HL 13: Focus Session: GaN-based single photon emitters

Sources of single photons will be of use for future quantum technologies. Although there are several technologies that can be used for the emission of single photons, in recent years III-nitride based quantum dots (QDs) have been the subject of increased attention due to their possible operation over a wide range of wavelengths from the ultraviolet to the red end of the visible spectrum. Furthermore, III-nitride QD-based single photon sources have also been shown to operate at room temperature and even at elevated temperatures.

Organizers: Frank Bertram, Jürgen Christen (OvGU Magdeburg), and Markus Wagner (TU Berlin)

Time: Tuesday 9:30–12:45 Location: H31

Invited Talk HL 13.1 Tue 9:30 H31

GaN-based quantum dot single photon sources at room temperature — •Yasuhiko Arakawa[1], Mark Holmes[1,2], and Munetaka Arita[1] — [1]Institute for Nano Quantum Information Electronics, The University of Tokyo, Tokyo, Japan — [2]Institute of Industrial Science, The University of Tokyo

III-Nitride quantum dots, with their large band offsets and wide range of bandgaps, are promising nanostructures for room temperature quantum information technologies. Growth of high-quality GaN/AlN quantum dots was reported by metal organic C chemical vapor deposition (MOCVD) with Stanski-Krastnanov growth mode in 2002. The quantum dots exhibited a large biexciton binding-energy and a strong phonon interaction, leading to observation of a single photon at 200 K in 2006. However, the magnitude of the binding energy of biexciton was not large enough to realize single photon emission at room temperature.

In this presentation, we discuss our recent progress in GaN-based single photon emitters operating at/above room temperature. A position controlled GaN/AlGaN nanowire quantum dot, with a typical lateral dimension of 10 nm and a vertical dimension of 1 nm, was grown by selective area MOCVD. A large binding energy of biexciton (> 60meV) in the quantum dot was realized, which enabled single photon emission at 350 K (77C). In addition, we also discuss interface-fluctuation GaN/AlN quantum dots for realizing high quality single photon emission. We obtained a measured raw g(2)(0) value smaller than 0.1 at 10 K, demonstrating the remarkable nature of these quantum dots.

Invited Talk HL 13.2 Tue 10:00 H31

Quantum light generation based on group III-nitride semiconductor nanophotonic structures — •Yong-Hoon Cho — Department of Physics and KI for the NanoCentury, Korea Advanced Institute of Science and Technology (KAIST), Daejeon 34141, Korea

We present quantum light generation and control with various group III-nitride semiconductor nanophotonc structures. We fabricated three-dimensional GaN-based semiconductor nano- and micro-structures, which was followed by the growth of quantum structures by metal-organic chemical vapor deposition. We demonstrated ultrafast and highly directional single photon generation from a quantum dot formed at the apex of pyramid structures, the self-aligned deterministic coupling of single quantum dot (QD) to nanofocused plasmonic modes, and exciton-polariton formation and condensation at room-temperature using GaN-based rod structures. Our approaches overcome the major hurdles in implementing practical solid-state quantum devices operating at room temperature and also show great promise for versatile quantum photonic applications.

Invited Talk HL 13.3 Tue 10:30 H31

Growth of desorption-induced GaN quantum-dots — •Christoph Berger[1], Gordon Schmidt[1], Hannes Schürmann[1], Sebastian Metzner[1], Peter Veit[1], Jürgen Bläsing[1], Frank Bertram[1], Armin Dadgar[1], Jürgen Christen[1], André Strittmatter[1], Stefan Kalinoswki[2], Stefan T. Jagsch[2], Gordon Callsen[2], Markus R. Wagner[2], and Axel Hoffmann[2] — [1]Institute of Physics, Otto-von-Guericke-University Magdeburg — [2]Institute of Solid State Physics, Technical University Berlin

We studied the MOVPE-growth of thin GaN films on top of AlN/sapphire-templates. After the deposition of a few monolayers GaN at 960°C, a growth interruption (GRI) with durations between 0 s and 60 s without ammonia supply was applied to allow for quantum dot formation. Each quantum dot (QD) structure was capped with AlN grown at 1195°C. Without a GRI, a continuous GaN layer with additional hexagonally-shaped truncated pyramids forms. On the other hand growth interruptions lead to desorption of GaN resulting in smaller islands without definite form located in close vicinity to threading dislocations. Ultra narrow line widths in the spectral range from 220 nm to 310 nm are observed from these islands and single photon emission is verified by Hanbury Brown-Twiss experiments. Aiming for efficient single photon sources realized as resonant cavity structures, such quantum dots were also grown on deep-UV AlGaN/AlN distributed Bragg reflectors with maximum reflectivities of 98 %.

