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SiC MOSFET Gate Oxide Quality Improvement Method in Furnace Thermal Oxidation with Lower Pressure Control

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Abstract. We have investigated carbon behavior resulting from pressure control in furnace thermal oxidation process and evaluated the effect on gate oxide quality resulting from this pressure control. In order to investigate the potential reduction of carbon defects by reducing CO and CO_2, an analysis of oxidized SiC wafers was conducted. To evaluate the effect of pressure control related carbon component change during thermal oxidation, Q_{BD} characteristic was evaluated in SiC MOS Capacitance. The analysis results revealed on observable decrease in carbon at the SiO_2/SiC interface and the SiO_2 layer. The Q_{BD} results shown that improved at lower pressure better than those obtained in the general pressure.

Introduction

The gate oxide is an insulating layer that separates the gate terminal from the channel of a MOSFET(metal-oxide-semiconductor field-effect transistor). It is responsible for controlling the flow of current through the channel, and thus plays a key role in determining the device's electrical characteristics such as its on-state resistance and switching speed. Overall, gate oxide integrity is a crucial factor in the performance and reliability of SiC MOSFETs, and it requires careful attention and expertise to ensure that it meets the high standards required for power electronics applications. Numerous research findings have been reported regarding the reduction of carbon related defect at the interface between the oxide and SiC to achieve better gate oxide quality in SiC MOSFET [1]. In this paper, we will verify carbon behavior from pressure control in furnace thermal oxidation process and evaluate the effect to gate oxide quality from this pressure control.

Results and Discussion

According to the kinetic model of SiC oxidation based on the interfacial silicon and carbon emission phenomenon, during SiC oxidation, the encounter between SiC and O_2 leads to the formation of SiO_2, C, CO_2 and CO [2-5]. These formed molecules of CO_2 and CO can react with SiO_2 [6]. In order to investigate the potential reduction of carbon defects by reducing CO and CO_2, an analysis of oxidized SiC wafers was conducted. SiC wafers were proceeded furnace thermal oxidation, while controlling the pressure to facilitate rapid removal of CO and CO_2. To ensure accurate comparisons, the analysis was performed using AES, Dynamic SIMS, and TOF-SIMS techniques, with a specific focus on examining the behavior of carbon. The analysis results AES in (Fig. 1), Dynamic SIMS in (Fig. 2) and TOF-SIMS in (Fig. 3), revealed observable changes in the

SiO_2/SiC interface and carbon content within the SiO_2 layer. Each analyst observed that carbon was reduced from the SiC interface of the wafer that had undergone lower pressure oxidation. It could be possible that by applying lower pressure to increase the gas flow speed within the furnace, rapid removal of CO and CO_2 was achieved, thereby reducing the subsequent reaction with SiO_2. Consequently, this reduction in reactivity led to a decrease in the carbon content at the interface and within the oxide layer.

