Extended Abstracts of the 21st Conference on Solid State Devices and Materials, Tokyo, 1989, pp. 337-340

D-7-2

Effects of $(NH_4)_2S$ Treatments on the Characteristics of AlGaAs Laser Diodes

Hidenori Kawanishi, Hirotaka Ohno, Taiji Morimoto※, Shinji Kaneiwa※, Nobuyuki Miyauchi※, Hiroshi Hayashi※, Yoshiro Akagi, Yoshiharu Nakajima, and Toshiki Hijikata
Corporate R&D Group, Sharp Corporation, 2613-1 Ichinomoto-cho, Tenri-shi, Nara 632
※LCD Division, Sharp Corporation, 492 Minosho-cho, Yamatokoriyama-shi, Nara 639-11

$(NH_4)_2S$ treatment technique is applied to the facet of 780nm AlGaAs high power laser diodes for the first time. The maximum achieved output power is 220mW without catastrophic optical damage ($\theta_\perp$=26.3°) under CW operation. The results of Auger electron spectroscopy and x-ray photoelectron spectroscopy indicate that the $(NH_4)_2S$ treatment is effective in reducing the surface native oxide and improving the high power characteristics.

1. Introduction

Recently, high power highly reliable single stripe lasers are strongly required as light sources for optical disc systems, laser beam printers and so on. One of the main reasons that cause the deterioration of high power lasers is the facet degradation due to the temperature rise at the active mirror facet. In fact, the temperature rise at the front facet has been measured to be as high as a few hundred degrees[1)2)]. Several approaches have been made to prevent the facet degradation. One approach is to reduce the optical power density by thinning the active layer[3)], widening the waveguide [4)2)] or with large optical cavity(LOC) structure[5)]. The second way is the non-absorbing mirror(NAM) concept[6)]. The temperature rise is a result of intense non-radiative recombination process at the facet. So the third approach to prevent the facet degradation is to reduce the non-radiative recombination centers themselves and keep the mirror facet from being heated up.

The GaAs surface is usually covered with native oxide layer. The GaAs-oxide interface has been known as a "pinned" interface due to the high density of the interface states. Recently, photochemical [7)8)] and chemical[9)10)] treatments have succeeded in passivating the GaAs surface. Especially the $(NH_4)_2S/(NH_4)_2S_x$ treatment was proved to be effective in reducing the interface state density[11)-13)]. But it remains unclear whether the treatment is also effective for $Al_xGa_{1-x}As$ surface.

In this paper, we report on the effects of the $(NH_4)_2S$ treatment on the $Al_xGa_{1-x}As$ surface. We applied the $(NH_4)_2S$ treatment to the facet of $Al_xGa_{1-x}As$ laser diodes for the first time and dramatic improvements of laser characteristics were obtained. And by analyzing the treated $Al_xGa_{1-x}As$ surface with Auger Electron Spectroscopy(AES) and X-ray Photoelectron Spectroscopy(XPS), we concluded that the improvement is mainly due to the reduction of the oxide layer on the $Al_xGa_{1-x}As$ surface.

2. Experimental

Lasers used in this work are ordinary 780nm high power V-channeled substrate inner stripe(VSIS) lasers[16] except that the cavity length is 375μm. A cross-sectional view is shown in Fig.1. After two-step liquid phase epitaxial(LPE) growth, the wafer was thinned, metallized, cleaved into 375μm bars. Then the bars were dipped into the $(NH_4)_2S$ solution for a few minutes at room temperature, rinsed in de-ionized water, blown dry with N_2 gas before 5%-95% coating. After coating and dicing, the individual laser diodes were mounted epitaxial-side down on Cu heat sinks. Laser diodes were tested under CW operation. The output power and the far-field patterns were monitored as functions of the drive current.

In order to clarify the effect of $(NH_4)_2S$ treatment, several analyses were performed. Experiments were performed on the (100) surface of the n-type $Al_xGa_{1-x}As$ (x=0.43) wafer, it was prepared by the same LPE process with that of the laser diodes with carrier concentration of about 1×10^{18} cm^{-3}. AES and XPS were employed to study the atomic concentration and chemical bonding of the surface before and after the treatment. As-etched surface were also studied as a reference sample.

