SiC Bipolar Junction Transistors

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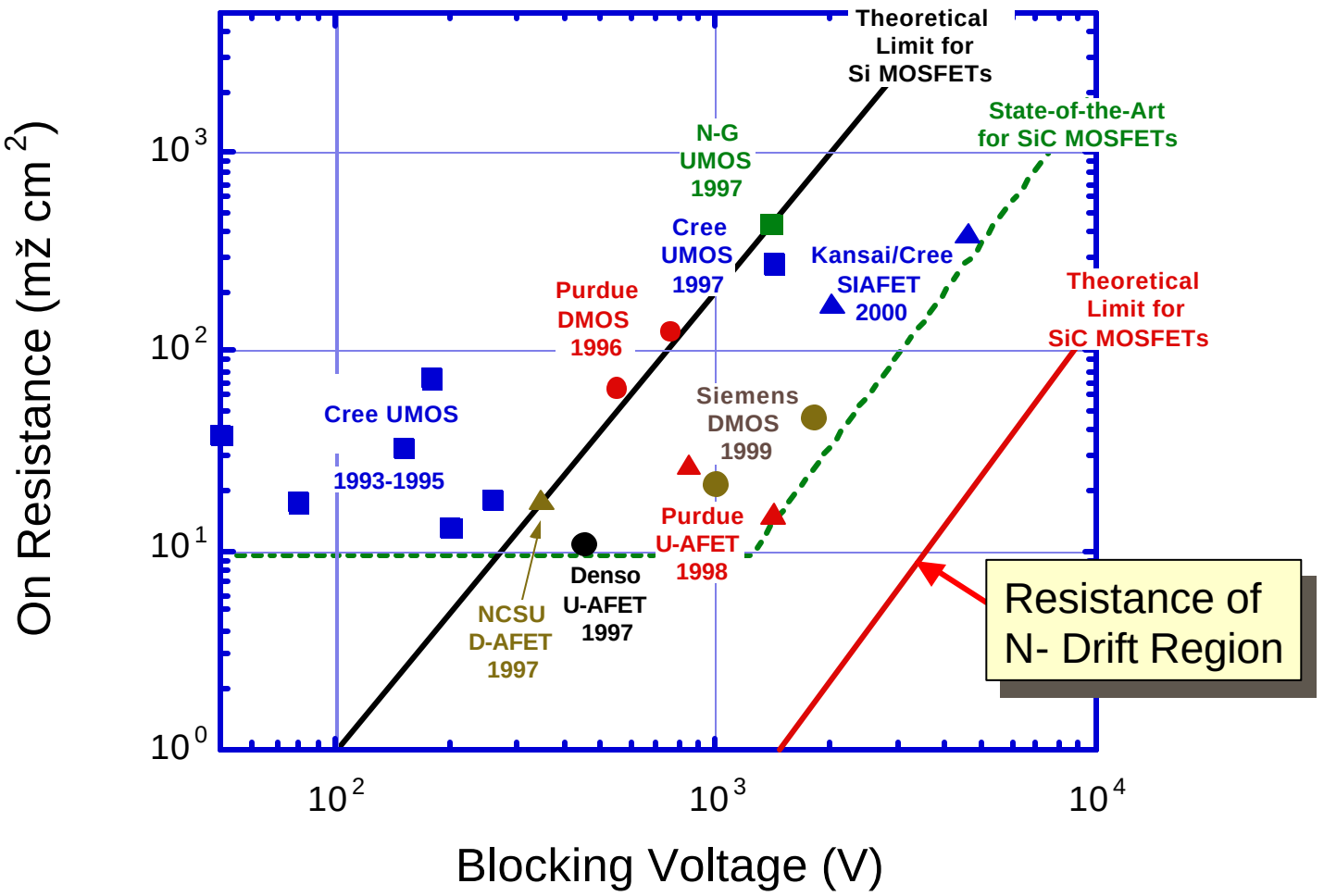
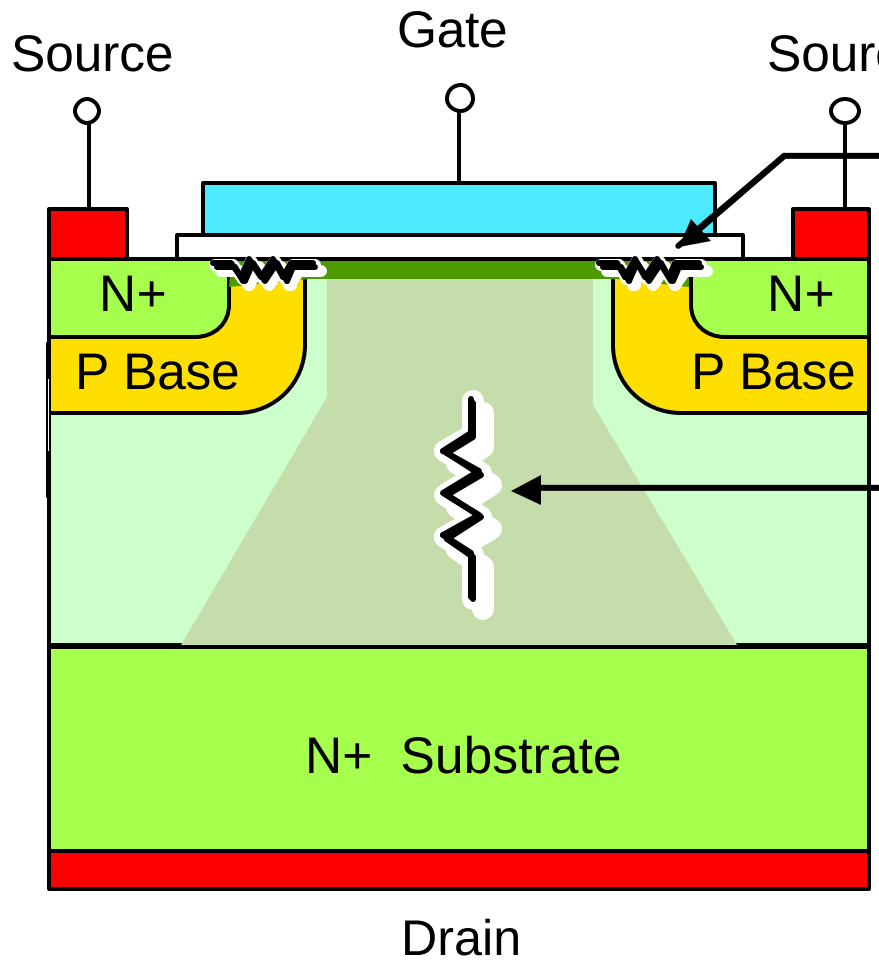
Motivation:
Comparison of SiC MOSFETs
and SiC BJTs