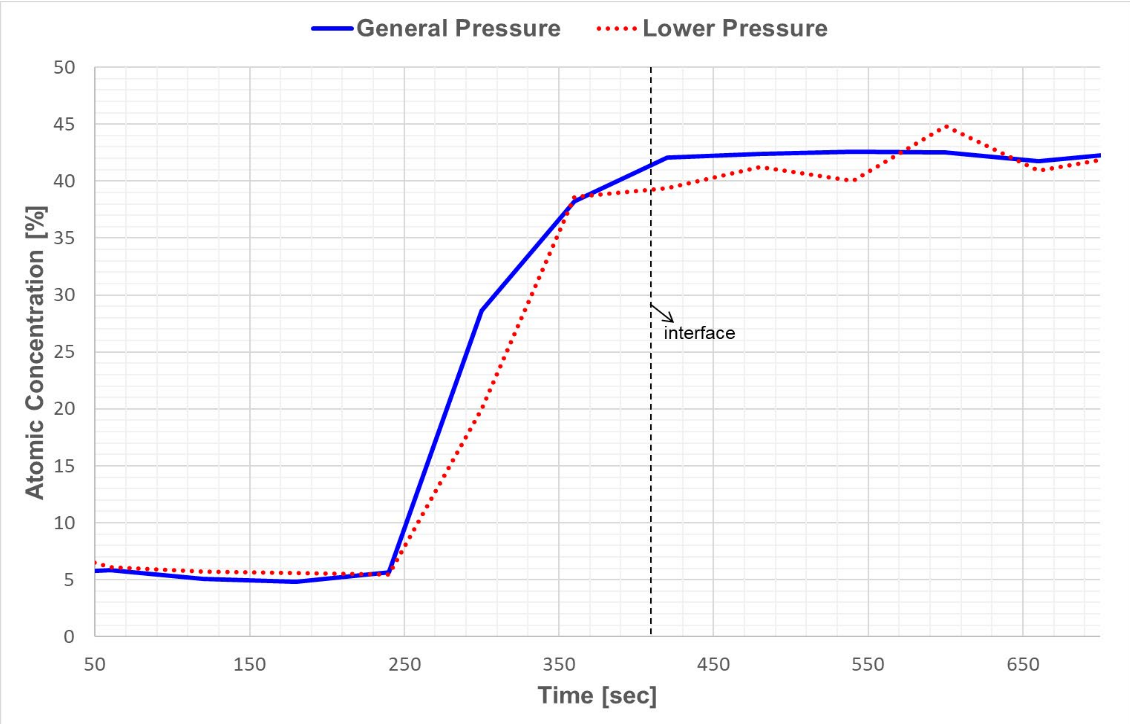

Fig. 1. Oxide on SiC wafer AES analysis results - Carbon profile.

