# Effect of Silver Epoxy Bonding of III-V Laser Dies on Silicon for LiDAR Applications

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**Abstract:** We investigate the effects of bonding micrometer-scale III-V laser dies on silicon using silver epoxy. IV, LIV, and intensity vs wavelength characteristics are presented and compared.

## 1. Introduction

Semiconductor lasers or laser diodes are essential in many applications where compact, coherent, and efficient light sources are needed, such as in telecom, datacom, sensing, and especially LiDAR systems [1]. III-V materials like Gallium Arsenide (GaAs) and Indium Phosphide (InP) have direct bandgaps, and therefore high efficiency [2]. Structures such as quantum wells and distributed feedback (DFB) gratings can be consistently fabricated using modern methods like molecular beam epitaxy (MBE) or Metal Organic Chemical Vapor Deposition (MOCVD) [3]. Some benefits include the ability to integrate these semiconductor lasers with metasurfaces or photonic integrated circuit (PIC) components through hybrid or heterogeneous integration. The most used method for integrating III-V laser dies with silicon is using a die bonding machine [4]. For small laser diodes like ours that are around 250 microns in length and width, the pick and place technique can be used to bond the laser dies to silicon. Here, we present our method for bonding micron sized laser dies to a silicon die by using conductive silver epoxy, shown in Fig. 1d. We will compare the effect of bonding on optoelectronic characteristics such as threshold current, turn on voltage, bandwidth, and peak wavelength across different temperatures at continuous wave (cw) mode.

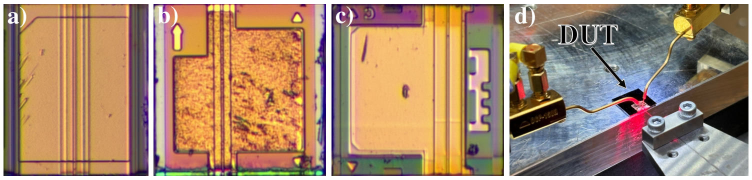

Fig. 1. a) GaAs, b) InP, and c) DFB laser die. d) Bird's eye view of device under test (DUT) during testing.

## 2. Methods

We tested GaAs and InP Fabry Perot laser dies and an InP DFB laser die (Fig. 1a, b, c) before and after bonding. A Keithley 2636B Sourcemeter is used for current-voltage (IV) measurements. The device under test sits on a thermoelectric cooler (TEC) to regulate and control the temperature. For light-current-voltage (LIV) or intensity vs wavelength testing, a lensed fiber is coupled to the device's optical output. This fiber is coupled to a detector or a Yokogawa Optical Spectrum Analyzer (OSA). Our bonded device consists of a laser die bonded to copper tape with silver epoxy atop a silicon die. To achieve this, a wafer was diced into 0.8 mm by 0.8 mm dies, a piece of copper tape was laid on top, before being covered by a thin layer of epoxy which the die was placed on, so that the emitting side was on the outside of the chip. Epoxy was cured at 100 °C for 30 minutes.

## 3. Results

IV, LIV, and intensity vs wavelength characteristics of these laser dies were obtained at different temperatures (Fig. 2a, b, c). The laser diodes' voltage per current stayed mostly consistent. Power per current dropped off significantly for GaAs and DFB laser diodes. Interestingly, the InP laser diode displayed consistent performance up to 70 °C before dropping off. DFB and GaAs output negligible power before 70 °C. GaAs showed a turn on voltage of 1.8 V and threshold currents of 11.3 mA and 16.2 mA at 25 °C and 40 °C respectively. DFB has a turn on voltage of 0.9 V and threshold currents of 5.7 mA and 8.6 mA at 25 °C and 40 °C. The InP laser diode displayed turn on voltages of 0.95 V from 25 °C to 70 °C and 0.9 V at 100 °C as well as threshold currents of 6.25 V, 9.4 V, 12 V

