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Study of Localized Surface Plasmon Polariton Effect on Radiative Decay Rate of InGaN/GaN Pyramid Structures

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Recently, InGaN/GaN multi-quantum well grown on GaN pyramid structures have attracted much attention due to their hybrid characteristics of quantum well, quantum wire, and quantum dot. This gives us broad band emission which will be useful for phosphor-free white light emitting diode. On the other hand, by using quantum dot emission on top of the pyramid, site selective single photon source could be realized. However, these structures still have several limitations for the single photon source. For instance, the quantum efficiency of quantum dot emission should be improved further. As detection systems have limited numerical aperture, collection efficiency is also important issue. It has been known that micro-cavities can be utilized to modify the radiative decay rate and to control the radiation pattern of quantum dot. Researchers have also been interested in nano-cavities using localized surface plasmon. Although the plasmonic cavities have small quality factor due to high loss of metal, it could have small mode volume because plasmonic wavelength is much smaller than the wavelength in the dielectric cavities.

In this work, we used localized surface plasmon to improve efficiency of InGaN qunatum dot as a single photon emitter. We could easily get the localized surface plasmon mode after deposit the metal thin film because lnGaN/GaN multi quantum well has the pyramidal geometry. With numerical simulation (i.e., Finite Difference Time Domain method), we observed highly enhanced decay rate and modified radiation pattern. To confirm these localized surface plasmon effect experimentally, we deposited metal thin films on InGaN/GaN pyramid structures using e-beam deposition. Then, photoluminescence and time-resolved photoluminescence were carried out to measure the improvement of radiative decay rate (Purcell factor). By carrying out cathodoluminescence (CL) experiments, spatial-resolved CL images could also be obtained. As we mentioned before, collection efficiency is also important issue to make an efficient single photon emitter. To confirm the radiation pattern of quantum dot, Fourier optics system was used to capture the angular property of emission. We believe that highly focused localized surface plasmon around site-selective InGaN quantum dot could be a feasible single photon emitter.

Keywords: Surface plasmon polariton, GaN pyramid structure