Performance of SiC MOSFETs



MOSFET Specific On-Resistance

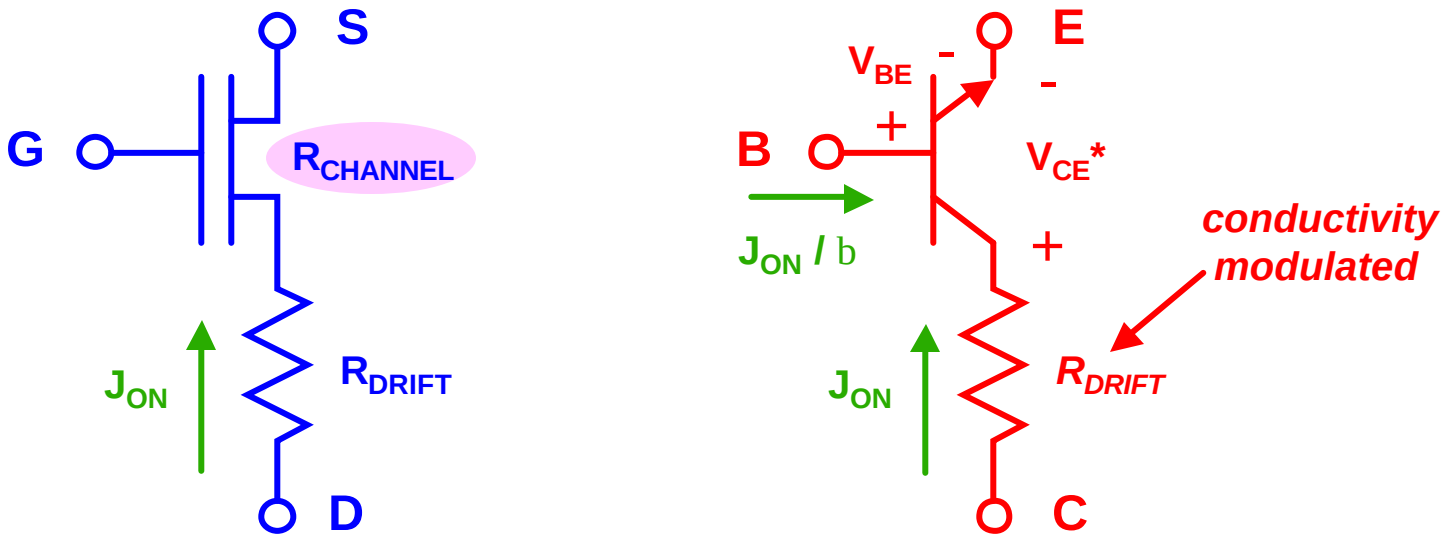


Resistance of Inversion Channel

Resistance of N- Drift Region

$$R_{ON,SP} = \frac{4\,V_B^2}{\mu_N\,\varepsilon_S\,E_C^3}$$

On-State Power Dissipation

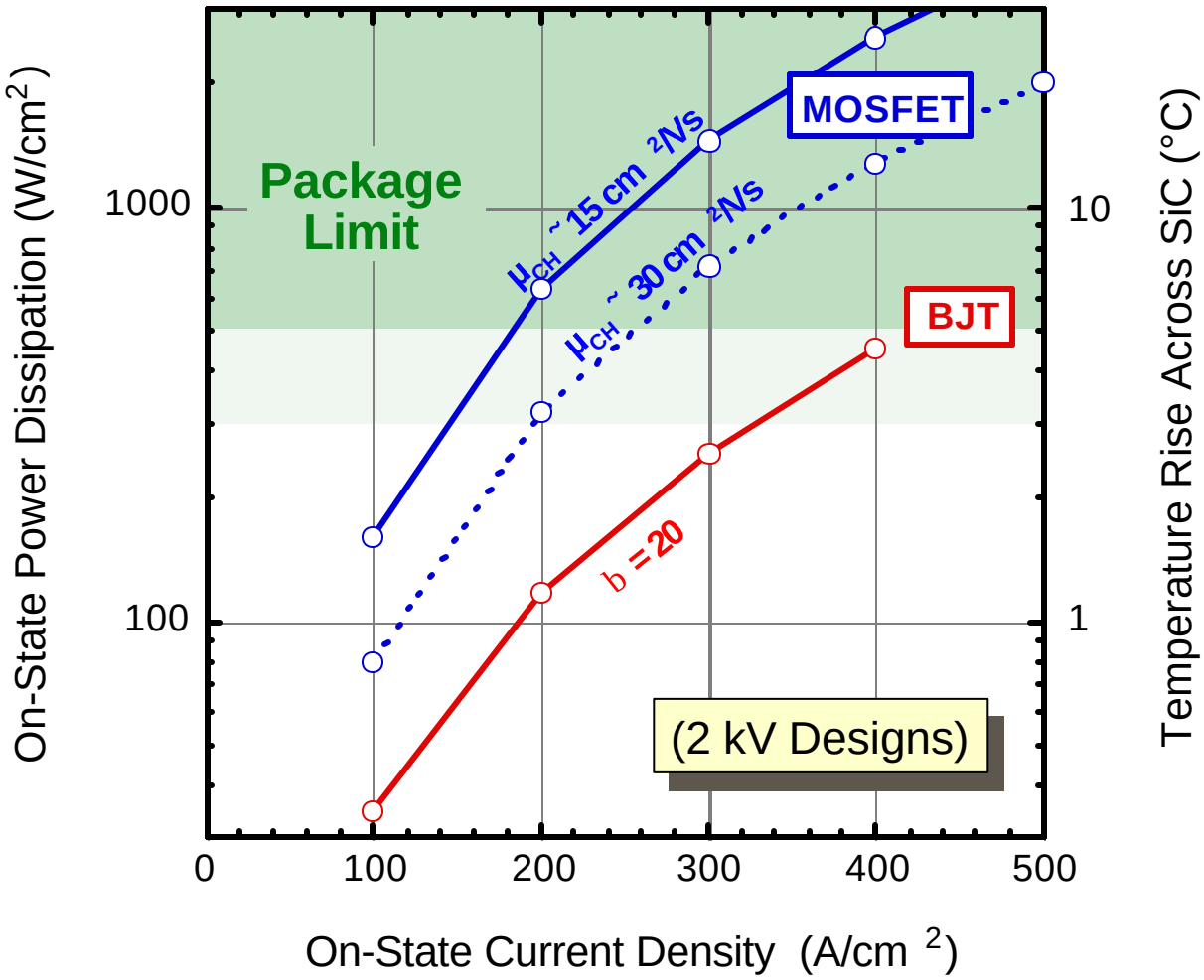


$$P_{MOSFET} = J_{ON}^2 (R_{DRIFT} + R_{CHANNEL})$$

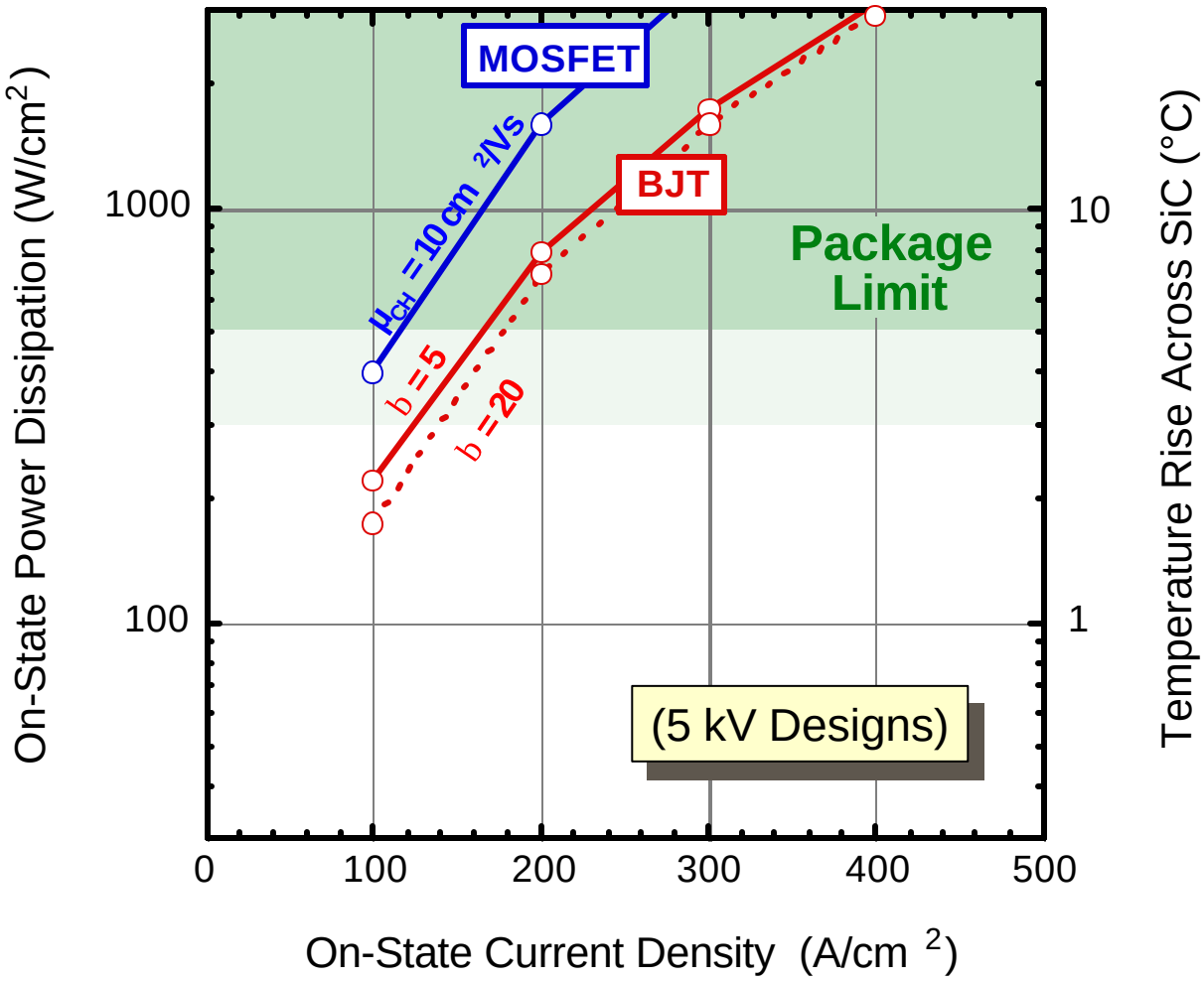
~ 0.1 V ~ 2.8 V

$$P_{BJT} = J_{ON}^2 R_{DRIFT} + J_{ON} V_{CE}^* + (J_{ON} / b) V_{BE}$$

Comparison of MOSFETs and BJTs



Comparison of MOSFETs and BJTs

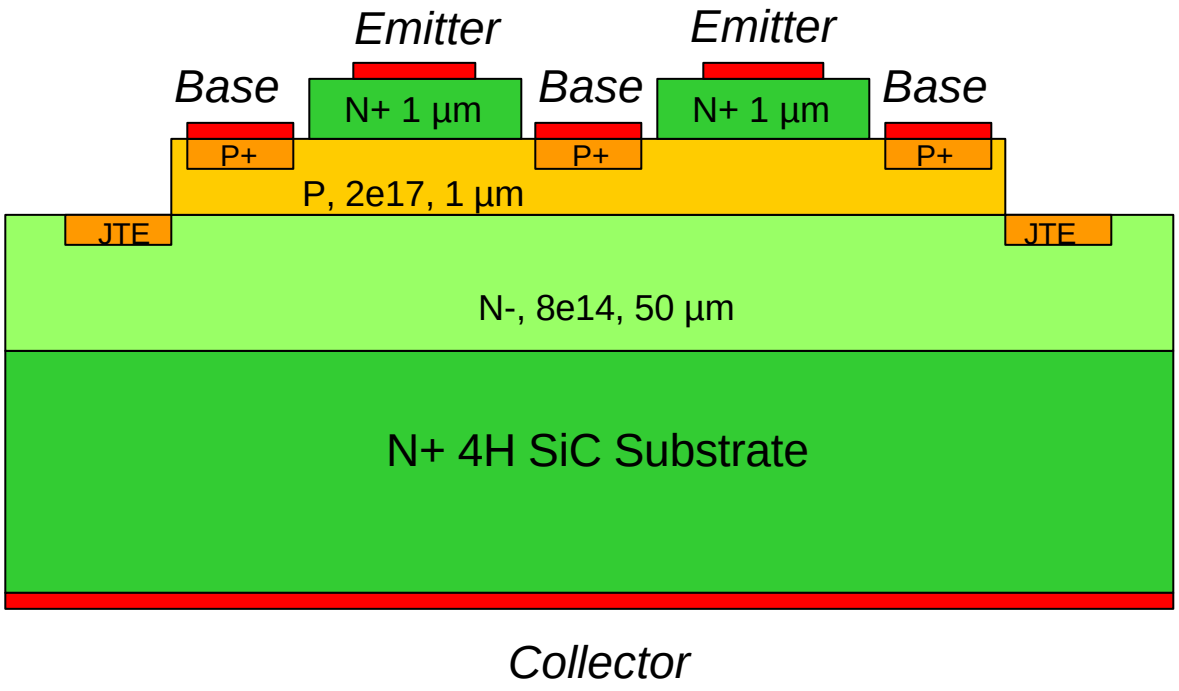


Advantages of BJTs Over MOSFETs

