Optoelectronic characteristics of aSi:C:H-based pin thin film LEDs having a thin Mo buffer layer in contact with p-type aSi:H

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To improve the electroluminescence (EL) properties of the aSi:C:H-based pin thin film light-emitting diodes (TFLEDs) with the promotion of hole injection efficiency, a thin Mo metal film was used as a buffer layer to prevent reactions between the ITO (indium-tin-oxide) electrode and the p'-aSi:H layer. With the formation of semi-transparent Mo silicide after annealing, a lower EL threshold voltage and a significantly higher brightness for a TFLED were achieved. The brightness of the obtained device was 1300 cd/m² at an injection current density of 600 mA/cm². Thus, the stable brightness as high as 1300 cd/m² while for device 1 for which Vₜ₈₀ = 14.5V, and its EL threshold voltage was 14V. Device 2 also had a lower EL threshold voltage and a higher current density under the same applied voltage as compared to device 1 for which Vₜ₈₀ = 14V.

Introduction: Owing to their high conductivity and transmittance coefficients for visible light, the indium-tin-oxide (ITO) and tin-oxide (TO) are usually used as the front electrode for optoelectronic devices. When these transparent electrodes are in contact with H₂-plasma, both physical and chemical reactions are initiated [1–3]. Usually, various amorphous films are deposited with a plasma-enhanced chemical vapour deposition (PECVD) system and their source gases are diluted in H₂, hence, these reactions take place during film deposition for device fabrication. These reactions cause the penetration of Sn and In into the consequently deposited p'-aSi:H layer. The p'-aSi:H film contaminated by Sn and In would possess more defect states and a lower concentration of free holes [4]. The injected holes from the external ITO electrode might easily be captured in the degraded p+-aSi:H layer. Moreover, the accumulation of holes in p'-aSi:H could build up a potential barrier to suppress the hole injection efficiency.

Several semi-transparent metals, such as thin Cr and Mo films, have been proposed for insertion between the ITO and p'-aSi:H as a buffer layer [3–5]. The thin Mo film has several advantages: it has a high visible-light transmittance and forms a stable Mo silicide with p'-aSi:H film. With a thin Mo film coated on the ITO, the migration of the Sn and In oxides in the ITO caused by the H₂-plasma would be suppressed and no oxidized p'-aSi:H layer would be formed. In this Letter, a 3nm Mo buffer layer [3, 6] inserted between the ITO and p'-aSi:H layers was adopted to improve the performances of a thin film light-emitting diode (TFLED). Moreover, as shown in Fig. 1, to reduce the effects of the notch barriers existing at the pi and in interfaces of a TFLED, a composition-dopant-graded (CDG) gap structure has been employed [7]. CDG1 could increase the hole injection efficiency. At the same time, CDG2 has an additional low-resistance aSiGe:H layer to further improve the electron injection efficiency [7].
log(J) for device 1, device 2 and a packaged HP HLMP-8405 high orange brightness LED. The brightness of device 2 was 1300cd/m² which was ~10 times less than that of the HP HLMP-8405 orange LED and ~2 times higher than that (620cd/m²) of device 1, at a current density of 600mA/cm². The mechanism of radiative recombination for a TFLED could be determined from the slope, n, of the log(B) against log(J) curve. As is shown in this inset, the values of n for devices 1 and 2 were very close to 1, so the radiation mechanism of a TFLED was considered to be monomolecular and/or tail-to-tail state recombinations [5]. As can be observed from the inset plot, the larger the n value, the higher the brightness of devices, and the n value for device 2 was slightly greater than that of device 1. So it was believed that the higher brightness of device 2 was due to an improvement in the quality of the interface between p'-a-Si:H and ITO with a thin Mo layer employed.

(ii) EL spectrum: As is shown in Fig. 3, the EL spectra of devices 1 and 2 peaked at wavelengths of 670 and 620nm, respectively. The peak wavelength of the emitted light may be related to the energy level of the injected carriers, as can be observed from the inset plot of Fig. 3 which depicts the EL spectra of device 2 under various applied voltages. Device 2 had a shorter peak wavelength as compared to that of device 1 at the same applied voltage. Moreover, in Fig. 3, the full-width at half maximum (FWHM) of the EL spectrum was 200nm for device 1 while that of device 2 is 160nm. These values provide evidence that the injected holes in device 2 had a higher energy level and a narrower energy distribution, due to the thin Mo layer employed.

Fig. 3 EL spectra of devices 1 (without Mo layer) and 2 (with Mo layer) under applied voltage of 15V

- — device 1
- — device 2
Inset: EL spectra of device 2 under various applied voltages
- — 19V
- — 17V
- — 15V

(iii) Effects of annealing: The qualities of the amorphous films in the device and the ohmic contacts between the external electrode (ITO/Mo or Al) and the contacted layer (p-a-Si:H or n-a-Si:H) could be improved by the technique of rapid-thermal-annealing (RTA) in an H₂ ambient. Device 2 was annealed with a temperature of between 260 and 320°C for 10min. The lowest average value of Vₜ and highest average value of B for TFLEDs were obtained at an annealing temperature of 280°C. An annealing temperature of 300°C was considered as a critical temperature at which the hydrogen started to diffuse out of the amorphous materials [9]. So, the devices that were annealed at a temperature of >300°C showed poor performances. To find the best time duration of rapid thermal annealing (RTA) for device 2, various RTA time durations, 8, 10, 12, and 14min, were tried, while the temperature was kept at 280°C. It was found that the best RTA time duration was 10min. Hence, the optimal conditions of RTA for device 2 were 10 min duration at 280°C in an H₂ ambient.

Conclusion: From the results of this study, it was obvious that the thin Mo buffer layer inserted between the ITO and p'-a-Si:H layers could be used to improve the optoelectronic performances of TFLEDs. The TFLED with (without) an Mo layer had a lower (higher) device resistance, a lower (higher) EL threshold voltage of 14V (14.5V), a higher (lower) brightness of 1300cd/m² (620cd/m²) at J = 600mA/cm², a shorter (longer) EL peak wavelength of 620nm (670nm), and better (poorer) EL stability. The optimal conditions of annealing for the proposed TFLED with a thin Mo layer were 10 min duration at 280°C in an H₂ ambient.

References

Picoscound switching due to electron tunnelling and avalanche in GaAs/Al,Ga₁₋₈As diode

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A new semiconductor heterostructure diode with an S-type current-voltage characteristic that can be used for high-speed voltage switching is proposed and demonstrated. This behaviour is caused by the electrons tunnelling through the potential barrier and initiating avalanche multiplication in a small energy gap base region.

Introduction: Two-terminal semiconductor devices with nonlinear current-voltage (I-V) characteristics are widely used in various ultrafast signal shaping and switching applications. Two extreme cases of such nonlinearity are I-V characteristics corresponding to N-type negative differential conductivity (N-NDC) and to S-type NDC (S-NDC). Devices exhibiting N-NDC are more numerous; Gunn diodes, tunnelling diodes and resonant tunneling diodes are the best known examples. In contrast, the development of semiconductor diodes with S-NDC was less successful, although the S-NDC effect is preferable to N-NDC for high-power switching and tunable high frequency generation applications.