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Generation and Recombination Carrier Lifetimes in 4H SiC Epitaxial Wafers

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1. Abstract

For the first time both generation and recombination carrier lifetimes are reported from the same device areas in a 10 ㎜ 4H-SiC epitaxial wafer. Average generation and recombination lifetimes at 400°C are 1489 and 605 ns, respectively. The magnitude of the ratio of generation to recombination lifetime is unexpected and quite different from silicon. Correlation between carrier lifetimes and the number of dislocations in active device area is investigated.

2. Introduction

Carrier lifetime is a very effective parameter to characterize impurities of materials or devices and has become a process characterization parameter in silicon IC industry [1]. While generation and recombination lifetimes have been extensively studied and characterized in silicon, lifetime studies for 4H-SiC epitaxial wafers are very limited. Microwave-Photoconductive Decay (PCD) high-resolusion recombination lifetime wafer maps from 4H-SiC are recently reported and show strong correlation between lower lifetimes and defective areas to suggest a possible non-destructive epitaxial wafer mapping tool for SiC epitaxial wafer qualification [2]. Generation lifetime is a more appropriate technique for localized lifetime characterization by the space-charge region width and device area but very few data have been reported in SiC [3,4]. In bipolar devices, diode leakage current depends on generation lifetime, and diode turn-off time and forward voltage drop depend on recombination lifetime. Thus, to achieve high-temperature, high-power, and fast-switching SiC bipolar devices, both generation and recombination lifetimes should be well understood and controlled. In this paper, both generation and recombination lifetimes are measured in the same device locations to achieve a direct comparison and correlation between lifetimes and underlying defects.

3. Experimental

MOS capacitors were fabricated on an n-type 4H-SiC epitaxial wafer grown at Dow Corning with a 45 nm thermal oxide. Generation lifetimes were measured using the pulsed MOS capacitor (MOS-C) technique at 400°C. This technique involves biasing a MOS-C into deep depletion and monitoring the capacitance change during the generation of the inversion layer. The data can then be used to calculate an effective generation lifetime for the material. An RIE MESA etch was performed to register accurate MOS capacitor locations, and the gate metals and oxide layers were etched off for recombination lifetime measurements by photoluminescence (PL). Recombination lifetimes were measured from the decay of the exciton/band edge PL peak at room temperature and 400°C with injection levels of about 10^{16}/cm^3. Finally, a KOH etch was performed at 500°C for 10 min to count underlying defects in active device areas.

4. Data and Discussion

Fig. 1 shows a box plot of recombination and generation lifetimes from the sample piece (56 MOS capacitors) of about 1cm^2 of 4H epitaxial wafer (N_d =10^{16}/cm^3, t_{epi}=10㎜). Average generation and recombination lifetimes are 1489 and 605 ns, respectively. For silicon the generation lifetimes are typically 20~100 times the recombination lifetimes [5,6]. The ratio of generation to recombination lifetimes in SiC is quite different and much smaller than silicon. In addition, the standard deviation of the generation lifetimes is much higher than that of recombination lifetime. This large fluctuation is also not expected from silicon experience. Surface recombination and leakage current through the gate are a possible explanation, and more measurements and analyses are underway to understand these observations.

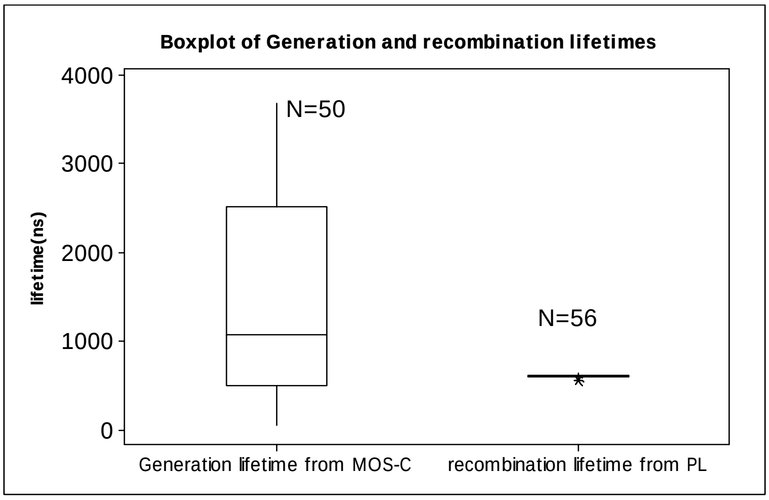

Figure 1. Boxplot of generation and recombination lifetimes. N is the number of data points

To understand the influence of material defects on carrier lifetimes, the sample was etched in KOH and the defects were categorized by etched shapes and counted under microscope. Fig. 2 shows regression plots of generation and recombination lifetimes with the number of threading edge dislocations (TEDs) in each device having only TEDs. Correlation is not very strong but in general, both generation and recombination lifetimes decrease with higher TEDs density. Other dislocations like threading screw dislocation (TSD) and basal plane dislocation (BPD) are also counted and correlation between lifetimes and these defects will be presented at the conference.

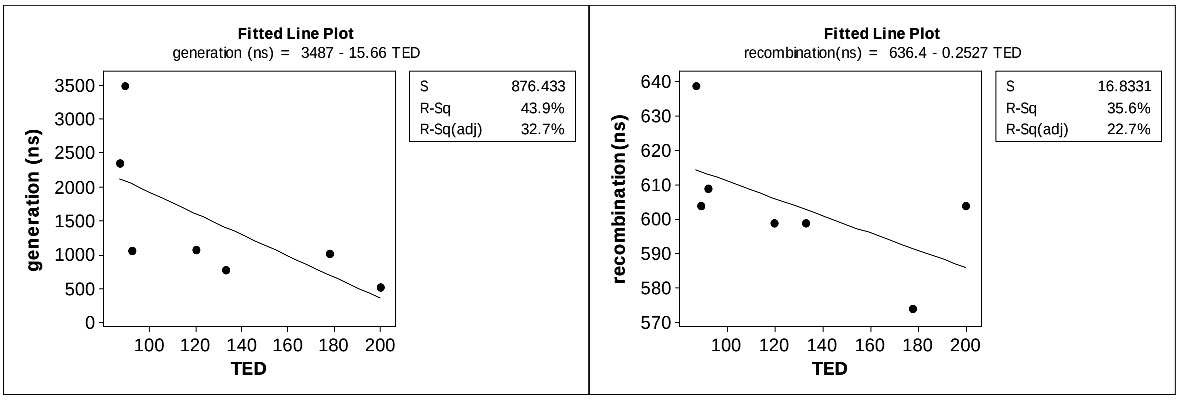

Figure 2. Regression fitted line plots of generation (a) and recombination (b) lifetimes with number of TEDs.

5. Acknowledgement

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6. References

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