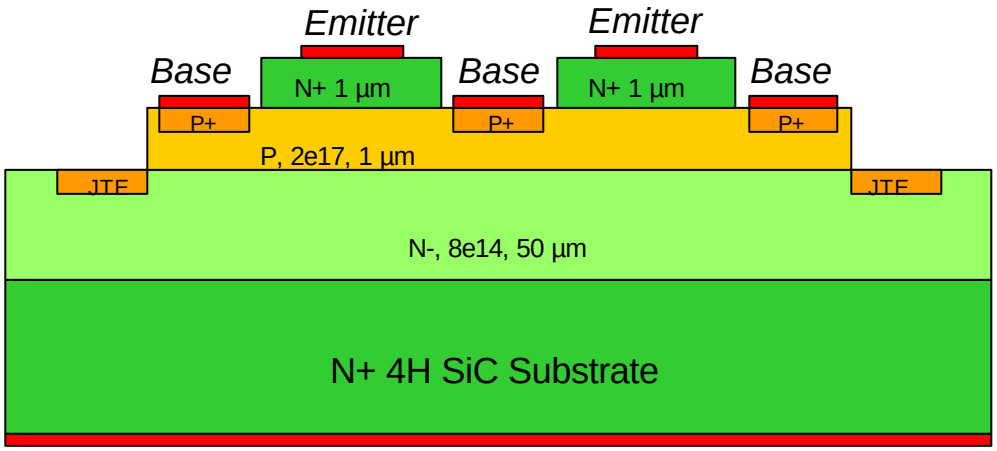
- BJTs do not suffer from surface mobility limitations
- BJTs offer lower on-state power dissipation, allowing operation at higher current densities
- BJTs do not expose their passivating oxides to high electric fields, implying better reliability
- BJTs can operate at higher temperature
- BJTs should have higher radiation tolerance

BJT Device Fabrication

Cross Section of SiC BJT



Fabrication Sequence



Emitter Etch	Base Etch	Base Contact Implant	JTE Implant	Implant Anneal	FOX Dep	Emitter Contact	Base Contact	Contact Anneal	Top Metal	Probe Test

