

Chapter 1

Introduction

1.1 Introduction

Power semiconductor devices which are usually used as switches in the power electronic system are widely used in the different sectors namely residential, commercial, industrial, transportation, utility system, aerospace and telecommunication [1]. Extensive research done in the semiconductor technology of power semiconductor devices have led to the higher current or voltage handling capability, faster switching speed and lower cost [2 - 4]. This results in the increase in the demand for it as more and more systems are using it.

The power semiconductor devices can be classified into three groups based on the degree of controllability i.e as a switch namely diodes, thyristors and controllable switches [5]. The n-channel enhancement mode power MOSFET device belongs to the controllable switches group and has the fastest switching speed among its group [6 - 7]. This power device has wide applications such as switching regulators, switching converter, motor drivers and relays driver in the power electronic system as mentioned earlier [8].

The performance characteristics of power MOSFETs are generally superior to those of bipolar transistors. Power MOSFET has a significantly faster switching time,

simpler drive circuitry, an advantage of the absence of a second-breakdown failure mechanism, the ability to be paralleled which results tremendously reduction in drain-source on resistance, and stable gain and respond time over a wide range temperature range [9]. The high operating temperature effects on the power semiconductor is important [10 -14]. A lot of device characterization works have been done all over the world to improve the performance of this power device including its switching properties especially at different operational temperatures. Commercially packaged power semiconductor devices can be available in the three different grades dependent on its application namely commercial grade (0°C to $+75^{\circ}\text{C}$), industrial grade (-25°C to $+85^{\circ}\text{C}$) and military grade (-55°C to $+125^{\circ}\text{C}$ or $+175^{\circ}\text{C}$) [8].

The main objective of this work is to study the high frequency capacitance-voltage (C-V) and conductance-voltage (G-V) characteristic of a commercially package n-channel enhancement mode power MOSFET device manufactured by Harris Semiconductor. In order to provide a clear understanding on the device operation, initial studies include measurements across the source-drain and gate-drain structures. A detailed study of the C-V and G-V characteristics were mainly done on the gate-source structure due to the importance of these terminals in the switching properties of this device.

Chapter 2 of this thesis presents a background theory and literature review of various semiconductor devices. A review on metal-oxide-semiconductor (MOS) device is presented in Section 2.2 with emphasis on its structure, energy band profile and characteristics. In Section 2.3, the field-effect-transistor (FET) was detailed also in terms of its structure, energy band profile. The principal of operation and current-voltage

characteristic of this device are also discussed. The different types of MOSFETs are also presented in this section. Power Semiconductor Devices are presented in Section 2.4 where the structures of thyristor and bipolar-junction-transistor (BJT) are introduced in Sections 2.4.1 and 2.4.2 respectively. Section 2.4.3 discusses the structure, principal operation and current-voltage characteristics of the power MOSFET device. This chapter is concluded in Section 2.4.4 with discussion on the importance and applications of power semiconductor devices.

The high frequency characterization technique of the n-Channel Enhancement Mode Power MOSFET is presented in Chapter 3. Section 3.2 introduces the power MOSFET device which is studied in this work concentrating mainly on the device structure. Section 3.3 presents the experimental set-up for characterization of this device. The test fixture design to facilitate measurement using the Keithley 590 C-V Analyzer is presented in Section 3.4. While the Capacitance-Voltage and Conductance-Voltage measurement techniques are detailed in Section 3.5. Section 3.6 presents the Capacitance-Voltage and Conductance-Voltage Measurement Techniques at Elevated Temperatures. The annealing process including the calibration of furnace are described in Section 3.7.

Chapter 4 analyses the results of the high frequency Capacitance-Voltage measurements on the n-channel enhancement mode power MOSFET device described in Section 3. The high frequency Capacitance-Voltage measurement results across various structures of the device at room temperature namely Gate-Source, Gate-Drain and Source-Drain are presented and discussed in Sections 4.2.1, 4.2.2 and 4.2.3 respectively. The high frequency Capacitance-Voltage measurement results at different measurement temperatures across the Gate-Source structure are detailed in Section 4.3 while results on

the effects of annealing on device are presented and discussed in Section 4.4. This chapter concludes with the analysis of results on the high frequency Capacitance-Voltage measurement of the device annealed at 400°C at room temperature and at different measurement temperatures.

Chapter 5 analyses the results of the high frequency Conductance-Voltage measurements on the n-channel enhancement mode power MOSFET device described in Section 3. As in Chapter 4, this section was introduced with analysis on the high frequency Conductance-Voltage measurement results across various structures of the device at room temperature namely Gate-Source, Gate-Drain and Source-Drain in Sections 5.2.1, 5.2.2 and 5.2.3 respectively. In Section 5.3 analysis was done on the high frequency Conductance-Voltage measurement results at different measurement temperatures across the Gate-Source structure while in Section 5.4 analysis was done on the effects of annealing on the G-V characteristic of device. This chapter concludes with the analysis on high frequency Conductance-Voltage measurement results of the device annealed at 400°C at different measurement temperatures. Results obtained from the annealed and unannealed device are compared and analyzed.

Chapter 6 concludes this thesis with suggestions for further works on this device.