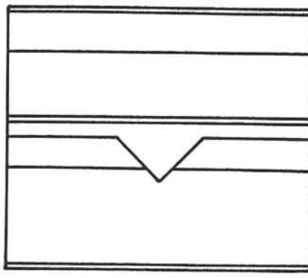

Fig.1 Cross-sectional view of the VSIS laser.

3. Results and Discussion

Figure 2 shows the typical light-current(L-I) characteristics and far-field patterns of a $(NH_4)_2S$ treated VSIS laser. The CW threshold current is 82mA and the differential quantum efficiency is 42% for the front facet. The maximum output power is as high as 220 mW under CW operation ($\theta_\perp$= 26.3°), while untreated sample shows a catastrophic limit of 120mW ($\theta_\perp$=27°). Other characteristics remains unchanged.

Figures 3 and 4 show a typical AES spectra and a core level XPS spectra in the

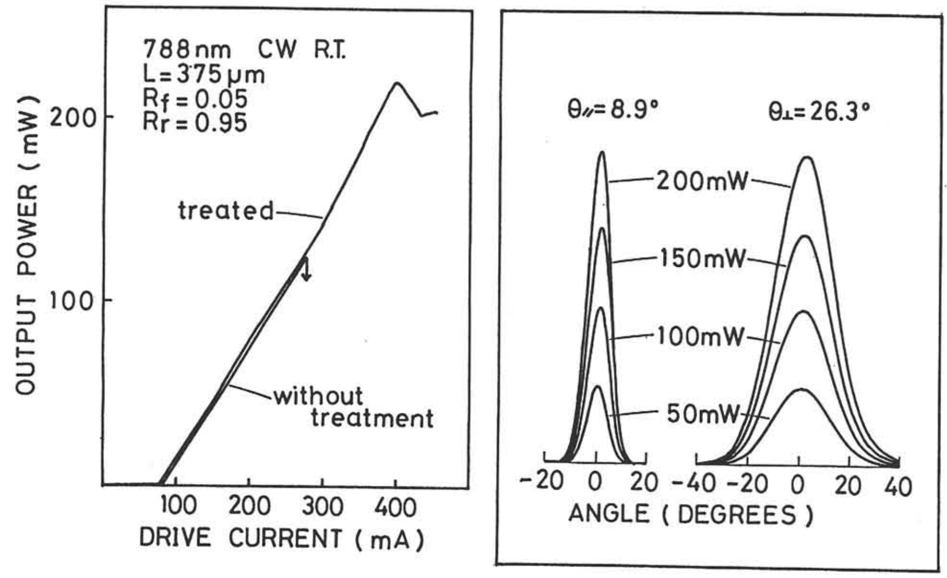

Fig.2 Typical light-current (L-I) characteristics and far-field patterns of a $(NH_4)_2S$ treated VSIS laser.

As(2p3/2), Ga(2P3/2), and Al(2p) regions on the n-type $Al_{0.43}Ga_{0.57}As$ (100) wafer respectively; (a) after 46 days of air exposure and (b) after 46 days of air exposure and 5min. $(NH_4)_2S$ treatment. The spectra were obtained with 10kV 30nA electron and AlKα x-ray using VG SCIENTIFIC MICROLAB 300-A spectrometer equipped with triplechannel detector. XPS spectra were calibrated by setting the binding energy of C1s level to 284.6eV. Background pressure were less than 5×10^{-8} Pa. Figures 5 and 6 shows the AES and XPS spectra on as-etched n-type $Al_{0.43}Ga_{0.57}As$ (100) wafer. The layer was grown on the n-type GaAs substrate followed by the successive growth of lattice-matched $Al_{0.8}Ga_{0.2}As$ layer, it was removed by HF just before measurement. So surface oxidation and contamination were minimized. The top surface of the layer were slightly etched in this process.