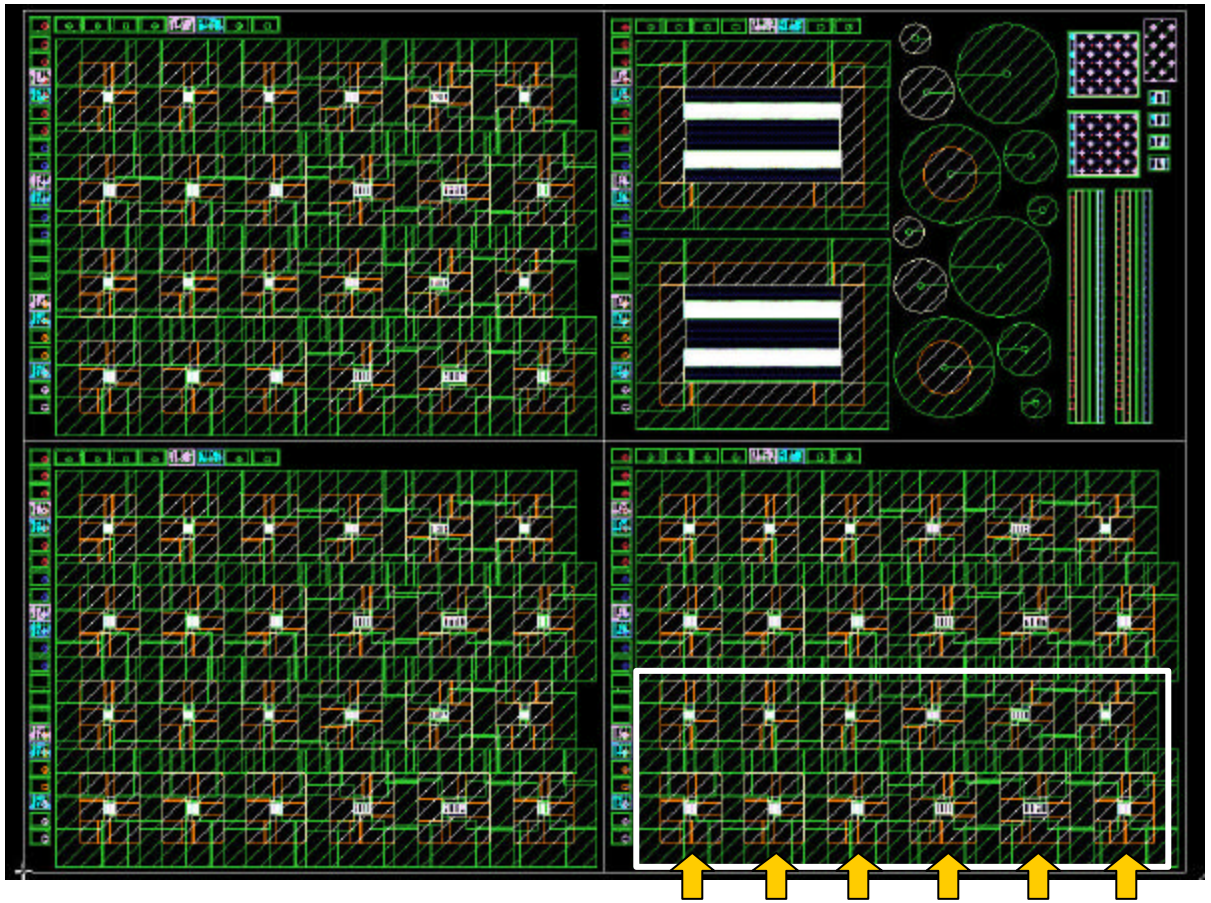
(skip)

(reprocessing)

Photo Step

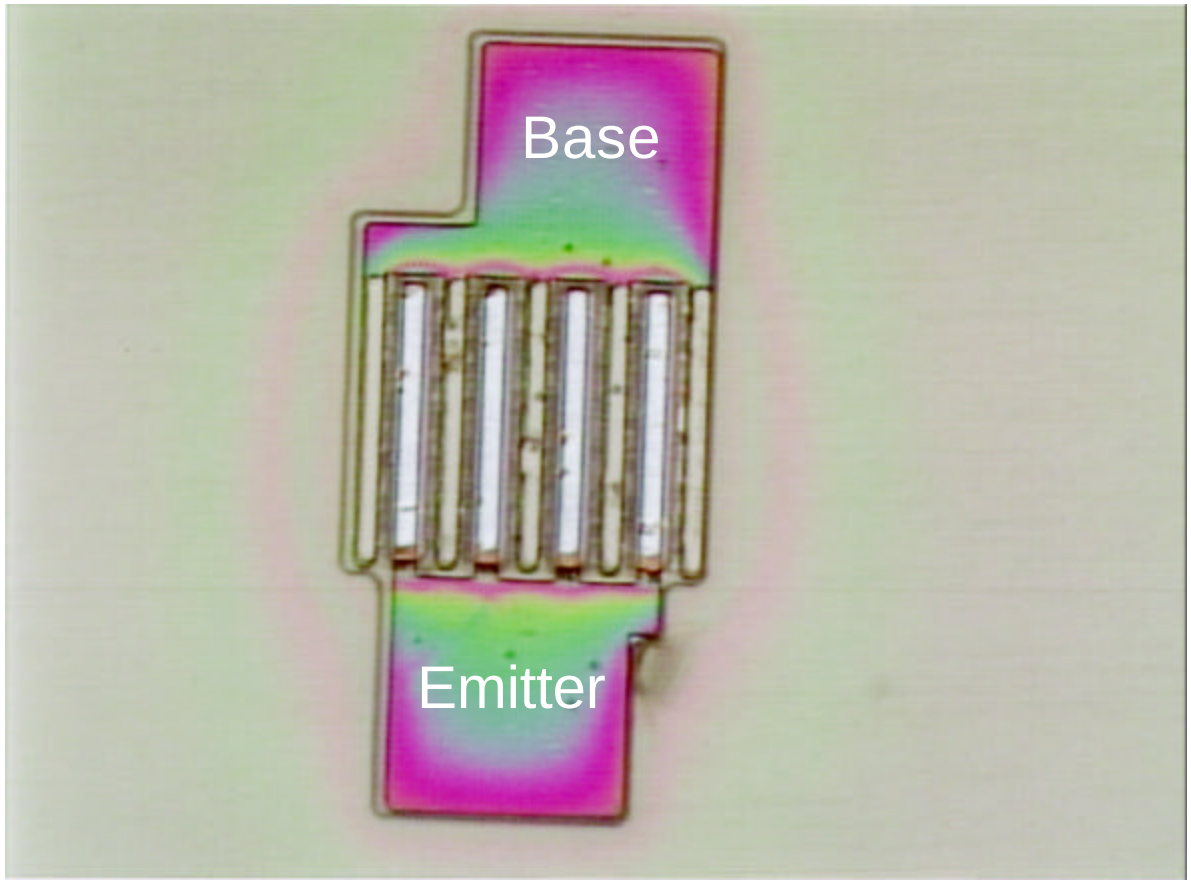
Non-Photo Step

Layout of BJT Test Chip

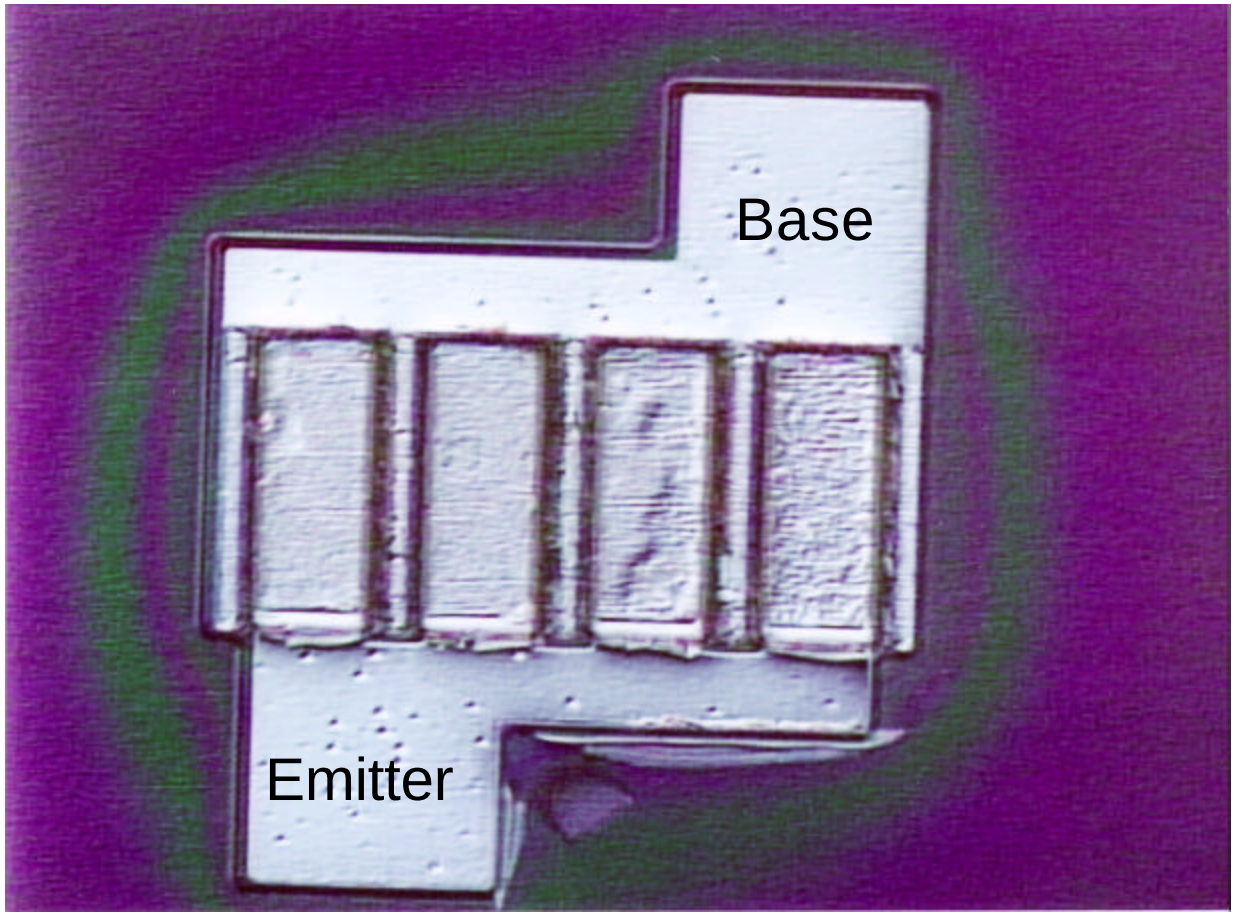


W_B/W_E = 3/7 3/7 3/7 3/14 3/21 7/7 µm

Narrow-Finger BJT (before metal)



