques have made it possible tocreate tunable quantum dots on semiconducting nanowires and carbon nanotubes. In particular, double-dots formed on carbon nanotubes [1-3], are interesting candidates for the implementation of qubits based on their unique electronic structure as well as the weakness of nuclear and spin-orbit coupling in the predominantly C12 host. Here we report measurements obtained from an integrated double dot and charge sensor [4,5] fabricated from a single carbon nanotube. The conductance through the single dot allows us to monitor the charge state of the double dot even if it is decoupled from the leads. We also demonstrate fast manipulation of the double dot using pulsed-gates techniques.

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