Growth and optical properties of GaN-based quantum dots

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Since the first proposal of the quantum dots (QDs) for the three dimensional quantum confinement of carries in 1982 by Arakawa et al.[1], much effort has been devoted to investigation of fabrication and physics of the QDs as well as device applications. There have been also lots of research on the QDs for wide bandgap semiconductors. In particular, GaN-based QDs are of great importance for highly efficient and low threshold current UV light emitters.

In this paper, we review the progress in the growth and optical properties of GaN-based QDs with emphasis on our recent work on high-quality GaN-based QDs with the Stranski-Krastnaow growth mode and observation of various optical properties [2-4]. Future prospect of the GaN-QDs is also discussed including possible application to single photon light sources and quantum computing devices in quantum information technologies.

Self-assembled GaN-QDs were grown by MOCVD on AlN epitaxial layers on 6H-SiC substrates. One of a unique growth condition for the QDs is that the V/III ratio is as low as 20. After the growth of the GaN QDs, a thin cap-layer of AlN was grown. Observation of two peaks from QDs and a wetting layer in photoluminescence spectrum is one of clear evidences that the growth is dominated by Stranski-Krastanow growth mode.

A time resolved measurement shows an extremely long radiative lifetime up to 1 μsec[3]. Such a long radiative decay time is due to smaller oscillator strength induced by the Quantum Confined Stark effect through a strong polarization effect in the GaN/AlN QD heterostructures. The result demonstrates that high quality of the GaN QDs which are free from nonradiative recombination process..

We also investigated single dot spectroscopy of the GaN QDs in a masked sample. The integrated photoluminescence intensity as a function of excitation power showed quadratic dependence of the biexcitons. The binding energy defined by $2E_x$-E_{xx} is a negative value of which the magnitude was about 30 meV. This negative binding energy is attributed to the effect of strong built in electric field inside the QD[4].

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