15 min. break

HL 13.4 Tue 11:15 H31

Self-organized GaN quantum dots grown on a wavelength-matched deep UV AlN/AlGaN distributed Bragg reflector — •Hannes Schürmann[1], Gordon Schmidt[1], Christoph Berger[1], Sebastian Metzner[1], Peter Veit[1], Jürgen Bläsing[1], Frank Bertram[1], Armin Dadgar[1], André Strittmatter[1], Jürgen Christen[1], Stefan Kalinowski[2], Stefan T. Jagsch[2], Gordon Callsen[2], Markus R. Wagner[2], and Axel Hoffmann[2] — [1]Institute of Physics, Otto-von-Guericke-University Magdeburg — [2]Intitute of Solid-State Physics, Technical University Berlin

We present emission properties of self-assembled GaN quantum dots (QDs) in an AlGaN cavity on top of a wavelength-matched deep UV AlN/AlGaN distributed Bragg reflector using cathodoluminescence (CL) experiments directly performed in a scanning transmission (STEM) and a scanning electron microscope (SEM). GaN QD growth results from metalorganic vapor phase epitaxy of a nominally 2 nm thick GaN layer (V/III = 30) directly followed by a growth interruption for 30 s. To avoid a degraded DBR, an Al-concentration of 70 % in the AlGaN layers was chosen regarding the trade-off between the lattice-mismatch of AlN and GaN and its high difference in refractive indices. The obtained sample has the highest reflectivity of 88 % at 272 nm with a stopband width of 9.2 nm. SEM-CL measurements at LHe temperatures demonstrate emission from GaN QDs with an intensity increase at the stopband position of the DBR at 271 nm, thus confirming the successful MOVPE growth of self-organized GaN QDs on top of a highly reflective deep UV DBR.

HL 13.5 Tue 11:30 H31

Pyramids on N-face GaN for the aim of light emitting quantum dot structures — •Uwe Rossow[1], Fedor Ketzer[1], Angelina Jaros[2], Tobias Voss[2], Hendrik Spende[2], Andreas Waag[2], Philipp Henning[1], Philipp Horenburg[1], Heiko Bremers[1], and Andreas Hangleiter[1] — [1]Technische Universität Braunschweig, Institut f. Angewandte Physik, 38106 Braunschweig — [2]Technische Universität Braunschweig, Institut f. Halbleitertechnik, 38106 Braunschweig

Semiconductor nanostructures are very promising for single photon emitters near or at room temperature. The group-III nitrides are especially interesting in this respect since the bandgap of $In_xGa_{1-x}N$ can in principle be tuned over the whole wavelength range from the near IR to the near UV. Quantum dots based on self-organized growth, in the top of pyramids, and embedded in nanorods have been investigated. The latter two cases are better suited if individual single photon emitters need to be addressed. Unfortunately, if such nanostructures are formed during growth, indium incorporation on side facets, edges, and tip varies and it is difficult to maintain a homogeneous composition.

Here we report on a new process to produce pyramids on the basis of GaN. First we grow InGaN/GaN (single or multi) quantum well structures on N-face GaN by MOVPE. In a second step pyramids are formed by KOH etching. We demonstrate that pyramids with sharp tips can be achieved which show blue-shifted photoluminescence. We aim to optimize the efficiency to allow the realization of arrays of single photon emitters with similar emission properties.

Invited Talk HL 13.6 Tue 11:45 H31

Nitride single photon sources: quantum dots and defects
— •Rachel Oliver[1], Tongtong Zhu[1], Igor Aharonovich[2], and Robert Taylor[3] — [1]Dept. of Materials Science, University of Cambridge, U.K. — [2]Faculty of Science, University of Technology Sydney, Australia — [3]Dept. of Physics, University of Oxford, U.K.

Single photon sources are a key enabling technology for quantum communications, and in the future more advanced quantum light sources may underpin other quantum information processing paradigms such as linear optical quantum computation. In considering practical implementations of quantum technologies, the nitride materials system is attractive since it allows single photon emission at accessible temperatures, potentially enabling the implementation of quantum key distribution in contexts where cryogenic cooling is impracticable. The wide variation in bandgap across the nitride semiconductors allows access to a vast range of wavelengths from the infra-red to the ultra-violet spanning the visible spectrum.

In the visible region, both epitaxial InGaN quantum dots (QDs) and defects in GaN have been demonstrated as single photon emitters. QDs currently are easier to engineer and to incorporate into device structures. Non-polar QDs in particular offer attractive advantages in terms of short radiative lifetimes and deterministically polarised emission. Whilst single photon emission from non-polar InGaN QDs has been demonstrated at temperatures up to 220 K, defects in GaN allow room temperature single photon emission and present an exciting option for the development of for integrated quantum photonic circuitry.

Invited Talk HL 13.7 Tue 12:15 H31

GaN-based single photon emitters
— •Donat Josef As — University of Paderborn, Department of Physics, Warburger Str. 100, 33098 Paderborn

Single-photon emission from cubic GaN/AlN quantum dots grown by molecular beam epitaxy is shown. Two different growth methods: the droplet epitaxy technique and the Stranski-Krastanov growth mode were used to fabricate single zinc-blende GaN/AlN quantum dots. By micro-photoluminescence we observed spectrally clean and isolated emission peaks from both kind of quantum dots. Clear single-photon emission was detected by analyzing one such peak at 4K and a $g^{(2)}[0]$ value of 0.25 was estimated, which becomes 0.05 by correcting the background and detector dark counts. Both excitonic and multi-excitonic recombinations in individual quantum dots with radiative lifetimes shorter than 287 ± 68 ps are demonstrated. Due to the large band offsets and a large exciton binding energy, the excitonic recombinations of single zinc-blende GaN/AlN quantum dots can be observed up to 300 K. These results indicate that cubic GaN quantum dots are possible candidates for high-temperature operating UV single-photon sources with the possibility of integration into photonic nanostructures.