A CO_2 laser rapid-thermal-annealing SiO_x based metal-oxide-semiconductor light emitting diode

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Enhanced near-infrared (NIR) electroluminescence (EL) of a metal-oxide-semiconductor light emitting device (MOSLED) made on CO_2 laser-annealed SiO_x film is demonstrated. An EL power of near 50 nW from CO_2 laser rapid-thermal-annealing (RTA) MOSLED under a biased voltage of 85 V and a current density of 2.3 mA/cm^2 is preliminarily reported.

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The observation of light emission and optical gain[1] in plasma enhanced chemical vapor deposition (PECVD) grown silicon-rich silicon dioxide (SiO_x, $x < 2$) films containing nc-Si corroborates the potential of Si laser. Typically, the synthesis of nc-Si embedded in the Si ion-implanted or PECVD-grown SiO_x film requires a long-term and high-temperature furnace-annealing process (longer than 30 min)[2]. This approach meets the difficulty in its compatibility with current integrated circuits (ICs) fabricating procedure, in which a high temperature over 500 °C may not be applicable since it could seriously damage the ICs integrated nearby the SiO_x based light emitting diodes (LEDs). It is known that the laser annealing techniques can be employed to locally modify the morphology or structural properties of metallic thin films and dielectric materials, etc.. In this work, we present the fabrication of a metal-oxide-semiconductor light emitting device (MOSLED), whose oxide layer is the nc-Si embedded SiO_x film fabricated by CO_2 laser rapid-thermal-annealing (RTA) process.

In the experiment, the PECVD-grown SiO_x film with a thickness of 280 ± 10 nm was deposited on the p-type (100) Si substrate with a gas mixture of SiH_4 and N_2O. Afterwards, the CO_2 laser RTA was performed in atmosphere using a continuous-wave (CW) CO_2 laser ranging from 1.5 to 13.5 kW/cm^2. The CO_2 laser illuminating time was as short as 1 ms. The photoluminescence (PL) of CO_2 laser RTA SiO_2 pumped by a HeCd laser at 5 W/cm^2 and 325 nm was detected by a fluorescence spectrophotometer (Jobin Yvon, TRIAX-320). Indium tin oxide (ITO) and aluminum (Al) films with thicknesses of 200 and 500 nm were used as surface and backside contacts, respectively. An ITO/$SiO_{1.25}$:nc-Si/p-Si/Al MOSLED with a contact diameter of 0.8 mm was made to perform electroluminescence (EL).

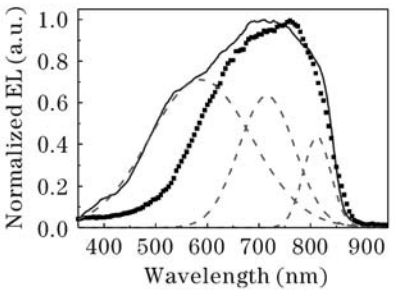

Fig. 1. EL spectra of MOSLEDs made by CO_2 laser RTA (line) and furnace-annealed (square) SiO_x with decomposed curves at 590, 715, and 810 nm (dashed).

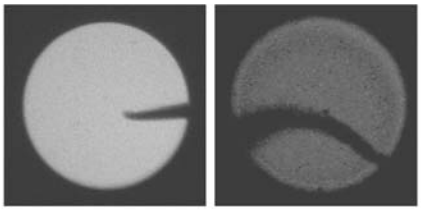

Fig. 2. Far-field EL patterns of CO_2 laser RTA (left) and furnace-annealed (right) MOSLEDs.

The enhanced near infrared (NIR) EL of an ITO/CO_2 laser RTA SiO_x/p-Si/Al MOSLED is preliminarily demonstrated in Figs. 1 and 2. Dense nc-Si can be synthesized in the $SiO_{1.25}$ film by using the CO_2 laser RTA at 6 kW/cm^2 for 1 ms. The comparison of PL spectra of CO_2 laser annealed and furnace-annealed PECVD grown $SiO_{1.25}$ samples reveals the contribution of oxygen related defects. Since the CO_2 laser annealing time is only 1 ms and much shorter than furnace annealing time (3 hours), the annealing time is insufficient for precipitating larger size nc-Si, whereas the oxygen-related defects are generated in the CO_2 laser annealed SiO_x film. These defects enhance the carrier transport through the MOSLED, reducing the tunneling threshold from 3.2 to 1.8 MV/cm as compared with the furnace-annealed sample. The elucidation on the role of the oxygen-related defects played on the improved carrier transport and enhanced light emission properties is addressed. A maximum EL power of near 50 nW from the ITO/CO_2 laser RTA SiO_x/p-Si/Al MOSLED under a biased voltage of 85 V and a current density of 2.3 mA/cm^2 is reported to date.

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