Surface Plasmon-Enhanced Light-Emitting Diodes

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Surface plasmons (SPs) have attracted much attentions because optical properties can be greatly enhanced by coupling between SPs and the multiple quantum wells(MQWs) in light-emitting diodes(LEDs). We demonstrate the SP enhanced InGaN/GaN MQW blue LED with an Ag nanoparticle layer located underneath the MQWs. An enhancement of 32.2% of optical output power of the LED was observed at an input current of 100 mA. The time resolved- photoluminescence(PL) result showed that the PL decay time of the LED with Ag nanoparticles was significantly decreased compared to that of the LED without Ag nanoparticles, indicating that the spontaneous emission rate was increased by the energy transfer between the QW light emitter and the SP of Ag nanoparticle. This result shows that the Ag nanoparticles can be used to greatly increase the internal quantum efficiency of InGaN/GaN MQW blue LED through the coupling of excitons in MQWs and SPs in Ag nanoparticles.

We also demonstrate the surface plasmon enhanced blue LEDs using Ag nanoparticles above the MQWs, which are embedded in *p*-GaN. A large increase in light output power of 48 % was achieved with Ag nanoparticles at an injection current of 20 mA due to the improved internal quantum efficiency of LEDs. The enhancement ratio was dependent on the density of Ag nanoparticles. This improvement was attributed to the coupling between MQWs and SPs at the Ag nanoparticles in *p*-GaN.

It is also demonstrated that the electroluminescence(EL) intensity of Si quantum dot(QD) LEDs with Ag particles can be enhanced by 434 % relative to a Si QD LED without an Ag layer. The large EL enhancement was attributed to an increase of internal quantum efficiency as a result of Si QD-SP coupling and increased injection efficiency through improved carrier tunneling into Si QDs.

These results indicate that the internal quantum efficiency of LEDs can be remarkably increased by coupling of excitons in quantum wells and quantum dots with SPs in metal nanoparticles.

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