Enhanced light extraction efficiency of silicon quantum dot light-emitting diode by surface roughening

Baek-Hyun Kim[1], Il-Kyu Park[1], Tae-Wook Kim[1], Chang-Hee Cho[1], Seong-Ju Park[1]*, Nae-Man Park[2], and Sung Young Gun[2]

[1]Department of Materials Science and Engineering, Gwangju Institute of Science and Technology,
[2]Electronics and Telecommunications Research Institute
* E-mail : sjpark@gist.ac.kr

For a silicon quantum dot (Si QD) light-emitting diode (LED) with an light-absorbing Si substrate and a planar surface, only a few % of the internally emitted light can escape to the surrounding air due to the high refractive index of Si_3N_4 as well as the absorption in the metal pad for current injection, even if the internal quantum efficiency close to 100% is reached. In this work, we have investigated the enhancement in the light extraction efficiency of a Si QD LED on nano-roughened surfaces self-forming by a wet etching process. The current-voltage characteristics of an LED with nano-roughened surfaces were remarkably reduced to 8.9 V from 11.7 V of an LED without surface roughening at the same current of 20 mA. By employing the nano-roughened top and bottom surfaces of an LED structure, the light-extraction was also efficiently improved about 400 % compared to that without surface roughening at the same current of 90 mA. The enhancement in the electrical and optical properties were attributed to the increase in the surface area and the angular randomization of photons emitted in Si QDs, resulting in an increase in the light extraction efficiency of the Si QD LED.