# On the Influence of Nitrogen and Carbon on the Formation of Dislocations in Heavily Doped Silicon Wafers

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## Introduction

Silicon wafers grown with the Czochralski method contain oxygen atoms which have been dissolved from the quartz crucible and incorporated in the silicon single crystal during crystallization. Due to the supersaturation of the interstitial oxygen, precipitation occurs during device manufacturing /1/ forming the so-called bulk micro defects (BMD). These defects act as getter sites for various metal impurities. For a proper getter efficiency, a sufficiently large number of BMDs is needed.

Large diameter, i.e. 200mm wafers are known to be sensitive to slip formation. Slip is observed to start at the wafer edge and to penetrate into the wafer area along {111} planes. From previous experiments it is known that slip formation can be suppressed by BMDs.

## Experimental

Antimony doped 200mm (100) CZ Si substrates with a phosphorus doped 17µm and 52µm thick epi layer are used in this study. The substrate resistivity is in the range of 10-20 mOhmcm. The substrate oxygen concentration is 6-7e17 /ccm (new ASTM) for both the reference and the test wafers. Test wafers have been intentionally contaminated with carbon (C) and nitrogen (N) atoms during crystal grown.

## Results and Discussion

### (a) Analytical

The bulk micro defect density after a thermal treatment which represents the device process exhibits the expected and desired increase in the precipitation behaviour. While the reference wafers show a low BMD density, it is significantly increased in the presence of nitrogen and carbon (fig. 1).

Laser scan maps show a considerably smaller area close to the wafer edge affected by slip if N and C is present (fig. 2).

Finally, from scanning infra-red depolarization maps (SIRD), showing wafer areas affected by lattice stress, it can be observed that the presence of N and C causes a significant reduction of the stress areas (fig. 3).

### (b) Electrical

From the electrical results, probe yields and leakage failure wafer maps, a small advantage can be observed in the presence of N and C, but only in the case of a "non-optimum" thermal process (fig. 4).

## Conclusion

From the analytical results it can be concluded that additional nitrogen and carbon atoms incorporated in the silicon crystal enhance the oxygen precipitation and thus suppress the formation of slip during device manufacturing.

However, a yield advantage can only be observed if thermal device processes run in a "non-optimum" stage. This observation can be explained as follows: If stress from "non-optimum" device processing exceeds a certain level, slip formation occurs starting at the wafer edges. However, slip expansion from the wafer edge towards the wafer centre can be suppressed by a sufficiently large number of BMDs pinning the slip lines.

## References

/1/ K. Sueoka et al, J. Appl. Phys., 74, 5437 (1993)

17µm

52µm

ref.

Fig. 1: BMD density profile from surface into the bulk of test samples with 17µm and 52µm epi layers compared to standard material without N nor C (ref.)

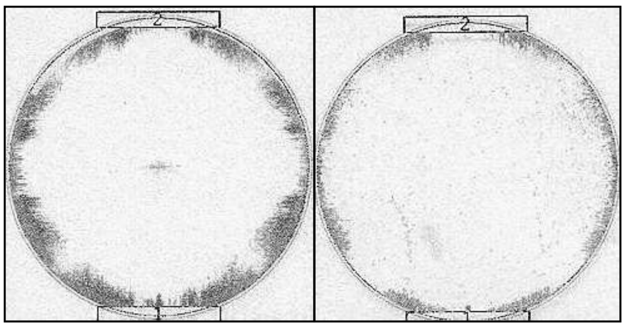

Fig. 2: Laser scan maps (Tencor SP1) of standard (left) and test wafers (right). The area affected by slip is considerably reduced in the presence of N and C (right)

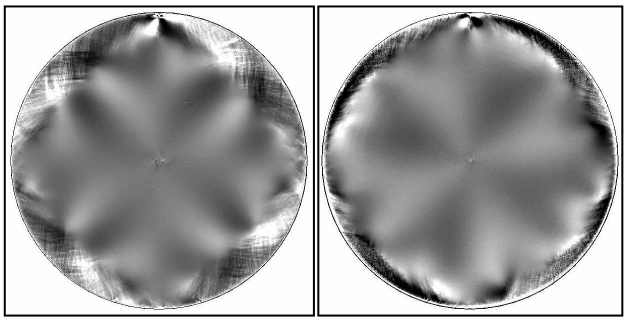

Fig. 3: SIRD maps of standard (left) and test wafers (right). Black, dark grey, and white areas symbolize strong lattice stress

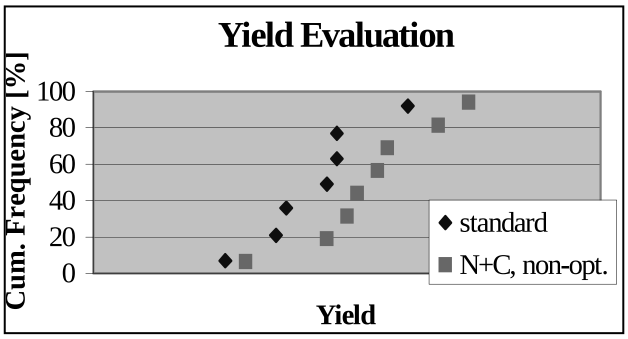

Fig. 4: Yield comparison of standard (◆) and test wafers (■), both in case of "non-optimum" thermal process conditions