The influence of both Mg-concentration and excimer laser annealing (ELA) on p-AlGaN cladding layer for the application of AlGaN-based UVB Laser Diodes

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Mg-doped p-AlGaN is very attractive material for numerous applications in short wavelength light-emitting diodes, laser diodes and high power devices due to its outstanding properties such as large optical transmittance, possibility of doping using Mg-atoms, and having wide bandgap of p-$Al_xGa_{1-x}N$ materials with direct bandgap (3.4~6.2eV). However, the activation of Mg-dopant in the p-AlGaN epitaxial layer is very challenging. High temperature annealing (> 850 °C) is typically required to activate p-dopants both in p-GaN and p-AlGaN [1-2], but it deteriorates the MQWs of UV devices [2]. Therefore, in this work first we investigated the influence of Mg-concentration on the crystalline quality, PL emission efficiency and relaxation conditions of p-AlGaN layers. As we know that the excimer laser annealing (ELA) has been used for the activation of the Mg-atoms in the p-GaN [1]. In this work, the influence of ELA on heavy doped Mg-doped p-AlGaN layers were also initiated [1].

In this regard, several samples (V24, V25a, V25b, V25c and V26) of Mg-doped p-AlGaN layers having thickness of 1.4µm were grown on the 4µm-thick AlN template on sapphire substrate in MOCVD by changing the Mg-concentration, as shown in the table 1. The detail about the growth technique of p-AlGaN epilayer is given elsewhere [2]. The crystallinity of the grown samples was investigated by using the XRD reciprocal space mapping (RSM) along (-1 -1 4) reflections and XRD rocking curve (XRC) measurement both along (102) and (002) planes as given in the table 1. XRC around 300 arcsec for (002) and 460 for (101) diffraction were maintained, which reflects the reasonable level of defects in all samples except sample V26 (heavily Mg- doped: 100 sccm). The influence of the Mg-concentration on the relaxation of the p-AlGaN layer were also confirmed, however the Al-composition were not influenced by the Mg-concertation variation in all samples, as shown in the table 1.

Table-1

sample name	Mg (sccm)	XRC (102)	XRC (002)	Al-composition (%)	Relaxation ratio (%)
V24	50	453	341	49	20
V25a	60	465	300	49	26
V25b	70	467	298	49	29
V25c	80	464	290	49	36
V26	100	531	319	49	65

The ELA technique was employed to irradiate and anneal a Mg-doped p-AGaN layers on AlN template. Two samples (V25c and V26) were irradiated with 1 shot at a fluence (F) of 300 mJ/cm^2 either in N_2 or in Ar by a KrF excimer laser (λ = 248 nm, pulse width = 9 ns). Subsequently the ELA's effect on the optical, physical, and chemical properties of p-AlGaN by performing, PL, XRC and RSM and X-ray photoelectron spectroscopy (XPS) measurements. The PL spectral intensities were reasonably enhanced in both sample V25c and V26 after ELA treatment, as shown in Figs. 1(a)-(b). Broader Ga 2p peak after ELA suggesting higher Ga-Ga (77.4%) and lower Ga-N (15.6%) bonding in the sample V25c, as shown in the XPS spectra of Fig. 1(c). These are our preliminaries results about the ELA treatment of p-AlGaN for Mg-activation and we need to investigate the electrical characterization after ELA treatment in the future.

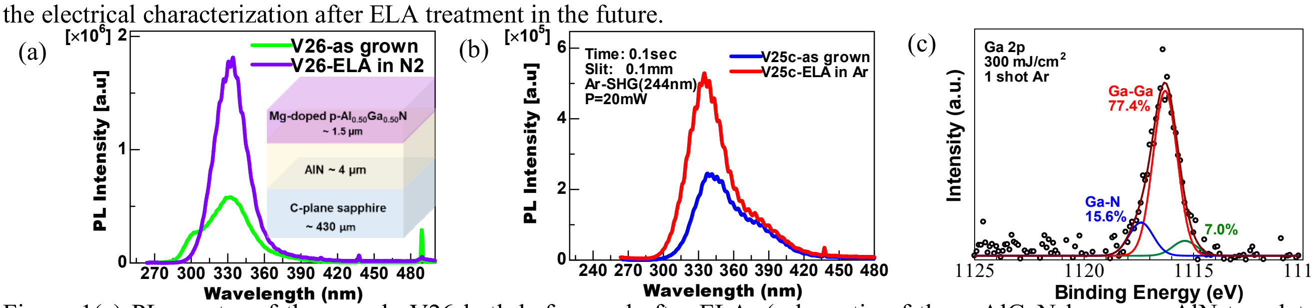

Figure 1(a) PL spectra of the sample V26 both before and after ELA, (schematic of the p-AlGaN layers on AlN templated is given in the inset), (b) PL spectra of the sample V25c both before and after ELA, and (c) XPS spectra of sample V25c after ELA treatment.

Acknowledgement: This work was supported in part by NEDO and SPDR of Riken.

References

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