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B — 2 — 7 ION-BEAM TECHNIQUES IN PROCESSING OF GaAs LASERS

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Introduction

Ion-beam milling and deposition techniques have found increasing application in semiconductor device processing. With these methods, sputter deposition can be performed under high vacuum conditions combined with *in situ* etching, giving excellent adherence and pure thin films [1-2]. This paper reports on ion-beam techniques utilized in metallization and passivation of MO-CVD-grown D-H GaAs/GaAlAs lasers.

Metallization

The ion-beam technique in combination with annealing was used to form PtTi ohmic contacts to the p^+ contact layer of the laser structure. The specific contact resistance on Zn-doped 2×10^{19} cm^{-3} GaAs is shown in Fig. 1. The annealing time was 5, 15 and 30 minutes, and the annealing temperature varied between 360 and 480°C. Two typical samples having different metal thickness, as indicated in the figure, illustrate the annealing behavior. The difference in contact resistance originates from the sputtering process, resulting in surface damage centers acting as donor-like traps [3]. It is shown that the contact resistance decreases with increasing annealing temperature and time. Moreover, the difference between samples decreases with increasing temperature due to out-leaking of the damage centers. Consequently, the ion beam technique in combination with annealing produces a contact formation process growing from and beyond the surface damages and is thus highly reproducible. The lowest specific contact resistance we obtained was 2.4×10^{-5} Ω cm^2. This low value is in the same order as the state-of-the-art of PtSi and Cr contacts reported on Si and, to our knowledge, the lowest resistance reported on *p*-type GaAs [4-5]. The Auger depth profile after annealing in 480°C for five minutes of the PtTi/p^+-GaAs system is shown in Fig. 2. The titanium is 800 Å and the platinum 2300 Å in thickness. The Ti film is shown to be a sufficient barrier for reaction between Pt and GaAs substrate, and there is no evidence of As out-diffusion.

In this way, a series resistance of 5 Ω was obtained for a 4 μm wide stripe contact laser with a cavity length of 250 μm, in good agreement with the present investigation.

Passivation

A passivation method to encapsulate the laser mirrors and other vulnerable parts on the laser diode have been developed using the ion-beam technique. Before coating, the lasers were *in situ* ion beam milled. The effect of different ions in milling performance is illustrated in the L-I curve for a laser diode before and after milling (see Fig. 3). After milling with relatively heavy ions, the threshold current increases. Continuing milling with comparably lighter ions results in a decrease in threshold. This is due to the fact that the heavier ions create more damage, which is then removed with the lighter ions.

Following milling, the device is coated with a λ/4-thick Al_2O_3 film and a λ/4-thick Si_3N_4 film. The Al_2O_3 reduces interfacial stress and Si_3N_4 resists corrosive actions from the surrounding atmosphere. MO-CVD-grown GaAs lasers passivated in this way show low degradation rate during 1000 hours of accelerated aging, indicating no mirror degradation after 350 hours of burn-in (see Fig. 4) ($\Delta I\ I_{op}^{-1} \leq$ 0.5% kh^{-1}, 3 mW, 325 K). Moreover, lasers have been operated underwater with 3 mW continuous light output for several days. In comparison, lasers without passivation or solely mirror coating operate only minutes in similar environment.

References

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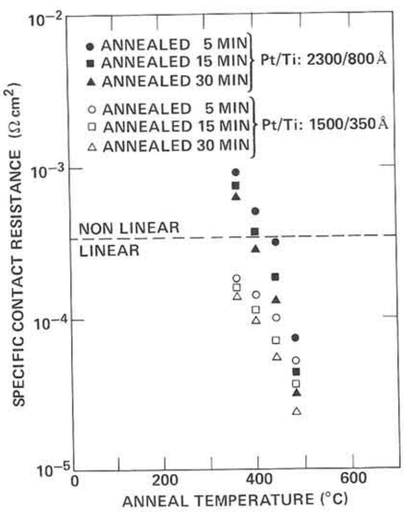

Fig.1 Specific contact resistance of $PtTi/p^+$-GaAs using Ion-beam deposition.

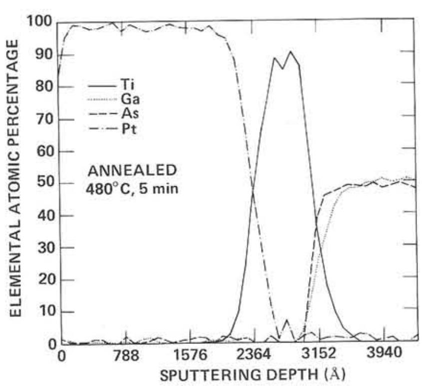

Fig.2 Auger depth profile of $PtTi/p^+$-GaAs

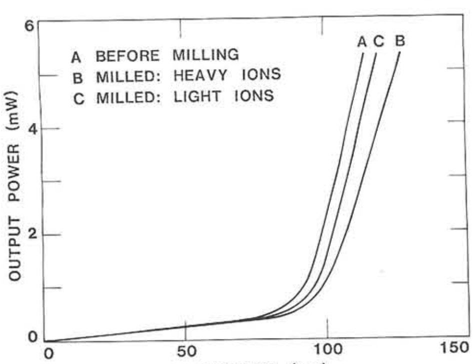

Fig.3 Mirror milling performance prior coating.

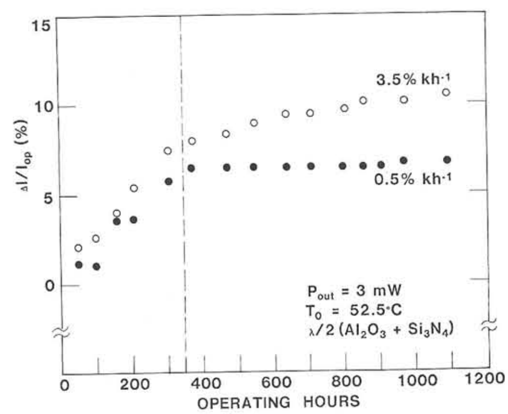

Fig.4 Accelerated life testing of coated lasers.