After $(NH_4)_2S$ treatment, Auger signal of oxygen at 510eV is reduced, and the sulfur signal at 152eV appears. XPS spectra

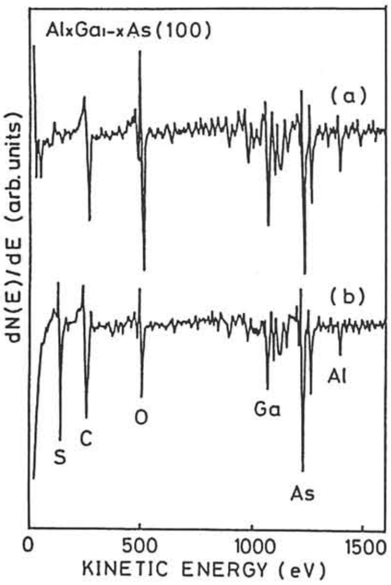

Fig.3 Typical AES spectra on the n-type $Al_{0.43}Ga_{0.57}As$ (100) wafer; (a) after 46 days of air exposure and (b) after 46 days of air exposure and 5min. $(NH_4)_2S$ treatment.

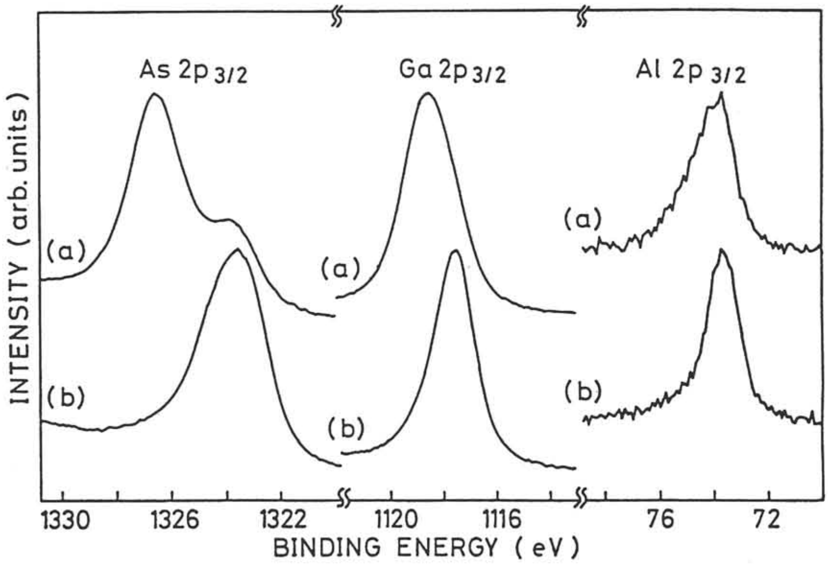

Fig.4 Typical XPS spectra on the n-type $Al_{0.43}Ga_{0.57}As$ (100) wafer (a) after 46 days of air exposure and (b) after 46 days of air exposure and 5min. $(NH_4)_2S$ treatment.

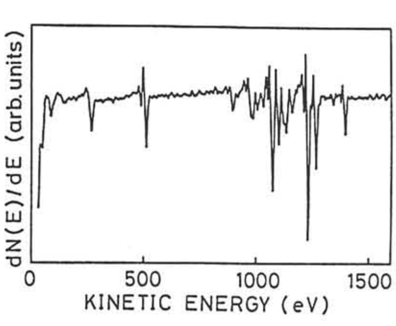

Fig.5 Typical AES spectra on as-etched n-type $Al_{0.43}Ga_{0.57}As$ (100) wafer.

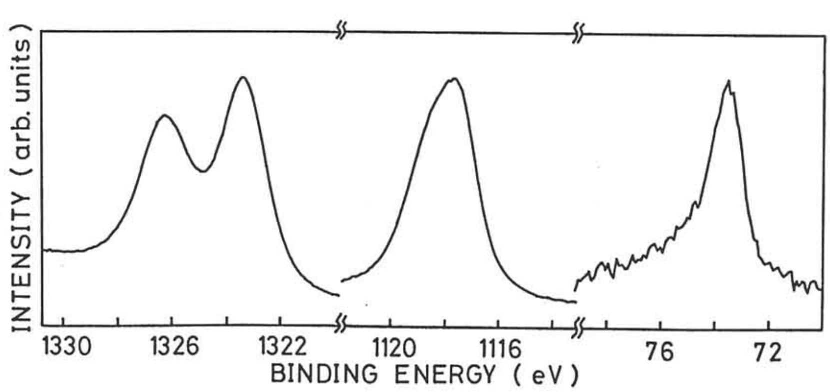

Fig.6 Typical XPS spectra on as-etched n-type $Al_{0.43}Ga_{0.57}As$ (100) wafer.

of the treated sample shows the remarkable reduction of oxide associated with Ga (1118.5eV), As(1326.6eV)[15]. The Al(2p) core level spectrum also indicate a similar reduction of a higher binding energy shoulder characteristics, which is identified to be Al_2O_3 (75eV) by the Al core level shift observed for the bulk sapphire.