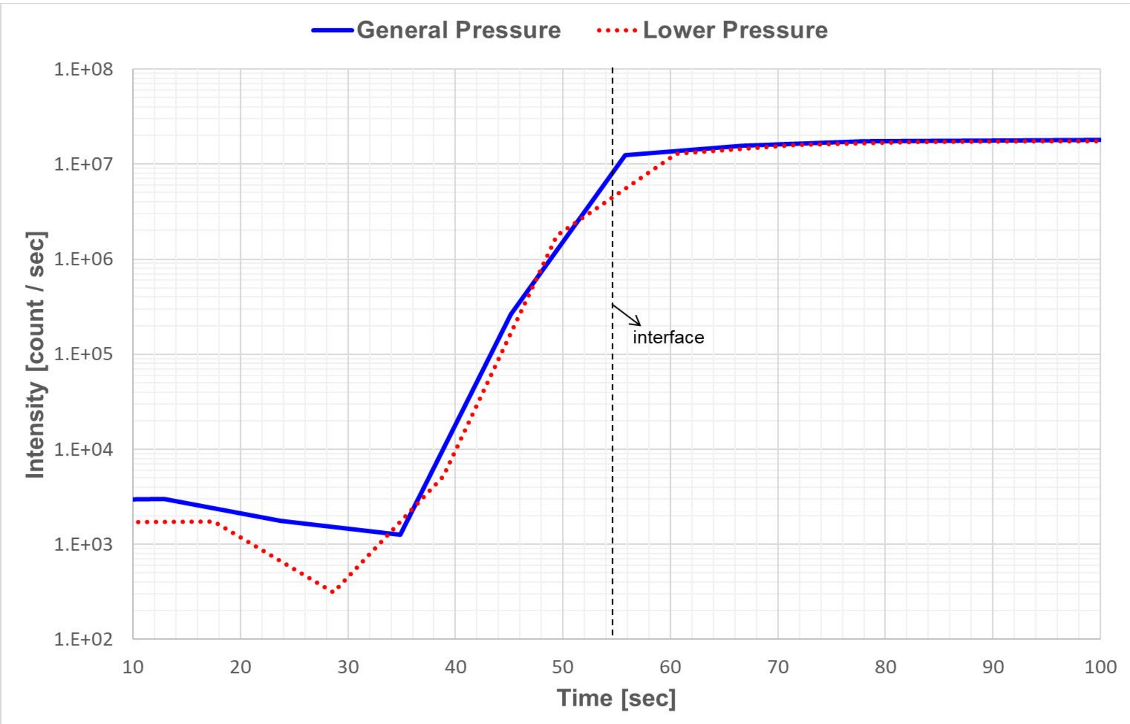

Fig. 2. Oxide on SiC wafer Dynamic SIMS analysis results - Carbon profile.

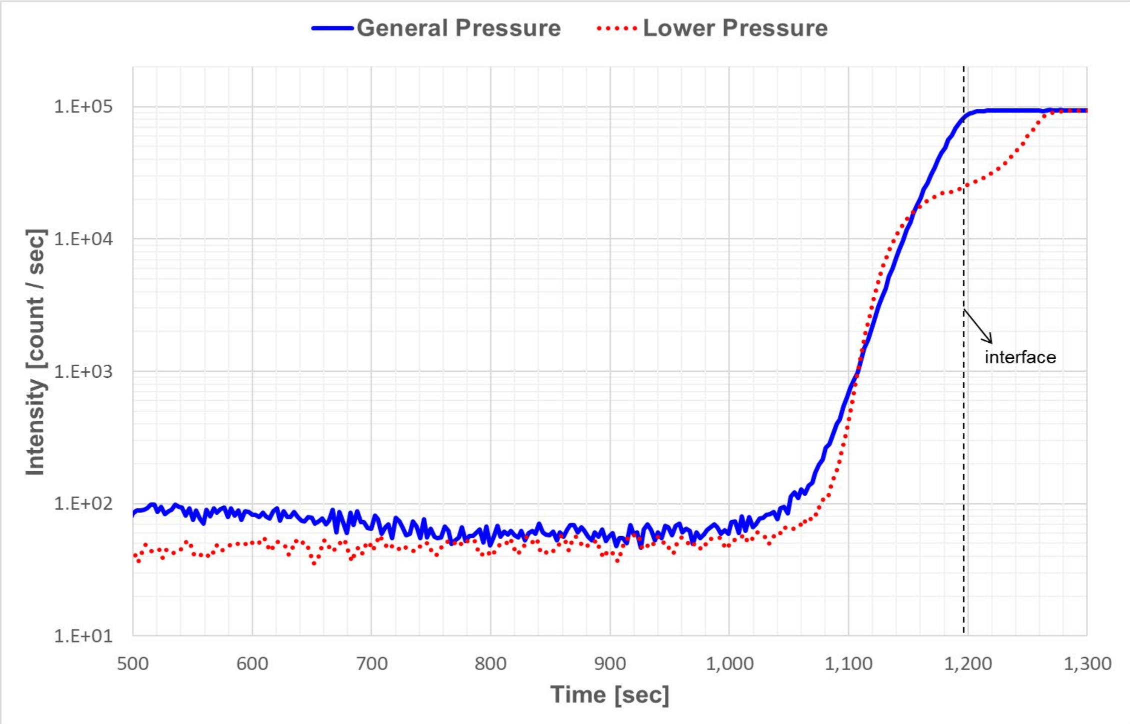

Fig. 3. Oxide on SiC wafer TOF-SIMS analysis results - Carbon profile.

The Q_{BD} is a standard destructive test method to verify the gate oxide quality in MOS devices. To evaluate effect of pressure control related carbon component change during thermal oxidation, Q_{BD} characteristic is evaluated. SiC MOS Capacitance Q_{BD} measured, then compared by Weibull plot. As shown in (Fig. 4), we obtained Q_{BD} results that improved at lower pressure (87 C/cm^2) better than those obtained in the general pressure (37 C/cm^2).