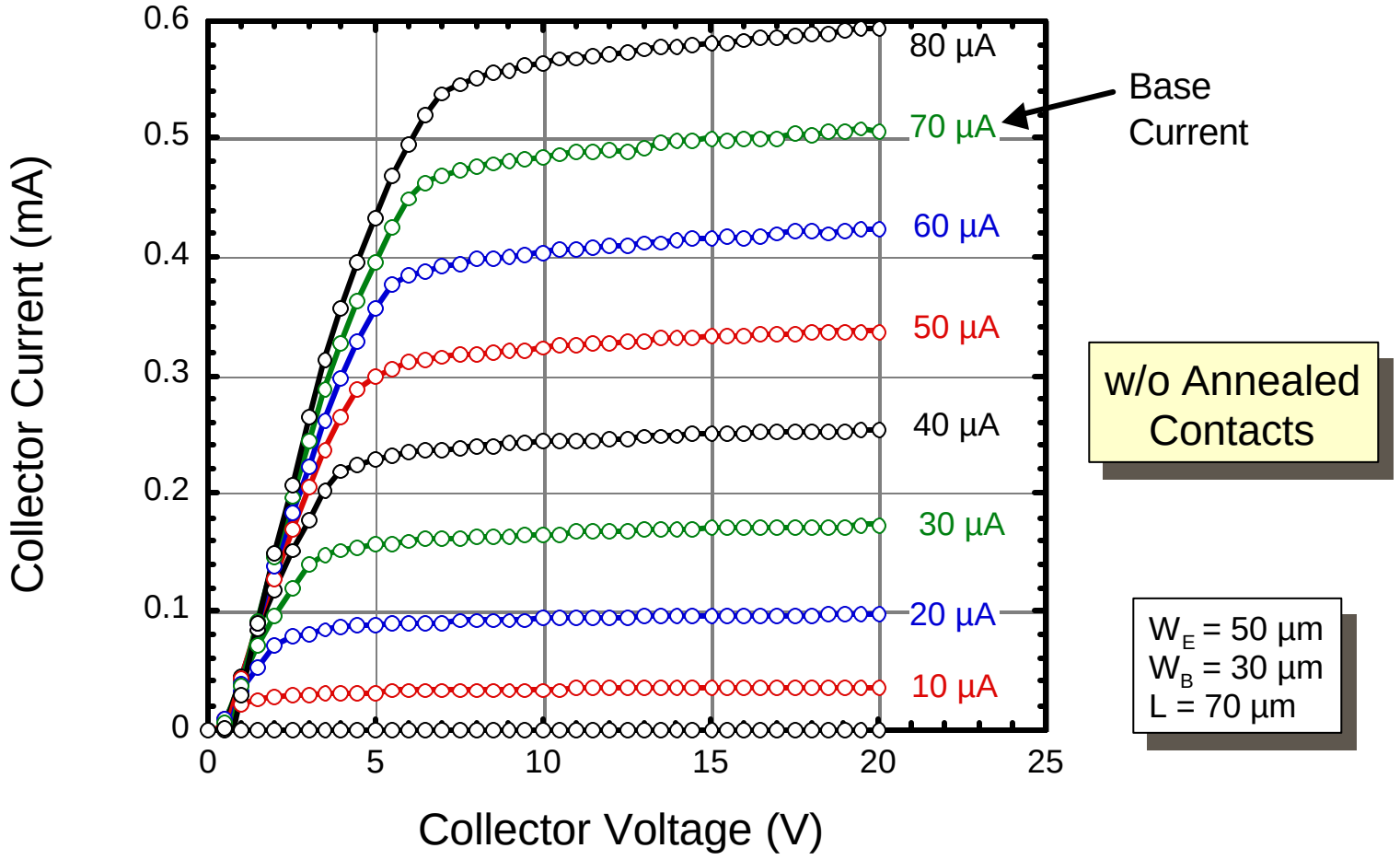
Wide-Finger BJT (after metal)



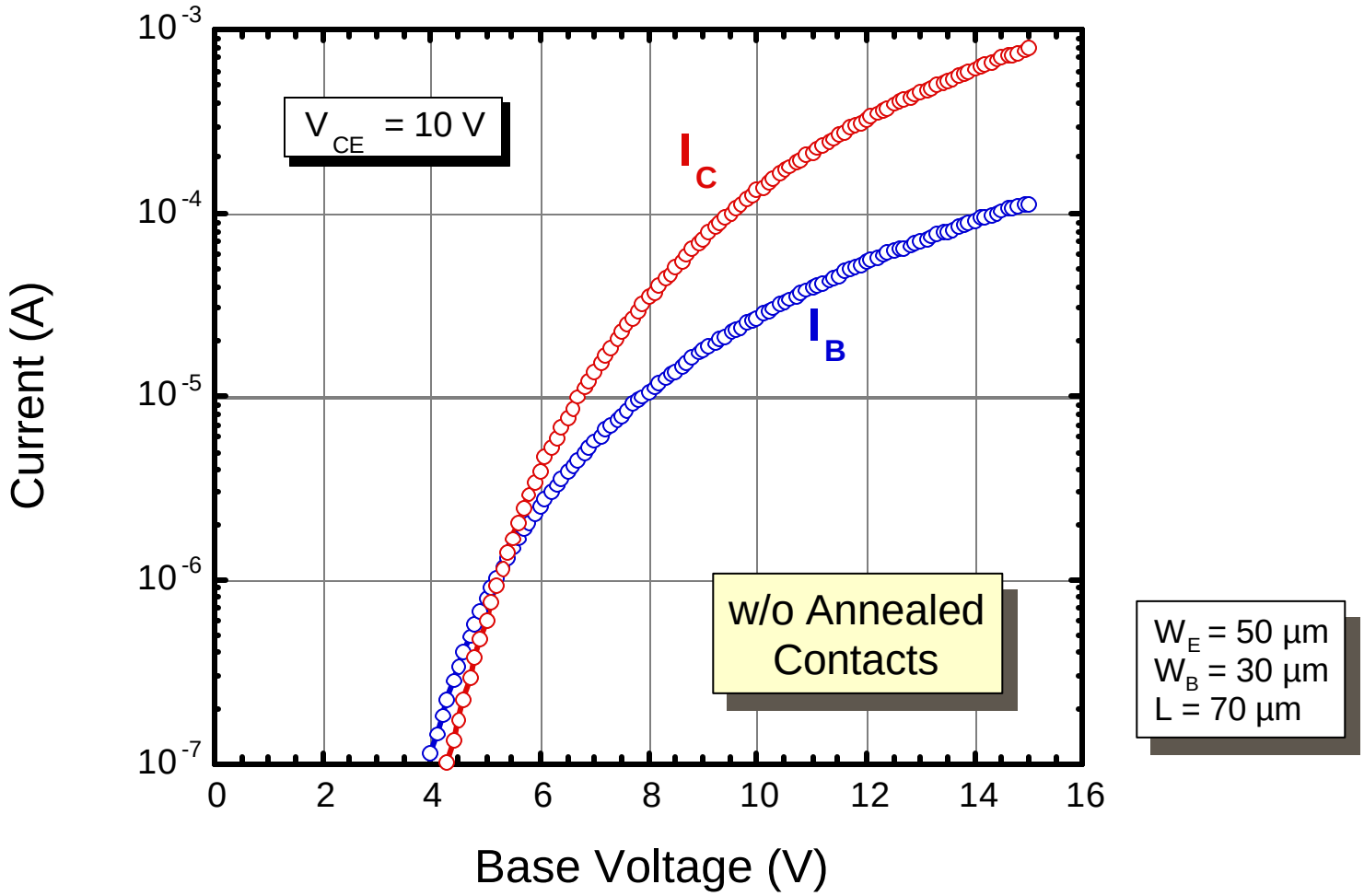
Preliminary
Electrical Measurements

(Contacts not yet annealed)

