The optical and electrical characteristics of the CO_2 laser treated Mg-doped GaN film

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Abstract

GaN and related group III nitrides have recently attracted extensive attenuation because of their potential application to optoelectric devices operating in blue and ultraviolet spectra regions. Some pioneering efforts have been realized for p-type GaN film, which are one of key to the success of GaN-based light-emitting diodes (LEDs) and laser diodes (LDs). P-type GaN typically grown under H_2 rich ambient using magnesium (Mg) as an acceptor dopant. Because of the as-grown Mg doped p-GaN shows high resistivity, it often needs the additional process step to electrically activate Mg dopant. Low energy electron beam and thermal annealing methods have been used to activate Mg-doped GaN by Akasaki et. al. and Nakamura et. al.. In this study, we demonstrate the first time successfully electrical activation of the Mg doped p-GaN by using the laser annealing technology. The laser used in this study was the continue-wave (CW) CO_2 laser. The study issues shown the relationship of the optical characteristic and electrical characteristic with laser power.

The Mg doped GaN layer was grown in a low pressure OMVPE reactor. The Gallium, nitrogen and magnesium sources were trimethylgallium (TMGa), ammonia (NH3) and biscyclopentadienyimagnesium (Cp_2Mg), respectively. A low-temperature-grown 25nm thick GaN nucleation layer was first deposited on a (0001) Al_2O_3 substrate. And then, an undoped GaN layer with thickness of 1.0μm was grown at 1025 ^{O}C. The Mg doped GaN layer was grown on the undoped GaN layer. The thickness of the Mg-doped GaN layer is 1μm. After the growth of the Mg-doped GaN layer, the sample was activated by the CW CO_2 laser with different power and different exposure time.

Figure 1 shows the PL spectra of the samples before and after laser annealing. The main peak position of PL spectrum for as-grown Mg doped GaN was at 445nm measured at room temperature. After sample under irradiated with a CO_2 laser, the intensity of the blue emission at 445nm becomes very strong as indicated in Fig.1. The intensity of the blue emission after 10W laser exposure is almost 10 times stronger than that as-grown film. It indicates that the CO_2 laser treatment enhances the blue emission.

The resistivities and carrier concentrations of the Mg-doped GaN film after the laser annealing treatment are shown in Fig.2. From Fig.2 it can be seen that the hole concentration of the laser activated Mg-doped GaN film was around $1x10^{17}cm^{-3}$ as the laser annealing power at 7.5W. When the laser annealing power above 10W, the hole concentration of the Mg-doped GaN film was increase to $8x10^{17}cm^{-3}$. Form fig.1 and Fig.2, they obviously indicate that the Mg-doped GaN film has been electrically activated by the CO_2 laser treatment.

We had successfully activated the Mg-doped GaN film by using CO2 laser treatment. Optical and electrical results of the CO_2 laser irradiated Mg-doped GaN films are demonstrated. The Mg-doped GaN film after 10W laser annealing has PL intensity 10 times stronger than the as-grown film. In addition, the hole concentration of Mg-doped GaN film is as high as $8x10^{17}$ cm^{-3} when the laser annealing power is above 10W.

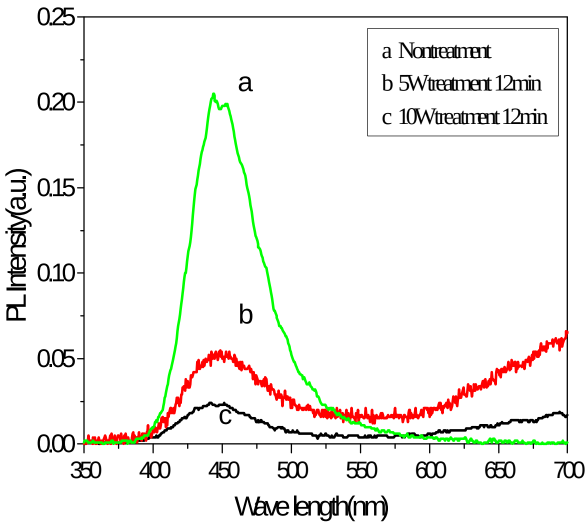

Fig.1 PL spectrum of different CO_2 laser irradiation power

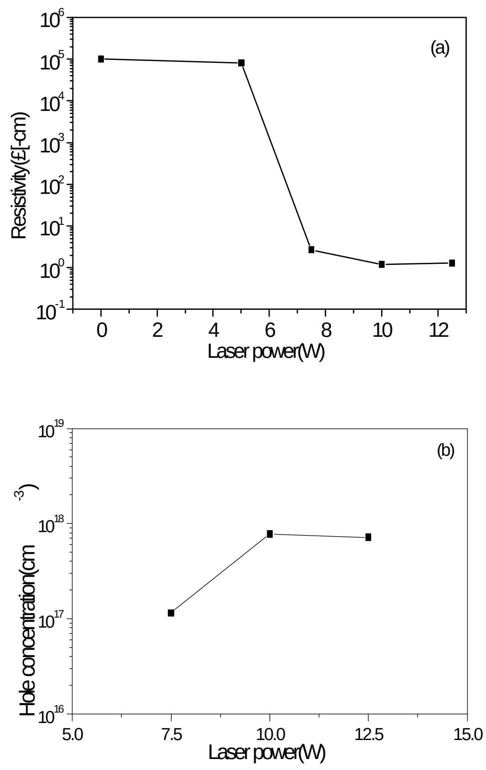

Fig.2 Relationship of (a) resistivity and laser power and (b) hole concentration and laser power of laser irradiatted Mg-doped GaN film