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4H-SiC Tunneling Light Emitter as a Light-Source for Monolithically Integrated Off-Resonant Excitation of V_{Si}

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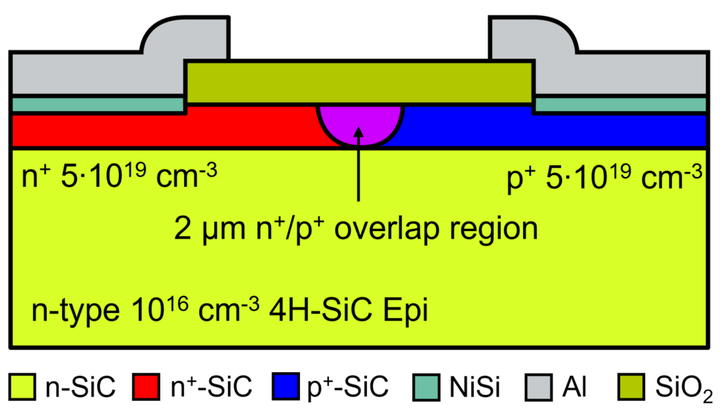
Motivation

- Silicon Vacancies in 4H-SiC (V_{Si}) are promising candidates for quantum sensor applications [1]
- For monolithic integration of a light source for off-resonant excitation, a sub-bandgap light emitter in the range of 730 nm wavelength is necessary [2, 3]
- The LED spectrum of a SiC pin-diode is lacking the necessary wavelength range [4] (Fig. 3)

→ A light emitter with broader spectrum is necessary

Device Structure and Fabrication

- Devices were fabricated using a subset of steps of the Fraunhofer IISB 2 µm SiC CMOS technology [5] (Fig.1)



- Deposition of 30 nm TEOS scattering oxide
- Implantation of p⁺ and n⁺ region
- Scattering oxide strip & annealing
- Deposition of PECVD passivation oxide
- Contact window etching
- NiAl lift-off & silicidation by RTA
- Aluminum contact deposition and patterning

Fig. 1: Device cross-section and fabrication process description

Electrical and Optical Characteristics

- Forward bias (blue in Fig. 2): Linear rise of the LED spectra with injection current, peak of the donor-valence band transition and to deeper trap transitions (Fig. 3, Fig. 5 a) & Fig. 6 a)) [6]
- Reverse bias: Zener tunneling current observed at negative voltage bias. Tunnel emission observed beyond -27 V (green in Fig. 2)
- Tunneling enhanced emission intensity rises linearly with injection current up to 4 mA. Thereafter emission is limited by the constant voltage drop due to self-heating (Fig. 2 & Fig.4, inset)
- No threshold current for the tunneling enhanced emission is observed
- White light emission with 43% of the max. intensity at 730 nm (Fig. 4)