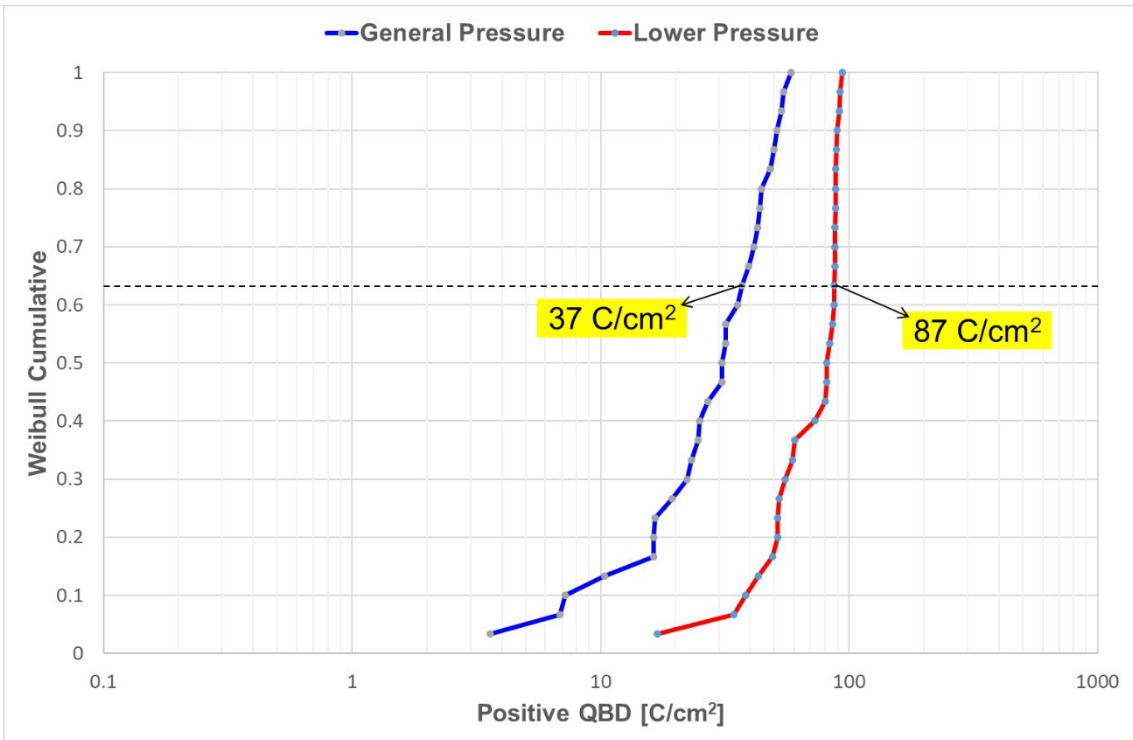

Fig. 4. Q_{BD} Weibull plot of general pressure and lower pressure. SiC MOS Capacitance charge to breakdown Q_{BD}, Istress=20mA/cm^2, Tstress=25°C.

Therefore, the results from analysis have revealed that pressure difference during oxidation can support forming less Carbon defects in SiO_2 layer and this effect is related with better Q_{BD} characteristic shown thermal oxidation process.

Summary

In summary, we verified carbon behavior from pressure control in furnace thermal oxidation process. It could be possible that by applying lower pressure to increase the gas flow speed within the furnace, rapid removal of CO and CO_2 was achieved, thereby reducing the subsequent reaction with SiO_2. The lower pressure thermal oxidation proceeded oxidized SiC wafer SIMS analysis results revealed observable Carbon decrease in the SiO_2/SiC interface and SiO_2 layer. As this effect, SiC NMOS Capacitance, which is proceeded lower pressure thermal oxidation, shown improved Q_{BD} results more than double. Therefore, lower pressure during furnace thermal oxidation can generate less Carbon in SiO_2 and SiO_2/SiC interface, and this effect improves SiC MOSFET gate oxide quality as shown Q_{BD} improvement results.

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