The comparison of the AES and the XPS spectra leads to the conclusion that most of the remaining oxygen in the Auger spectra of $(NH_4)_2S$ treated sample is the overlayer adsorbed on the surface like carbon contaminants[14]. XPS spectra of as-etched sample also shows the oxide peaks of As and Ga. And the Al spectra also has the 75eV shoulder.

From these data, we can conclude that the oxide of As, Ga and Al are formed immediately after HF etching or during the etching process. But these oxides can be reduced by the $(NH_4)_2S$ treatment.

4. Summary

Dramatic improvement of AlGaAs laser characteristics was realized by the $(NH_4)_2S$ facet treatment. And by analyzing the (100) $Al_xGa_{1-x}As$ (x=0.43) surface with AES and XPS, we observed the reduction of the oxide layer associated with As, Ga, and Al. Considering the previous results[13], the $(NH_4)_2S$ treatment seems to be effective on the (110) plane, too. And we conclude that the improvement of the laser characteristics is mainly due to the reduction of the oxide layer on the laser facet.

References

(1) S.Todoroki, M.Sawai and K.Aiki; J. Appl. Phys. 58 (1985) 1124.

(2) H.Kawanishi, T.Morimoto, M.Yamaguchi, S.Kaneiwa, N.Miyauchi, T.Yoshida, H.Hayashi, S.Yano, and T.Hijikata; Jap. J. Appl. Phys. 27 (1988) L1310.

(3) T.Murakami, K.Ohtani, H.Matsubara, T.Yamawaki, H.Saito, K.Isshiki, Y.Kokubo, A.Shima, H.Kumabe, and W.Susaki; IEEE J. Quantum Electron. QE-23 (1987) 712.

(4) D.F.Welch, P.S.Cross, D.R.Scifres, W.Streifer, and R.D.Burnham; Appl. Phys. Lett. 50 (1987) 233.

(5) T.Hayakawa, T.Suyama, H.Hayashi, S.Yamamoto, S.Yano and T.Hijikata; IEEE J. Quantum Electron. QE-19 (1983) 1530.

(6) H.Yonezu, M.Ueno, T.Kamejima, and I.Hayashi; IEEE J. Quantum Electron. QE-15 (1979) 775.

(7) S.D.Offsey, J.M.Woodall, A.C.Warren, P.D.Kirchner, T.I.Chappell, and G.D.Pettit; Appl. Phys. Lett. 48 (1986) 475.

(8) T.Sawada, H.Hasegawa, and H.Ohno; Jpn. J. Appl. Phys. 26 (1987) L1871.

(9) C.J.Sandroff, R.N.Nottenburg, J.C. Bischoff, and R.Bhat; Appl. Phys. Lett. 51 (1987) 33.

(10)M.S.Carpenter, M.R.Melloch, M.S. Lundstrom, and S.P.Tobin; Appl. Phys. Lett. 52 (1988) 2157.

(11)J.Fan, H.Oigawa, and Y.Nannichi; Jpn. J. Appl. Phys. 27 (1988) L1331.

(12)Y.Nannichi, J.Fan, H.Oigawa, and A.Koma; Jpn. J. Appl. Phys. 27 (1988) L2367.

(13)H.Oigawa, J.Fan, Y.Nannichi, K.Ando, K.Saiki, and A.Koma; Jpn. J. Appl. Phys. 28 (1989) L340.

(14)P.Etienne, P.Alnot, J.F.Rochette, and J. Massies; J. Vac. Sci. Technol. B4 (1986) 1301.

(15)B.A.Cowans, Z.Dardas, W.N.Delgass, M.S. Carpenter, and M.R.Melloch; Appl. Phys. Lett. 54 (1989) 365.

(16)S.Yamamoto, H.Hayashi, S.Yano, T. Sakurai, and T.Hijikata; Appl. Phys. Lett. 40 (1982) 372.