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InGaAsP Laser on GaAs Fabricated by the Surface Activated Wafer Direct Bonding Method at Room Temperature

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1. Introduction

Semiconductor wafer direct bonding to fabricate micro mechanical system and electronic chips is a key technology to realize highly integrated micro electro mechanical devices. Most to existing methods need high temperature annealing. High temperature annealing is necessary to strength and stabilize the bonding. However, high temperature process may cause still serious problems in realizing highly integrated microelectro and mechanical devices such as thermal stress introduction, defect generation and metal wiring corruption. Many special techniques have been developed to overcome those problems, but they often make fabrication process more complicated. InP-based long wavelength lasers on GaAs and Si substrate have been reported[1-2]. High quality active layer without any threading dislocation, which is observed for epitaxial layer using hetero-epitaxy, is obtained. This technology can be a candidate to realize optoelectronic integrated circuits(OEICs). Surface activated bonding method in ultra high vacuum at room temperature has many advantage as a low damage bonding method[3-5]. The purpose of this paper is to report the first successful attempt of the room temperature bonding of InGaAsP laser and GaAs substrate.

2. Experimentals

Figure 1 shows a schematic diagram of a fabricated device. An InP-based laser wafer is prepared by metalorganic chemical vapor deposition. Six compressively strained InGaAsP quantum wells separated by lattice-matched InGaAsP with a band gap wavelength of 1.3 μm is used for the active layer[6]. Graded-index separate confinement heterostructure(GRIN-SCH)layer consisted of decreasing bandgap wavelengths of 1.1 μm, 1.05 μm, 1.0 μm and 0.95 μm with a layer thickness of 30nm is used for an optical confinement layer. A 1.5 μm thick Inp was used for laser application as the cladding layer. Both of the laser wafer and an n-GaAs substrate are cleaned acetone and ethanol, followed by rinsing in the deionized water. Specimens were then set in the introduction chamber of the ultra high vacuum apparatus. Before bonding, the surface of the specimens was activated by sputter cleaning with Ar fast atom beam(FAB). Sputter cleaning conditions were 1.5kV accelerated voltage, 15mA plasma current for etch gun. After the cleaning, two specimens were transferred to the bonding chamber and brought into contact as soon as possible at room temperature.

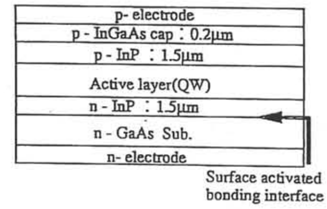

Figure 1. Schematic diagram of a 1.3 μm InGaAsP laser on a GaAs substrate using the surface activated wafer direct bonding method.

After surface activated bonding, InP substrate was preferentially etched off by concentrated HCl. To analysis the surface of properties of the specimen by the Auger Electron Spectra(AES), before FAB and irradiation time 30 sec. The ridge waveguide laser was fabricated using self-aligned process. The I-V characteristic of directly-bonded n-GaAs/LD on InP substrate has been measured. The carrier concentrations of the wafers were 2×10^{18} and $5\times10^{18}cm^{-3}$, respectively. Ohmic contact was formed using AuGeNi for n-type samples and Ti/Pt/Au for p-type one.

3. Results

Figure 2 shows the result of Auger Electron Spectra.

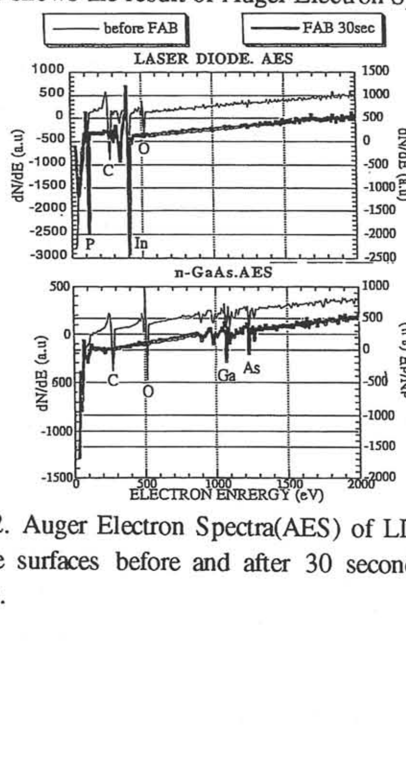

Figure 2. Auger Electron Spectra(AES) of LD and GaAs substrate surfaces before and after 30 seconds Ar FAB cleaning.