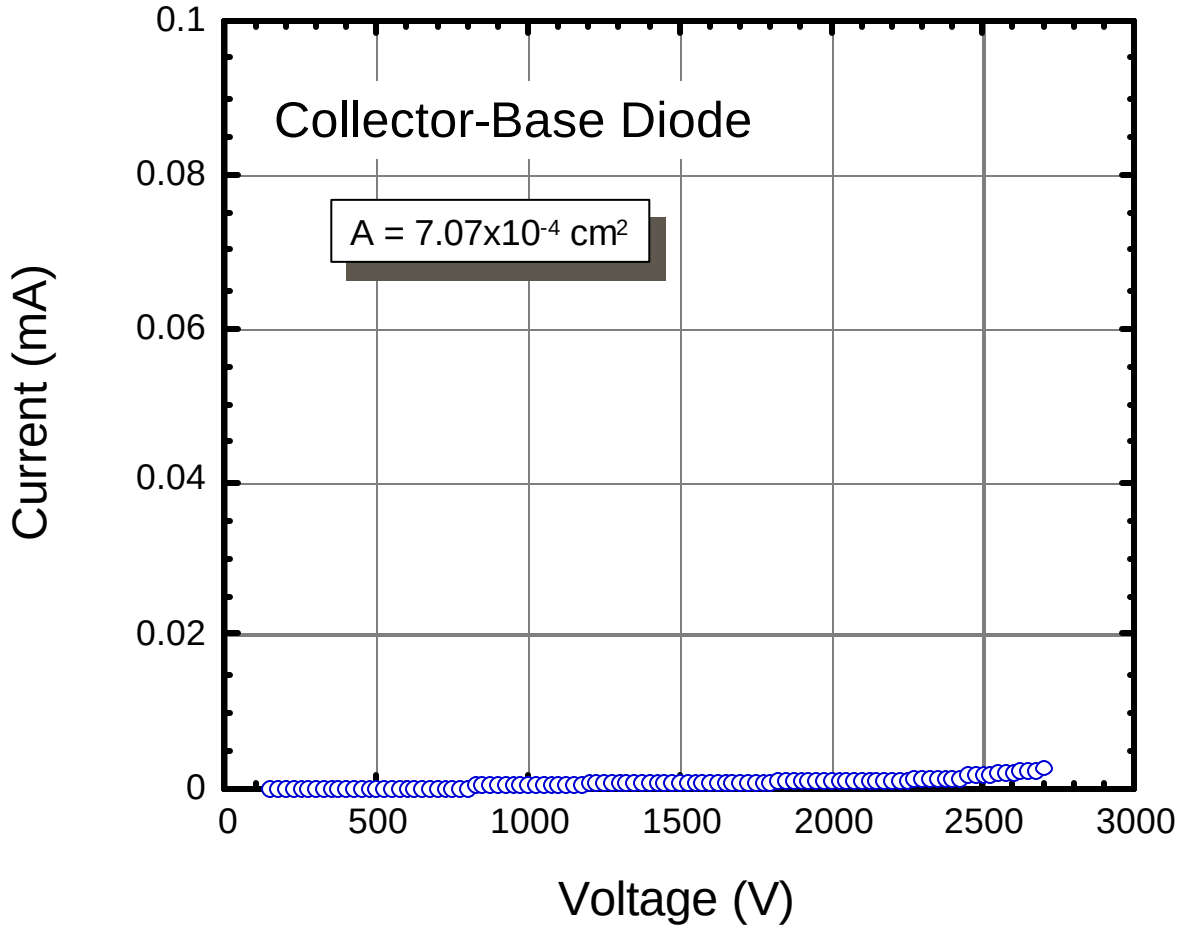
BJT On-State Characteristics



Gummel Plot

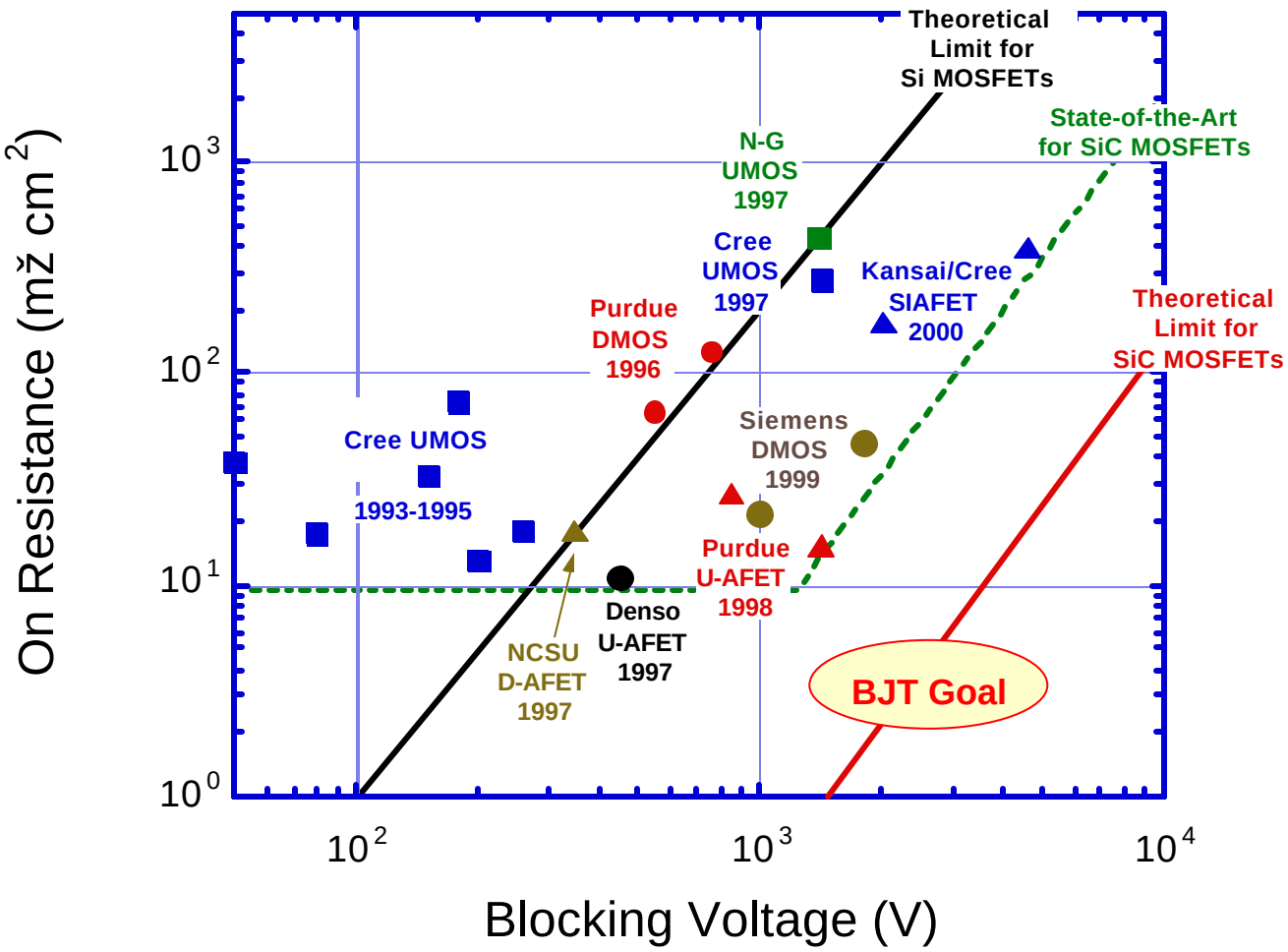

10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
Current (A)
V_{CE} = 10 V
I_C
I_B
w/o Annealed Contacts
W_E = 50 µm
W_B = 30 µm
L = 70 µm
0
2
4
6
8
10
12
14
16
Base Voltage (V)

