p-Ohmic Contact Study for Intra-Cavity Contacts in AlGaAs/GaAs VCSELs

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Thermally stable and low contact resistance are essential for high performance of 850nm VCSEL. Meatllization and optimization of annealing for p-ohmic contacts on 850nm VCSEL were investigated. The effect of O+ ion implant on p-contact, which was used to define the aperture, was also studied.

The cross section of VCSEL structure is illustrated in Figure 1. The epitaxial layers was grown by Metal Organic Chemical Vapor Deposition on semi-insulating GaAs substrates. The undoped mirror stack consisted of quart-wavelength thick layers of AlGaAs/GaAs, while the p-i-n diode structure employed Si-doping for n-type and C-doping for p-type layers. The InGaAs quantum wells were clad by lightly-doped AlGaAs for carrier confinement. The final layers consisted of undoped InGaP/GaAs for index guide formation. The InGaP acts as a thin (200Å) etch-stop layer. The aperture was formed by O^+ implantation into the graded p-layer beneath the p+ GaAs injection layer, while a deeper He^+ implant was used for capacitance reduction and electrical isolation.

In this study, both contacts directly to $Al_{.12}Ga_{.88}As$ and to InGaP were investigated. Forming contacts to the InGaP layer would reduce the number of processing steps for contact formation as well as help to preserve the underlying p-$Al_xGa_{1-x}As$. Different metallization, metal thickness and annealing conditions were considered. Combination of E-beam deposited AuBe, Ag, Pd, Pt, Au, and Ti based metals were used as the contact metallizations. Transmission line method (TLM) were used to estimate the contact resistance(R_C), sheet resistance(ρ_S), and specific contact resistance(ρ_C). Samples after deposition were annealed in N_2 ambient at temperature of 300~450°C for 30 sec in a RTA system. The TLM measurement was conducted with a HP 4145B parameter analyzer.

The specific contact resistance of different metallic compositions with different thickness at varied anneal temperature is shown in Table 1. Most of the various compositions showed Schottky behavior when the annealing temperature was in the range of 300~350°C. Once the annealing temperature was raised to 400°C, the specific contact resistances improved to 10^{-5}~10^{-6} Ω-cm^2. As illustrated in Table 1, AuBe/Au/Ti and Pd/AuBe/Pt/Au/Ti based meatllization showed lowest contact resistance.

The effect of annealing temperature, metal thickness and metallization on the p-contact will be presented in the meeting.

Composition		350°C	400°C	450°C
AuBe/Ag/Au/Ti	No implant		10.8	7.98
400/300/800/200	Implant		7.38	14.7
AuBe/Pt/Au/Ti	No implant		50.3	13.4
400/300/800/200	Implant		55.8	22.2
Pd/Ti/Pt/Au	No implant		33.2	9.90
50/200/300/800	Implant		112	10.7
AuBe/Au/Ti	No implant	87.4	5.15	6.46
400/800/200	Implant		7.52	13.5
Pd/AuBe/Pt/Au/Ti	No implant	10.2	4.18	5.58
50/400/300/800/200	Implant	580	6.12	4.08

* The specific contact resistance is in the scale of 10^{-6} Ω-cm^2.

Table 1. Specific contact resistance of different metallic compositions at varied annealing temperature.

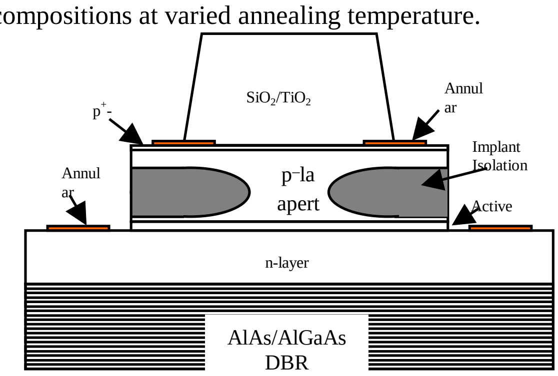

Figure 1. cross section of 850 nm VCSEL structure.