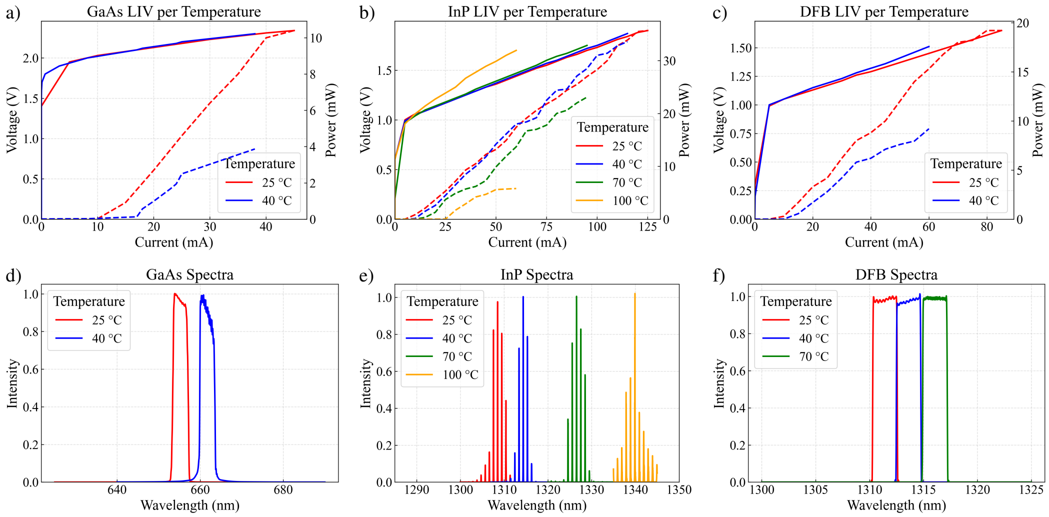

Fig. 2. IV and LIV curves for a) GaAs, b) InP, and c) DFB laser dies respectively. Power is shown by dotted lines and voltage is shown by solid lines. Optical spectra of d) GaAs, e) InP, and f) DFB laser dies.

and 25 V at 25 °C, 40 °C, 70 °C, and 100 °C, respectively.GaAs displays a peak wavelength of 653.9 nm and 660.9 nm and FWHM of 3.7 nm and 3.6 nm at both temperatures while DFB displayed peak wavelengths of 1312.1 nm, 1314.7 nm, and 1317.1 nm and a consistent FWHM of 2.3 nm at temperatures of 25 °C, 40 °C, and 70 °C, and InP displayed peak wavelengths of 1308.5 nm, 1314.4 nm, 1326.6 nm, and 1339.9 nm and FWHM of 2 nm, 2 nm, 3 nm, and 1 nm at 25 °C, 40 °C, 70 °C, and 100 °C. Fig. 3a, b,c show the laser dies performance after bonding against their performance before bonding. Efficiency can be calculated using the wall plug equation $\eta = {}^{P_{\text{opt}}}/_{IV}$ where $P_{\text{opt}}$ is optical power output, $I$ is current and $V$ is voltage. The GaAs laser die reached an efficiency of 9.8% before bonding and 5.6% after, while InP reached 15.7% and 14.3% after, and DFB reached 14.9% and 14.2% respectively near their peak powers.

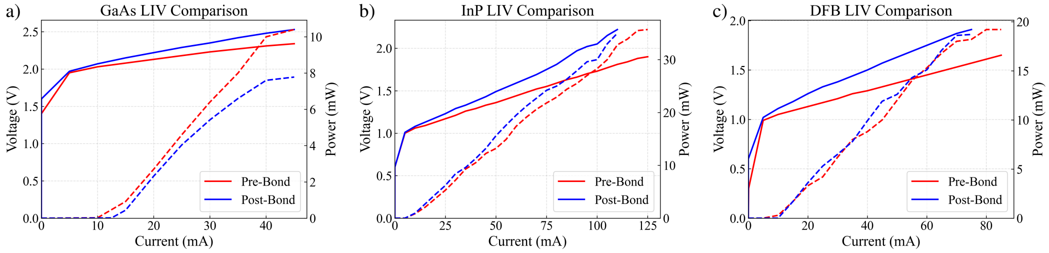

Fig. 3. IV and LIV comparisons for a) GaAs, b) InP, and c) DFB laser dies before and after bonding.

## 4. Conclusion

We demonstrate a method using the pick and place technique for bonding laser dies to silicon. The infrared laser dies displayed high efficiency after bonding. Our next steps for this research is to optimize the amount of epoxy used to limit the die's movement in the drying process, install a less noisy TEC, and test these diodes' LIV characteristics on pulsed mode.

## References

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