Polarization Controlled Light Emitters Based on Elongated InGaN/GaN Pyramidal Quantum Dots

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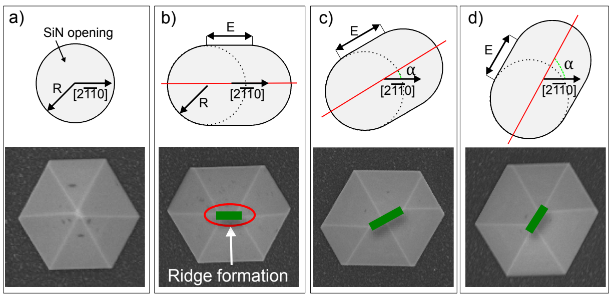
Polarized light is the basis for a manifold of optoelectronic technologies ranging from telecommunication and LCD-displays to quantum cryptography. However, in most applications of today, polarized light is generated by filtering unpolarized light, i.e. a process setting an upper limit of 50% for the light transmission.

In our approach, we employ the unique properties of the III-nitride materials. GaN pyramids with six facets are formed in the etched circular holes of a patterned substrate by Selective Area Growth (SAG) (1-5). The pyramids are subsequently overgrown by a thin optically active InGaN quantum well and finally capped with a thin GaN layer. InGaN quantum dots (QDs) will evolve on the slightly truncated top of the GaN pyramid due to the accumulated strain caused by the lattice mismatch between the GaN and InGaN well. Well-defined single excitonic emission lines appearing at around 400 nm with a FWHM down to 0.3 meV are monitored in μ-photoluminescence (μ-PL) spectra from these deterministic QDs. In a subsequent step, the etched circular holes were replaced by elongated holes, which in turn resulted in elongated pyramids, fabricated primarily in various directions (see Fig 1 (lefthand)). Interestingly, the excitonic emissions from these extended QDs on top of the elongated pyramids exhibit a strong degree of linear polarization, about 85% (2), in the direction of the elongation (see Fig 1 (righthand)). The exciton lifetimes have been investigated by means of μ-PL with a high spatial resolution combined with a streak-camera detector for recording the time spectral evolution. The exciton lifetimes have been demonstrated to vary between 100 ps to 1 ns.

For demonstration of the single photon characteristics of the QDs, temporal photon correlation spectroscopy has been performed by means of a setup of a Hanbury-Brown and Twiss interferometer equipped with sensitive single photon detectors. Excitonic single photon emission and biexcitonic photon bunching from the pyramidal dots have been monitored, confirming the sound single photon properties of these dots (6-7).



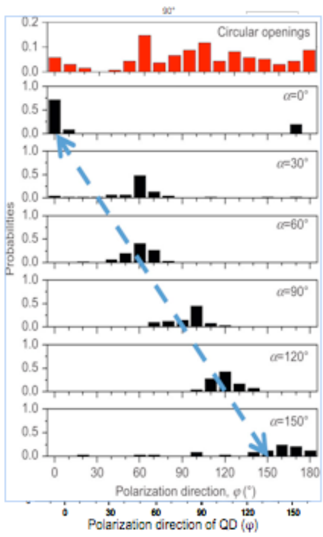


Fig. 1. An illustration of the elongated pyramidal quantum structures (lefthand figure). The resulting polarization dependence for pyramidal quantum structures elongated in different directions.

References

1. C.W.Hsu, A. Lundskog, K. F. Karlsson, U. Forsberg, E. Janzén and P.O.Holtz, Nano Letters Vol.**11**, **2415** (April, 2011)
2. A. Lundskog, C.W. Hsu, D. Nilsson, U.Forsberg, K. F. Karlsson, P.O. Holtz and E. Janzén, Nature: Light, Science & Applications (2014) 3, Article:139; doi:10.1038/lsa.2014.20
3. A. Lundskog, J. Palisaitis, C. W. Hsu, M. Eriksson, K. F. Karlsson, L. Hultman, P.O.Å. Persson, U.Forsberg, P. O. Holtz, E. Janzen, Nanotechnology 23, 305708 (2012)
4. A.Lundskog, C.W. Hsu, D. Nilsson, U. Forsberg, P.O. Holtz and E. Janzén, Journal of Crystal growth 363, 287 (2013)
5. A. Lundskog, U. Forsberg, P.O. Holtz and Janzén, Crystal growth and design 12, 5491 (2012)
6. S. Amloy, K. Fredrik Karlsson, P. O Holtz arXiv: 1311.5731
7. T. Jemsson, H. Machhadani, P.O. Holtz and K. F. Karlsson, Nanotechnology 26, 065702 (2015)