From the analysis, Ar FAB 30 seconds cleaning is enough to remove surface contaminants such as absorbed gas, hydrocarbon and natural oxide. The specimens of non-Ar FAB cleaning was not bonded. Bonding does not occur in ultra high vacuum without Ar FAB cleaning. its result demonstrates that Ar FAB cleaning has important role to achieve strong bonding at room temperature. Figure 3 shows the I-V curves measured at room temperature. Good electrical conduction has been found to be obtained. The measured PL peak intensity is shown in Fig. 4.

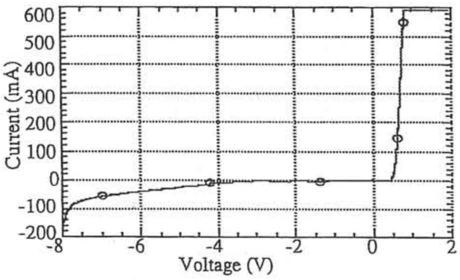

Figure 3. Current -voltage characteristic of the laser fabricated on GaAs substrate using surface activated wafer direct bonding.

The PL intensity of bonded specimen after 30 seconds Ar FAB cleaning is similarly the reference epitaxy wafer. Its result means that strong and tight bonding can be attained at room temperature. The light output power versus injection current (L-I) characteristic is shown in Fig 5. for L=600 μm, W=290 μm-long ridge waveguide laser at 25℃. The threshold current was as low as 1.5A.

4. Conclusion

We have demonstrated that, by the surface activated method, strong and tight bonding of laser diode formed wafer and GaAs substrate can be attained at room temperature. The L-I characteristic is almost identical and the threshold current density is estimated to be 0.86kA/cm^2.

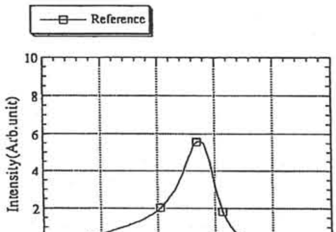

Fig 4 - a)

Figure 4. Normalized PL peak intensity of InGaAsP laser on GaAs substrate using surface activated wafer direct bonding.

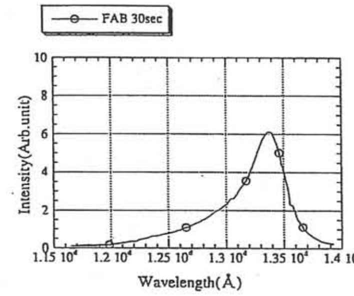

Fig 4 - b)

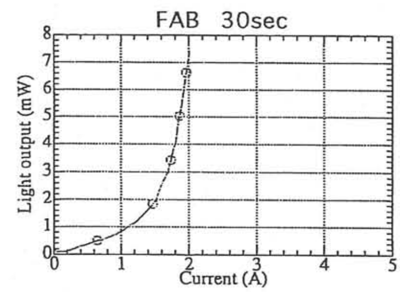

Figure 5. Light-current characteristic of the laser fabricated on GaAs substrate using using surface activated wafer direct bonding.

These results imply this direct bonding technique is very promising as a key technology to realize OEICs. Although there remain many issues concerning with the mechanism of the bonding and L-I characterization, the present method might be expected to provide new possibility of wafer direct bonding technique for fabrication and integration of optoelectronic integrated circuits due to its low process temperature, or eventually room temperature.

Acknowledgments

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Reference

1) Y. Okuno, K. uomi, M. Aoki, T. taniwatari, m. Suzuki: Appl. phys. Lett. 6(1995) 451-453

2) H. wada and T. Kamijoh: IEEE Photonics Technol. Lett. 8(1996)173-175

3) T. Suga and K. Miyazawa: Acta Scripta Metall. Proc. Ser. 4(1990)189

4) T. Suga, Y. Takahashi and H. Takagi: Ceram. Trans. 35(1993)323

5) T.R.Chung, L. Yang, N. Hosoda and T. Suga: Nucl.Instr. and Mech.in Phys. Res. B121 (1997)203-206

6)T. Namegaya, N. Matsumoto, N. Yamanaka, N. Iwai, H. Nakayama, A. Kasukawa: IEEE J. Quan. Elect. 30(1994)578-584