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Behavior of in-grown Stacking Faults in 4H-SiC Epitaxial Layer Through Annealing Process

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1. Introduction

SiC power devices are already on the stage pioneering the actual application. Numerous efforts for the reduction of micro-pipes and the related defects in 4H-SiC substrates had been paid, and production effective Φ4" 4Hn-SiC substrates are getting to be supplied in the market, recently. Restraint of in-grown stacking faults (SFs) introduction in the epitaxial layer is one of the seriously issues for the power device production, because some of them shutdown the current flow or cause the carrier leakage [1-5]. We reported the PL topographic imaging technique as a usable inspection technique of SFs in SiC epitaxial layer [6]. There exist many kinds of structures of in-grown SFs, which appear as the specific PL wavelengths and patterns.

In this paper, we report the behavior of SFs during the high temperature process, especially the implantation annealing process at around 1600℃, using the PL topographic imaging technique.

2. PL topographic imaging inspection of in-grown SFs

In-grown SFs may be introduced during the epitaxial growth with many types of origin, especially at the initial stage of the epitaxial growth, such as dislocation edge, surface roughness, or surface remaining contaminants.

SFs are namely the abnormal sequence of basal-plane stacking as (A-B-C-A-B-) in ABC-notation of 4H-SiC (A-B-C-B-A-), which consist of quantum-well like structure of foreign poly-types inserted in the 4H-SiC single crystal. Therefore, despite of their small volume occupation, some SFs show bright luminescence effectively gathering electron-hole pairs after over excitation with the wavelength to characterize structure. N-doped n-type 4H-SiC epitaxial layer shows band-edge emission peak at 390nm and impurity related broad emission peaks around 500-600nm at room temperature. Epitaxial layer including SFs shows some abnormal emission peaks, as 423nm or 465nm, on the background spectra as Figure 1.

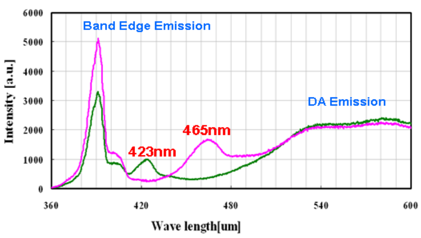


Figure 1 abnormal PL spectra of SFs in 4Hn-SiC epitaxial layer

Figure 2 shows PL topographic imaging patterns of SiC epitaxial layer at the same spot with optical band-path filter of the specific abnormal peak wavelengths; (a) 420nm and (b) 460nm, are shown in figure 2. In our previous work [6], TEM cross sectional inspection of each pattern indicated that 4H-type stacking sequence includes single Shockley type SF and 8H type SF, respectively.

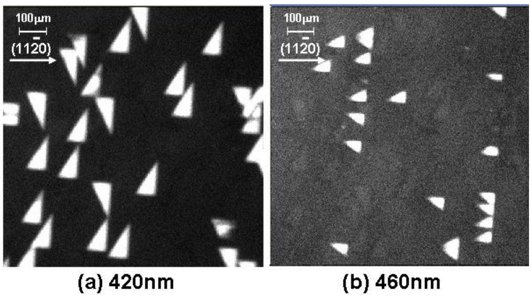
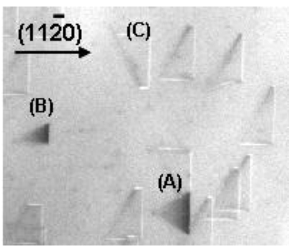


Figure 2 PL topographic imaging of SiC epitaxial layer including some types of SFs at the same spot

Furthermore, PL imaging inspection with IR-path optical filter shows existence of non-radiative patterns with the specific triangle shapes which does not correspond to the dark replicas of any radiative patterns, as shown in figure 3. In the figure, (A) is the non-radiative SF, (B) is the dark reolica of 420nm SF, and (C) are the shadows of 460nm SFs.. Although we could not analyze every such dark SFs, in the case of most dark SFs consist of thick 3C polytype inclusion of (A-B-C-)x20～80 in ABC notation, as shown in figure 4



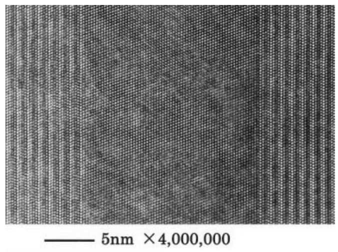


Figure 3 PL topografic image of Non-radiative SF

Figure 4 Cross sectional TEM of non-radiative SF

3. Change of PL topographic patterns after anealing

Impurity hardly diffusible SiC materials permit only implantation process for the modification of the conductivity. For the activation of impurity atoms, SiC wafer needs to be heated up to higher than 1600℃. The activation annealing is the most severe experience for SiC materials in the whole of SiC device fabrication process. Therefore, we investigated the behavior of SFs during the annealing process.

We investigated the change in PL topographic patterns before and after the annealing process of 1650℃-1min., where molten KOH etching was carried out to carve as the position marks for PL im-aging observation. In figure 5, 420nm and 460nm PL topographic patterns before and after the annealing process were demonstrated. Red-circles in each photo are the landmarks to identify the changes.

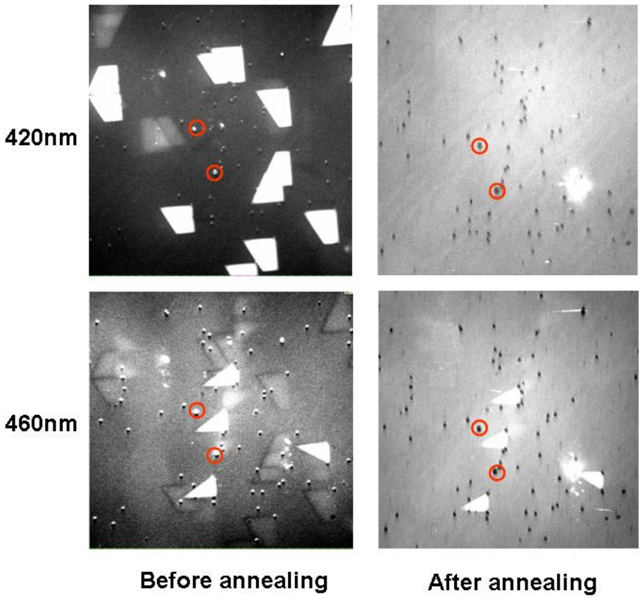


Figure 5 PL topographic patterns before and after annealing process

Obviously 420nm patterns were vanished after the an-nealing process, and 460nm patterns still remained. We confirmed the same phenomena even in the wide range observation. Even any traces of 420nm patterns could not be identified in the whole area of the wafer.

On the other hand, non-radiative patterns remained as 460nm patterns. And any newly appearing PL patterns could not be identified in our investigation.

We did not confirm the lattice structural changes after the annealed process by TEM cross sectional inspection. However, we think that Single Shockley SFs, which appear as 420nm patterns, could be recovered by the activation anneal-ing, and other types of SFs, such as 8H, double Shockley type or large 3C inclusion, could not be changed in their structure by the annealing process.

4. Conclusions

We investigated the behavior of SFs in 4Hn-SiC epi-taxial layer during annealing process with PL topographic imaging inspection. 420nm patterns were completely va-nished by the annealing process, however other PL patterns did not show any change after the process. Single Shockley SFs could be recovered by the activation annealing process and other SFs still remain after the process.

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