Off-State Blocking Characteristics

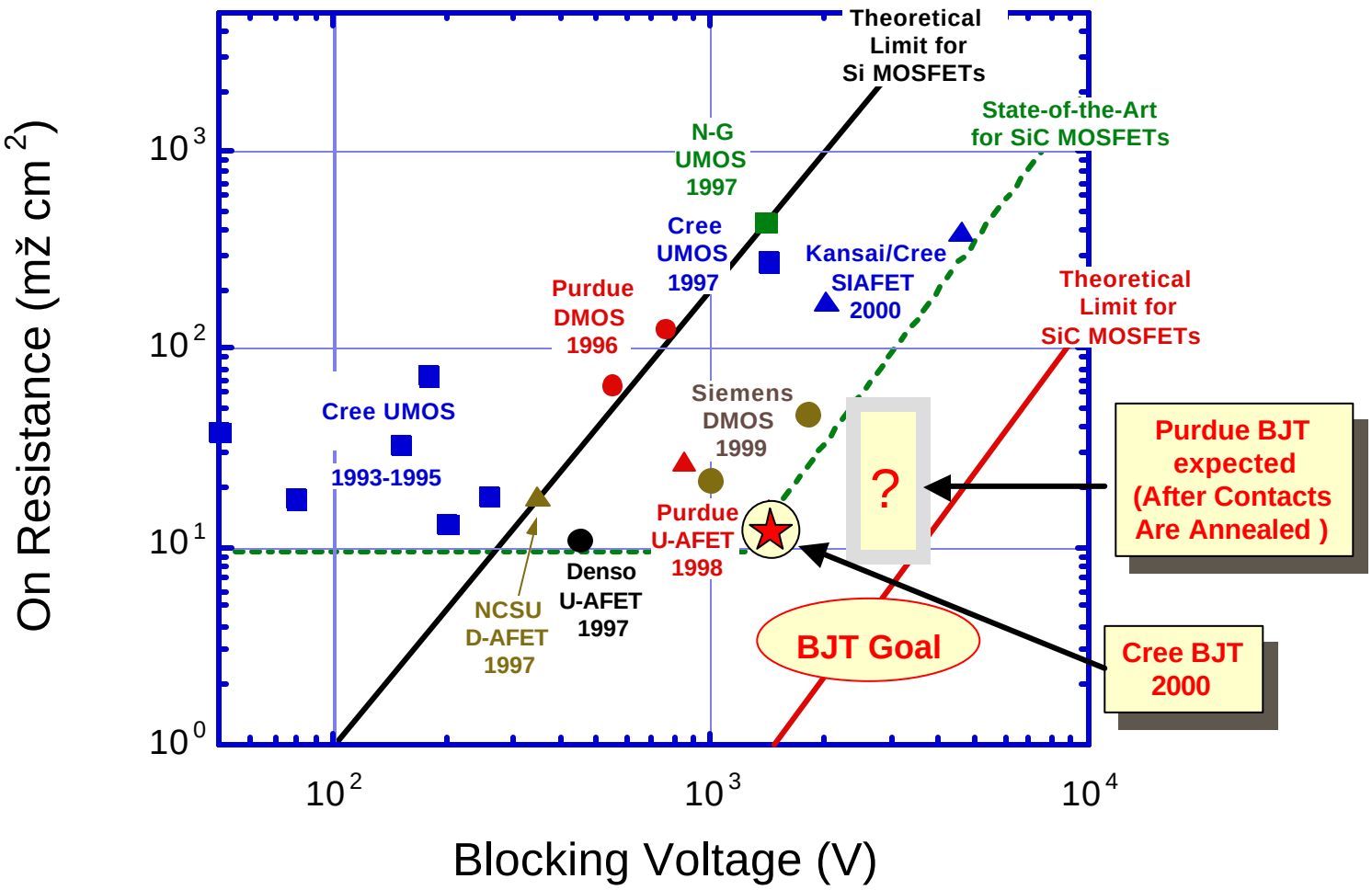


Goals and Current Status

BJT Device Goals

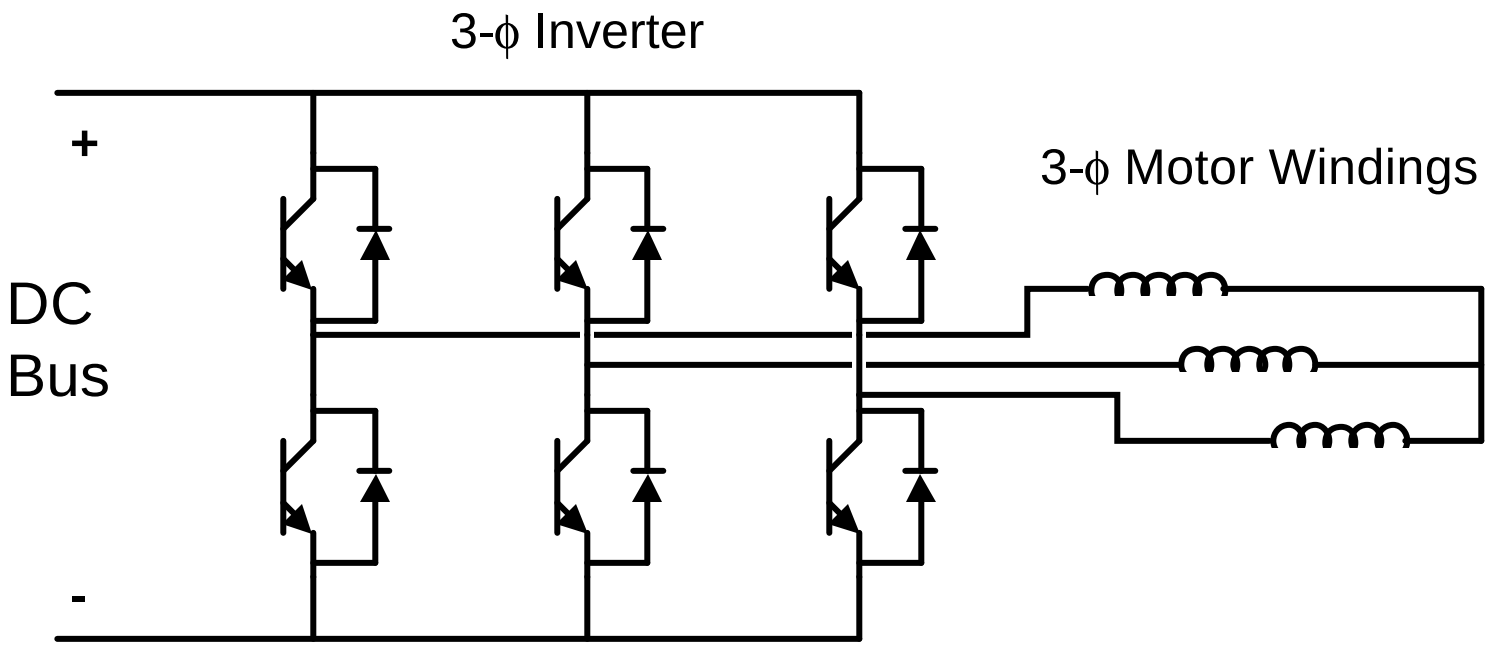


Current Status of SiC BJTs

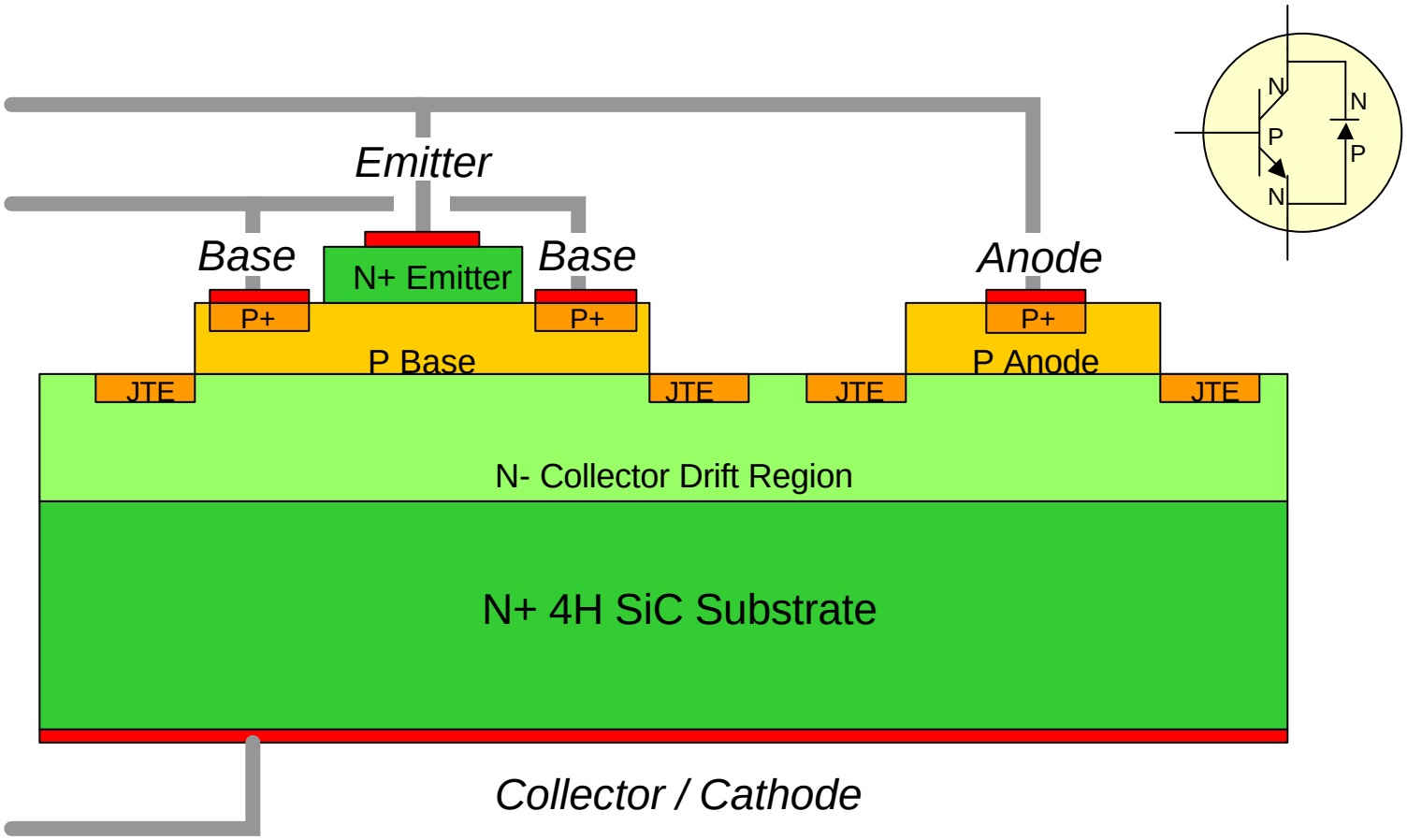


Future Directions: Monolithic Integration of SiC BJTs and PiN Diodes

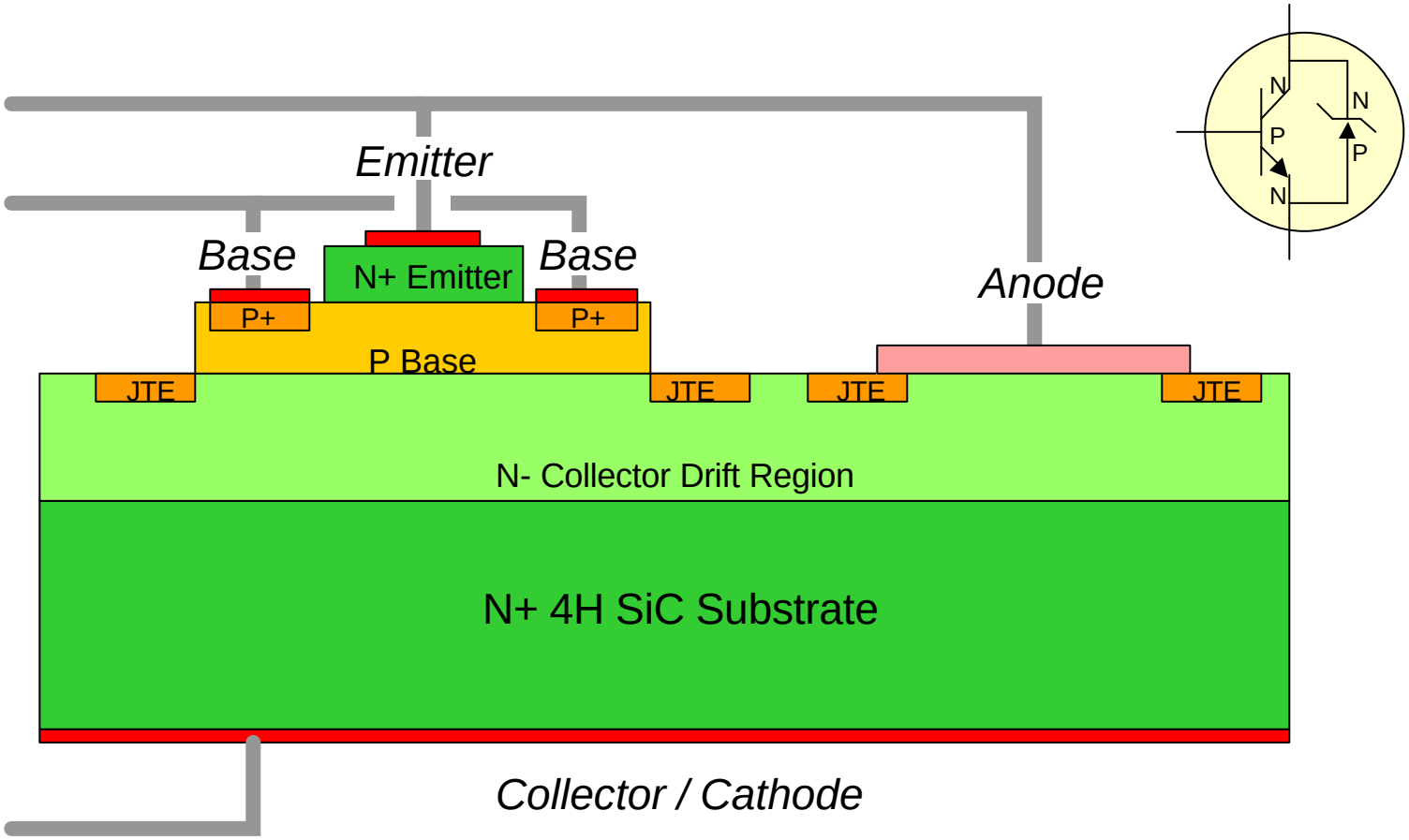
Typical Motor Drive Circuit



Monolithic Integration of BJT & PiN Diode



Monolithic Integration of BJT & SBD



Conclusions

- SiC BJTs can operate at higher current densities than SiC MOSFETs
- BJTs have higher reliability than MOSFETs, and can operate at higher temperatures
- BJTs avoid critical fabrication issues of MOSFETs
- 1.8 kV SiC BJTs have been demonstrated under the ONR/MURI program, and nominal 5 kV BJTs are under development under this DARPA program