Current Status and Future Prospects of 4H-SiC RF BJTs

Feng Zhao
Department of Electrical Engineering, University of South Carolina, Columbia, SC, 29208

4H-SiC BJTs are attractive candidates for applications such as radar, avionics and communication due to their ability to handle higher RF power density and higher power dissipation capability compared to their Si counterparts. This paper reviews the current status of 4H-SiC BJTs at UHF and L-band frequencies. Rationale and approaches to the further improvement will be presented. Table 1 summarizes the development of 4H-SiC RF BJTs in the past few years. Recent work was focused on the devices on n-type conductive substrates because of the advantages of lower material cost and higher material quality, as well as simplified fabrication process when comparing to semi-insulating substrates. UHF devices with a 50 W output power and 10 dB gain were tested at 500 MHz under a long-pulse condition of 15 ms pulse width and 25% duty cycle. L-band devices were tested from 1 to 1.4 GHz under a 1 ms pulse width and 10% duty cycle. At 1 GHz, the devices can deliver a 10 dB gain with 23 W output power. At 1.4 GHz, the devices are capable of delivering an output power of 28 W with a power gain of 7.5 dB after power scaling of two identical devices. The RF performance makes these devices promising for long-pulse UHF and L-band radars.

Simulation based on a transit-time model shows that to further improve RF performance, narrower emitter (currently 3 μm) and base (currently 1 μm) stripes, tighter base-emitter alignment spacing (currently 1.2 μm), n- and p-type ohmic contacts (currently 7.8×10^{-4} Ωcm^2 without ion-implantation) with lower specific contact resistance, and optimized design of epitaxial layer thickness and doping density need to be achieved. Fig. 1. shows the f_T and f_{MAX} promising for power amplification at S-band when above improvements are applied.

Freq (MHz)	Power (W)	Power Density (W/mm)	Gain (dB)	PW& DC	PAE (%)	Reference
450	215	4.1	7.5	0.5 μs, 0.1%	27	C. Huang et al., DRC 2004
425	2100	7	6.3	2 μs, 1%	35	A. Agarwal et al., ICSCRM 2005
500	52	14.4	10	15 ms, 25%	43	F. Zhao et al., DRC 2006
500	71	19.7	8.5	15 ms, 25%	50.7	
1000	22.9	6.3	10.1	1 ms, 10%	40.8	F. Zhao et al., IEEE EDL 2007
1000	16.2	4.5	10	6 ms, 10%	28.3	
1200	35	4.8	8	1 ms, 10%	32.6	F. Zhao et al., DRC 2007
1400	28.2	3.9	7.5	1 ms, 10%	28.2	

Table 1 Development of 4H-SiC RF BJTs

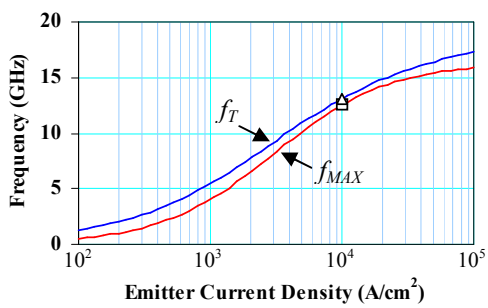

Fig. 1. Calculated f_T and f_{MAX} in new design

Parameters	Values
Emitter doping (cm^{-3})	3×10^{19}
Base doping (cm^{-3})	2×10^{18}
Collector doping (cm^{-3})	2×10^{16}
Base thickness (nm)	100
Collector thickness (μm)	2
Emitter stripe width (μm)	0.5
Base stripe width (μm)	0.5
B/E alignment (μm)	0.5
Base contact resistivity Ωcm^2	1×10^{-5}

Table 2 Material parameters used in f_T and f_{MAX} calculation