Stabilization of Photon/Electron Emission from Nanocrystalline Si Devices

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Abstract

We recently developed a nanocrystalline porous silicon (nc-PS) EL device which offers the red emission with an external power efficiency (EPE) of 0.4% [1] and an external quantum efficiency (EQE) of 1.1% [2] at an operating voltage of 5 V. On the other hand, the nc-PS diode also operates as an efficient surface-emitting ballistic cold cathode [3]. It is useful for excitation source of flat panel display [4]. These devices are basically composed of a top contact, nc-PS layer, and a single- or poly-crystalline n^+-type Si substrate, and an ohmic back contact. To prolong the operation life of EL and electron emission to a practical level, the following two approaches have been pursued.

(1) Encapsulation of device surface with a water-proof film

The first one is capping of the PS layer with some transparent films to protect against penetration of oxygen and water molecules followed by current-triggered oxidation of nc-Si layer. By employing electron cyclotron resonance (ECR) sputtering technique for coverage of the active nc-PS layer with semitransparent SiO_2 films, the EL operation is significantly stabilized without affect on the EL efficiency. It is shown that from thermal desorption spectra analyses, the capability of capped films as a barrier against penetration of water molecules is a key factor for stabilizing the EL operation.

(2) Chemical functionalization of nc-Si surfaces

Another approach is complete passivation of each nc-Si surfaces. As recently reported [5], chemical modification of hydride nc-Si surfaces by conjugated organic molecules is very effective to preserve the intensity and the emission band of photoluminescence. This technique was applied to EL-emissive nc-PS diodes using $CH_3(CH_2)_8CHO$. By thermal treatment in it, the Si-H bonding on nc-Si surfaces should be converted into more stable Si-O bonding. Actually, the EL life time is significantly enhanced under a cw operation.

By combining the above two techniques, the EL operation would be more sufficiently stabilized. The same stabilizing effects are expected in the ballistic electron emitter as well.

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