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Design and Characterization of an Optical 4H-SiC Bipolar Junction Transistor

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SiC bipolar transistors and thyristors have been introduced in the literature and have shown to have a promising performance [1]-[2]. Those applications include but not limited to flexible ac transmission systems (FACTS), high-voltage direct current (HVDC) and wind power [3]. In this paper, an optical 4H-SiC BJT have been designed and characterized at Ampere Lab and fabricated at L2N. The BJT was designed to withstand a voltage of 10kV. The BJT were fabricated on a 4H-SiC wafer using a 120 μm thick epilayer with a doping concentration of $8 \times 10^{14} \text{ cm}^{-3}$ (Fig. 1). After electrical characterization, we obtain a breakdown voltage about 11 kV [4]. For the optical structures, there is no contact and metal on the base fingers.

Four different structures have been implemented in the layout for the optical parameters see on Fig. 2. Three different Base and Emitter lengths have been implemented 10, 15 and 20 μm . The last implemented BJT has got a 20 μm length without Metal on the Base PAD (Fig 2) and no P⁺ implantation on this structure.

A pulsed (5 ns) laser emitting UV at 349 nm is used to generate electron-hole pairs into SiC. The frequency of the laser is 1 kHz. In order to enlarge the laser beam size, a beam expander is used. Fig. 3 presents the electrical circuit for the characterization of the BJT. Actually, we have fixed the R_{Load} at 4.7 Ω . The role of the capacitor is to stabilize the input voltage when the BJT switches on.

First measurements have been performed on the structure without metal and P⁺ implantation on the base. We have characterized for two different Powers of Laser and Input voltage. At a given input voltage, we see an impact on the current peak (see Fig. 4, 5 and 6). Regarding the impact of the input voltage, the switching time is the same.

The first goal of our work was to turn-on an optical BJT with a pulsed UV emitting laser and it has been obtained as it can be observed. Now, we need to optimize the PCB design regarding parasitic inductors and integrate the capacitor very closed to the die. Moreover, we need to add a shunt resistor to measure the current. As the pulse duration of the laser is short, an optimization of the voltage and current measurements through the device is mandatory.

In the final paper, we will present results for the different structures of the BJT using our new design of the PCB integrating the Load Resistor, Capacitor and shunt resistor.

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[2] N. Dheilily, G. Pâques, S. Scharnholz, D. Planson, "Pulse characterization of optically triggered SiC thyristors", *Materials Science Forum Vols. 717-720 (2012) pp 1179-1182.*
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[4] A. Ammar, M. Lazar, B. Vergne, S. Scharnholz, L. V. Phung, C. Sonneville, C. Raynaud, H. Morel, D. Planson and M. Zielinski, *Optimized Junction Termination Extension and Ring System for 11 kV 4H-SiC BJT*, (2022), IEEE 2022 International Semiconductor Conference (CAS), pages 191-194. doi: 10.1109/CAS56377.2022.9934390

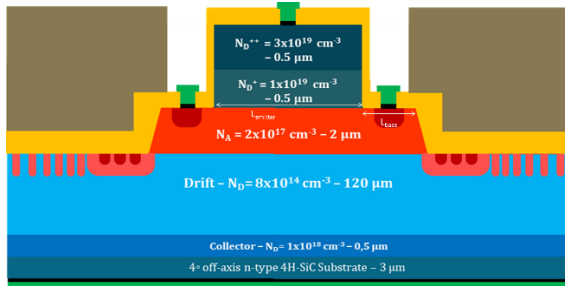


Fig. 1. Cross-section of the optical 4H-SiC BJT

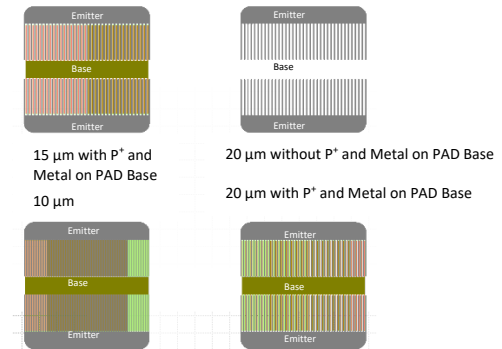


Fig. 2 Picture of 4 selected optical BJT with key parameters (Base and Emitter length)

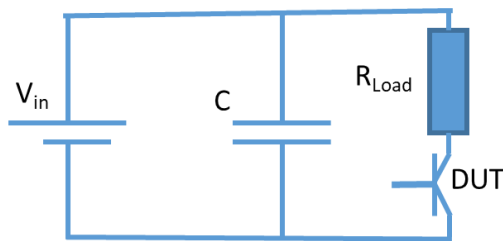


Fig. 3. Electrical schema of the testbench to switch-on the 4H-SiC BJT

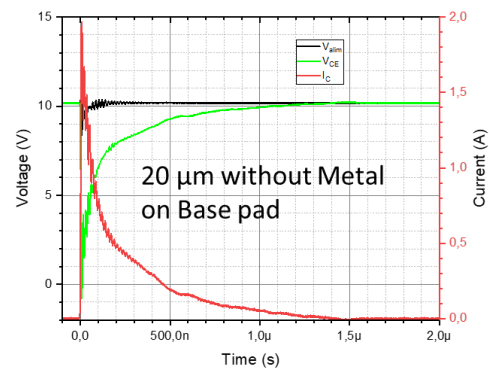


Fig. 4. Input Voltage, Collector Voltage and Current versus time at 16 mW Laser Power, $V_{in} = 10V$, BJT without Metal on Base Pad

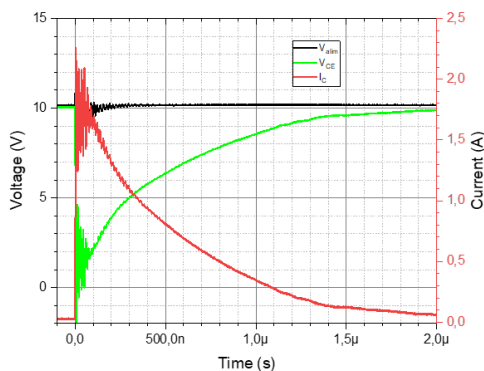


Fig. 5. Input voltage, Collector Voltage and Current versus time at 102 mW Laser Power, $V_{in} = 10V$, BJT without Metal on Base Pad

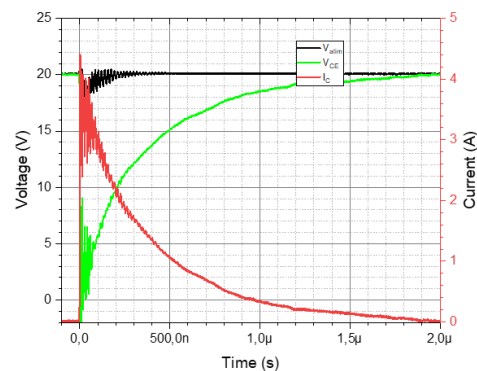


Fig. 6. Input Voltage, Collector Voltage and Current versus time at 102 mW Laser Power, $V_{in} = 20V$, BJT without Metal on Base Pad