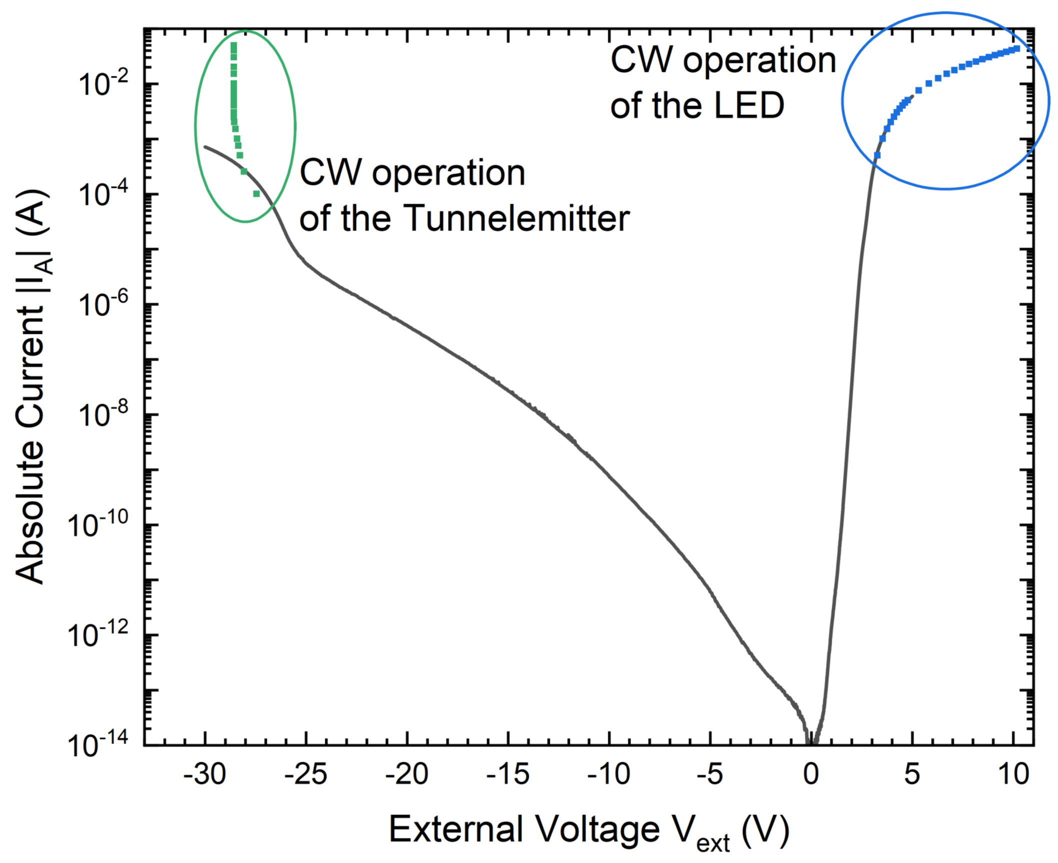


Fig. 2: Device characteristic and operation points

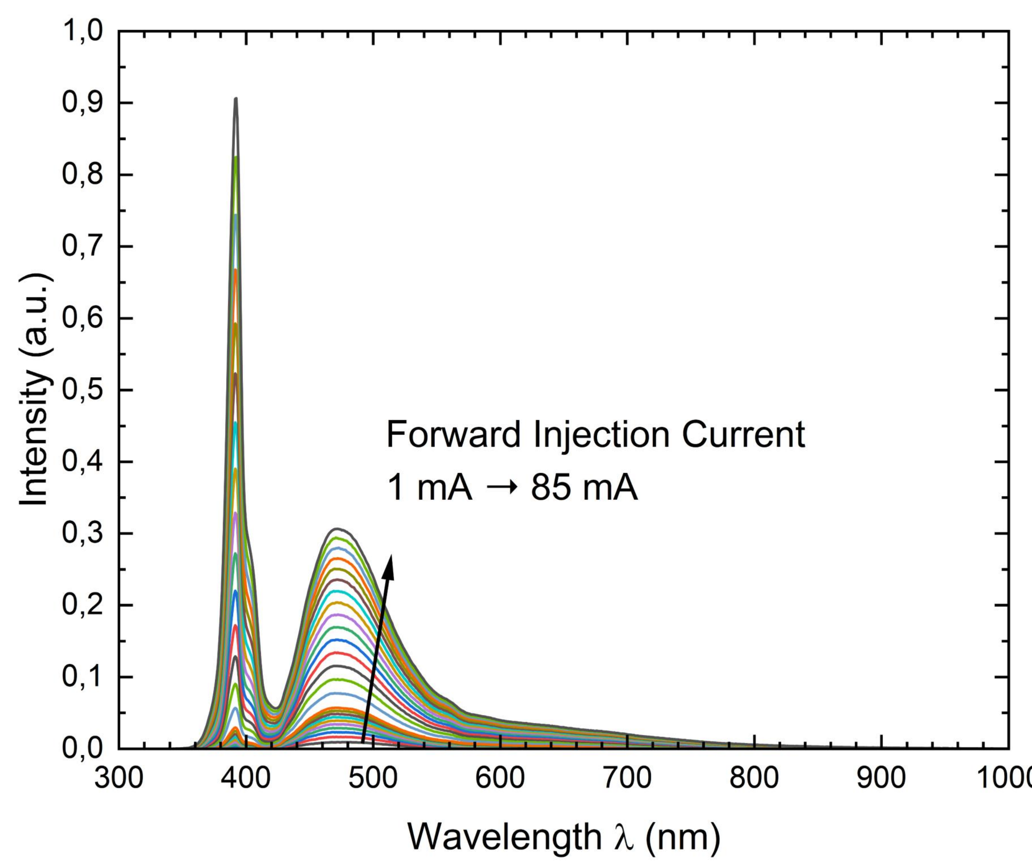


Fig. 3: LED spectra under forward bias

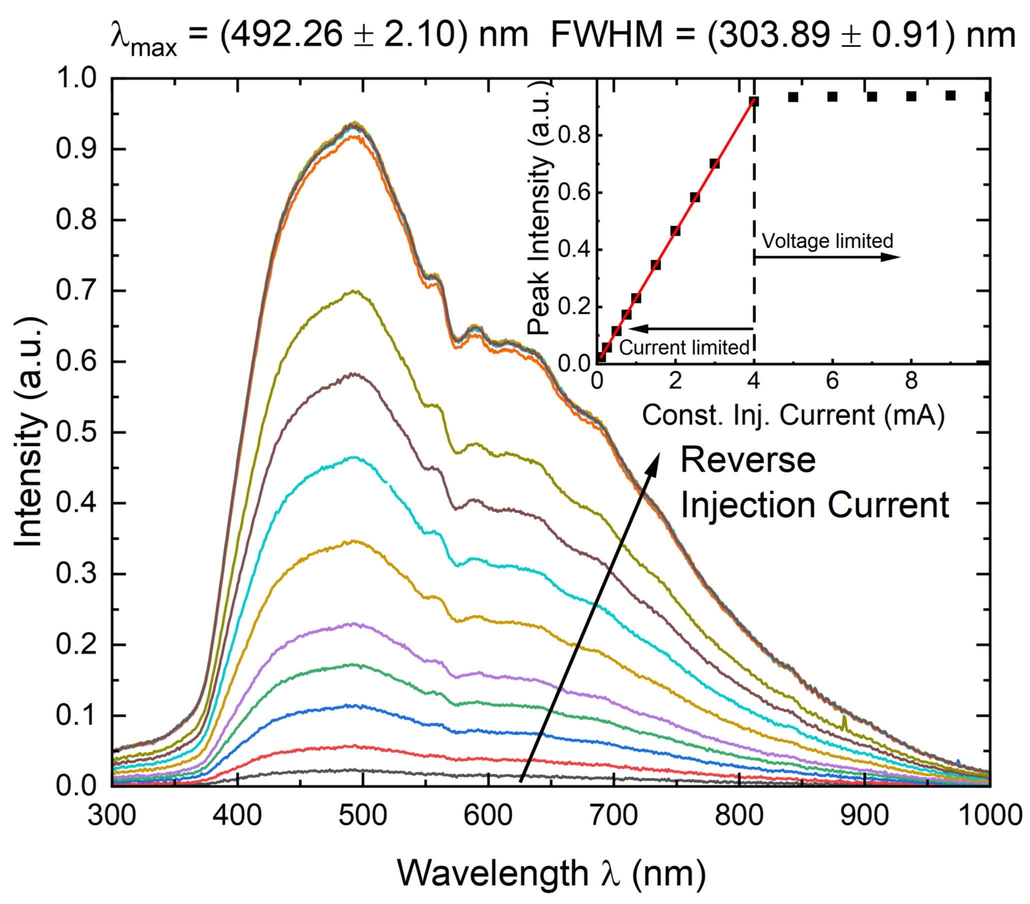


Fig. 4: Emission in tunneling regime and current bias

The Tunneling Enhanced Emission Process

- Tunneling enhanced emission: Emission localized to the space-charge-region (Fig.5 b)) → high electric field, depleted of free charge carriers
- Transitions between acceptor and donor due to co-doping in the overlap region [4] (see Fig. 1)
- Underlying luminescent mechanism (Fig. 6 b)):
  - Donors are filled by quantum tunneling from the valence band
  - Recombination into a nearby unoccupied acceptor state
  - Tunneling of carriers from occupied acceptor states into the depleted conduction band
- Distribution of acceptor states along the electric field with respect to the donor state yields the energetic variance for the broadband emission spectrum

