MAR10-2009-020218

Abstract for an Invited Paper
for the MAR10 Meeting of
the American Physical Society

The contribution of carrier localisation to efficiency droop in GaN LEDs[1]

COLIN HUMPHREYS, University of Cambridge

One of the most significant problems preventing the widespread adoption of Solid State Lighting is the reduction in efficiency at high drive currents: so called "efficiency droop". A number of mechanisms have been proposed for explaining this phenomenon for example Auger recombination. However, the reason InGaN LEDs work, even though the dislocation density is high, is widely believed to due to carrier localisation. We propose that modification of carrier localisation may also control the droop. In this paper we discuss three localisation mechanisms which may be relevant to efficiency droop. In an InGaN/GaN QW the active region is strained and is also a random alloy. We have shown theoretically that random alloy fluctuations localise the holes on a 1-2 nm length scale (localisation mechanism 1). In addition, monolayer and bilayer steps on the upper InGaN/GaN QW interface localise the electrons on a 5-10 nm lateral length scale (mechanism 2). In addition, some InGaN QWs (depending on the growth conditions) exhibit a QW network structure with gross thickness fluctuations. These localise electrons and holes at room temperature on a typically 100 nm lateral length scale (mechanism 3). There are two related reasons carrier localisation may contribute to efficiency droop. First, localised carriers are in local potential minima. As the current density increases, carriers may fill these dot like regions and became delocalised, enabling them to diffuse to dislocations, reducing the light emission and resulting in efficiency droop. Second, in polar and semi-polar materials, as the current density increases, the electric field across the QW decreases, which reduces the size of the confining local potential wells, allowing the carriers to become delocalised. Experimentally we have found that the efficiency droop is significantly different in QWs with localisation mechanisms 1 plus 2 operating relative to those in which all three mechanisms operate.

[1]EPSRC is thanked for their financial support.