THEORETICAL RESEARCHS ON TEHNICAL CHARACTERISTICS OF SILICON CARBIDE

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ABSTRACT**.** The high electric breakdown field of SiC allows thinner layers and higher doping to be used for the voltage blocking layer of a power device compared to that required for Si-based power devices. In addition, the high thermal conductivity and wide bandgap of SiC allows these devices to operate at very highpower levels and/or temperatures.These properties, combined with the high saturated electron drift velocity of 2.0 x 10^7 cm/sec, indicate that SiC is a very promising material for high power,high frequency operation ,and the wide bandgab will allow SiC microwave FET 's power devices to operate at high temperatures. The ability to operate at highpower levels and high temperatures greatly reduces the complexity of the electronics cooling systems required for both the power conditioning and RF applications. Other applications for SiC wafers include use as substrates for epitaxial deposition of materials such as GaN, AIN and diamond and as a heat sink for other semiconductors to take advantage of its high thermal conductivity.

1. INTRODUCTION

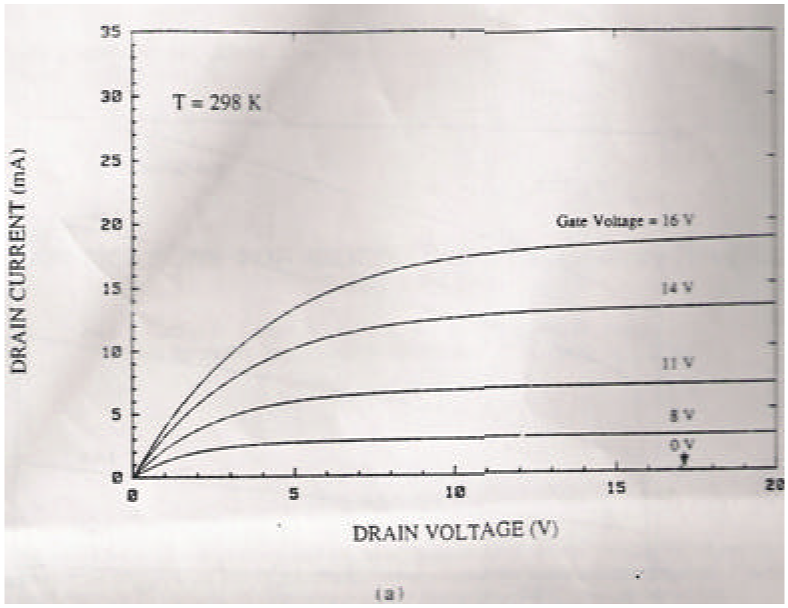
The wide bandgab of 6H-SiC gives the added advantage of high temperature operation for almost any device fabricated in this material. High temperature applications include devices for digital, analog, and power functions. In order to improve efficiency, new jet engine electronics. These electronics include devices for the ignition systems as well as sense and control electronics.

Since radiation is the only method of cooling electronics in space and since the energy radiated is a T^4 function, the ability to operate electronics at higher temperatures greatly reduces the size and weight of the radiator panels required for spacecraft. Other application areas are for automotive electronics, where the trend is to operate at higher temperatures, and for transmitters for deep well drilling.

A number of 6H-SiC devices have recently been demonstrated at high temperature. Packaged high temperature 6H-siC on junction rectifiers have been reported that have very good characteristics up to 623 K (3).A variety of FET's have also been measured at high temperature. Both MOSFET's and buried-gate FET's have been demonstrated to have very good characteristics at elevated temperatures.Both of these structures show similar behavior with temperature. The on-current and transconductance decrease with increasing temperature due to decreasing electron mobility. At 623 K these parameters are roughly half of their room temperature values. These devices were measured to have good characteristics to 773 K.

Promising results have also een obtained with 6H-SiC MOSFET's. The I-V curves shown in Fig.1 are for a n-channel enhancement-mode MOSFET with a 7 µm gate length and 1 mm gate width. The room temperature drain current at V_G =+16V is 18.6 mA and the transconductance (g_{max}) at that gate voltage is 2.8

mS/mm, as is shown in Fig.1.a..