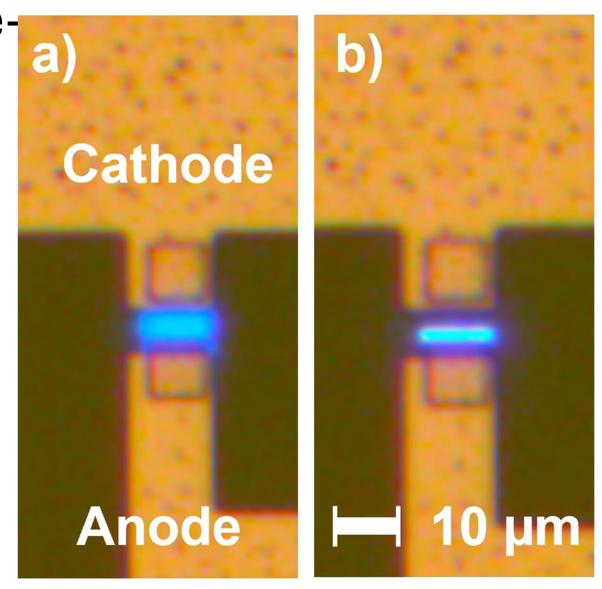


Fig. 5: Micrograph of a diode in (a) LED operation and (b) tunneling enhanced operation

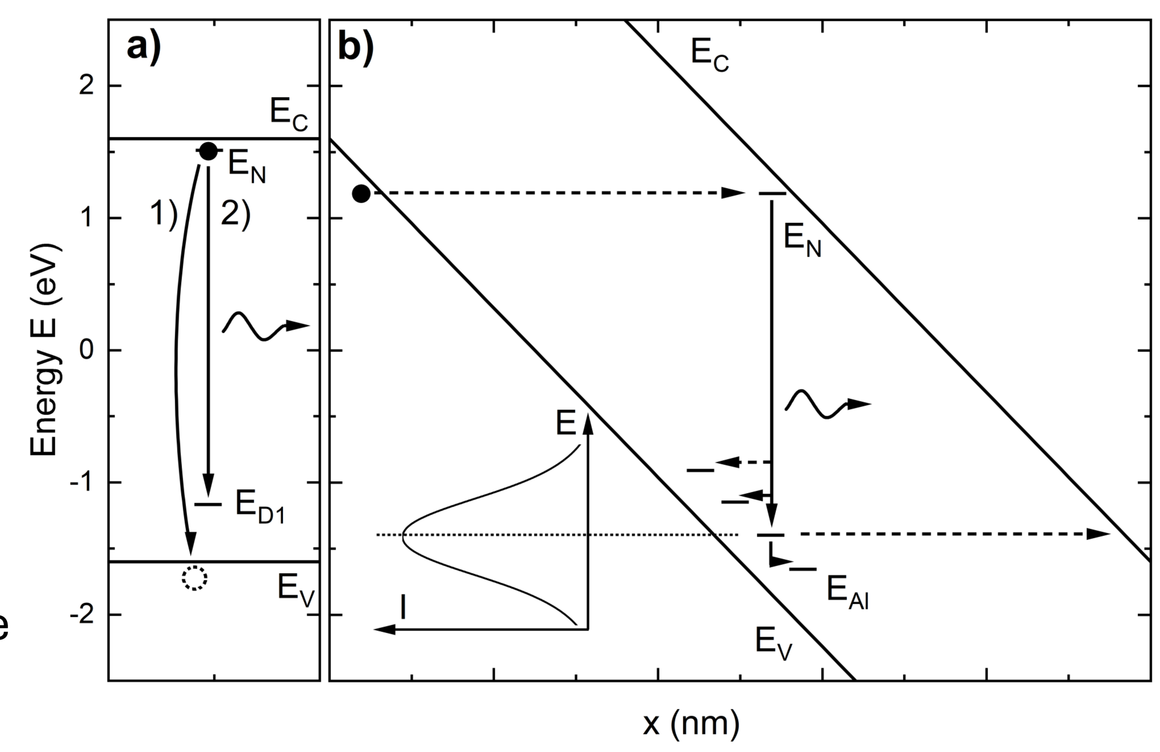


Fig. 6: Luminescent mechanism of the (a) LED and (b) tunneling enhanced emission

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