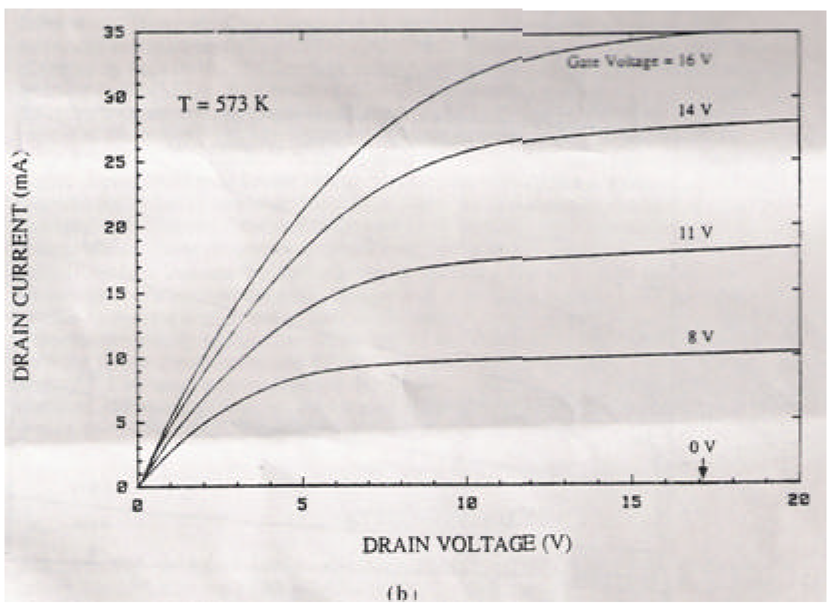


Fig.1. Drain current-voltage characteristics of n-channel 6H-SiC enhancementmode MOSFET at (a) 298 K and (b) 573K.The gate length and width were 7µm and 1000 µm, respectively.

The threshold voltage (V_{th}) is about 1.9 V. When the temperature is raised, both the current and g_{max} increase and the V_{th} decrease. This trend continues up to 573 K, as shown in Fig.1b.

At this temperature the current and $g_{max,}$ are35 m? and 3.9 ms/mm, respectively.

That drain current at V_G =0 V was 47 m? at 573 K. Some MOSFET's had very good characteristics to temperatures as high as 923 K.

High temperature operation of 6H-SiC bipolar junction transistors (BJT's) has also recently been demonstrated. The base width and doping for these devices was 0.55 µm and p=2-3 x 10^{17} cm^{-3}. The I-V characteristics for a 6H-SiC npn BJT at room temperature is shown in Fig.2.a.The maximum common-emitter gain of this device at V_C=50 was 10.4.The maximum current transfer ratio measured in the common-base mode was 0.89.The common-emitter gain decreased to 7.8 as the temperature was increased to 523 K. Above this temperature, the gain began to increase with increasing temperature. At 673 K, the gain had returned to a value of 10.2 as shown in Fig.2.b.

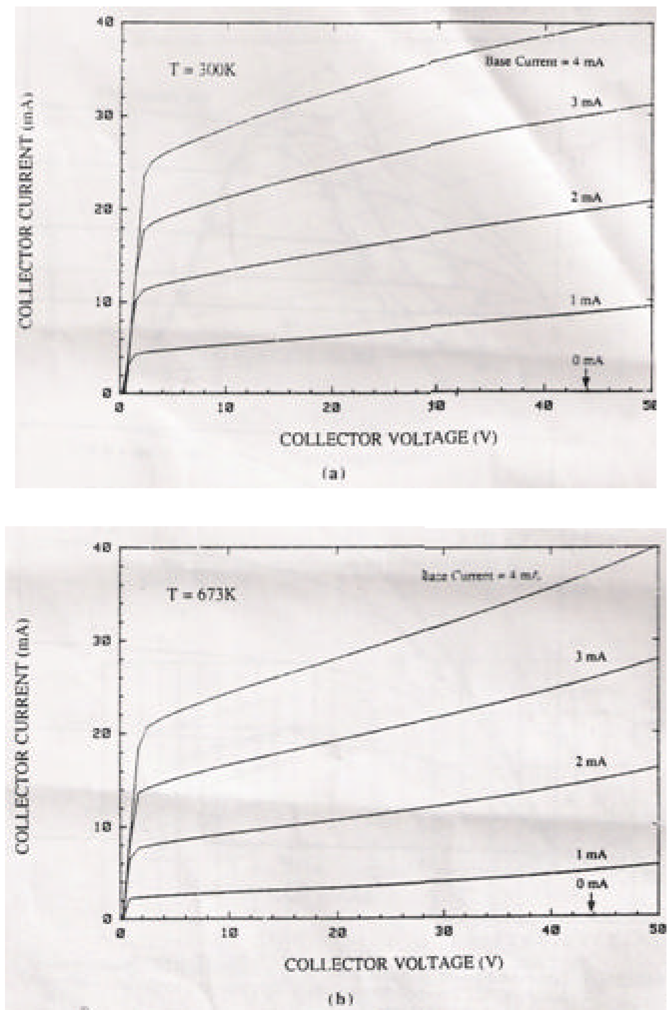


Fig.2. Common emitter mode I-V characteristics of a 6H-SiC BJT at (a) 300K and (b) 673K.The base width was 0.55 µm and the emitter periphery was 0.4 cm.

3.HIGH FREQUENCY DEVICES

As was started earlier, one of the main applications for SiC is higher power RF and microwave devices. Threw, et al [7] have modeled 6H-SiC MESFET's and shown that RF output power as high as 65W could be achieved at 10 GHz (4 W/mm)These devices would offer much higher reliability than present traveling wave tube technology. Applications for high frequency SiC MESFET's would be in Electronic Countermeasure Systems, such as jamming and threat warning systems, and in solid-state phased array radar systems. Communication systems and high frequency power supplies will also benefit from the enhanced operating range of SiC.

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