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Intrinsic Gettering In Nitrogen Doped and Hydrogen Annealed Czochralski-Grown Silicon Wafers

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1. Introduction

This paper described the quality of surface layer and the gettering ability of nitrogen doped (N-doped) Czochralski-grown silicon (CZ-Si) wafers that annealed in a hydrogen atmosphere.

As one of these basic materials, Si wafers are being required to have a better quality in their surface layer (denuded zone: DZ) due to the development of higher integrity of electronic devices in these years. And accompanying with the trend of low-temperature process of device production, metallic impurities are becoming harder to be trapped in intrinsic gettering (IG) layer of the wafer. To solve these problems, people developed epitaxial (Epi) wafers and DZ-IG wafers (hydrogen or Ar annealed wafers [1]). On the other hand, N-doped CZ-Si wafer [2, 3] is greatly concerned and is expected to be developed as one of DZ-IG wafers. The wafer is found with smaller size of grown-in defects [4] and the nucleus of oxygen precipitates in it are hard to be annihilated. However, as a substrate of DZ-IG wafers, the perfection of surface layer and IG ability of N-doped CZ-Si wafers are still remained unknown.

Here, we measure the generation lifetime of minority carriers in the surface layer and research the Ni-gettering ability of N-doped and hydrogen annealed CZ-Si wafers (N-HAs) added high-temperature heat treatment.

2. Experiment

Polished Si wafers (PWs) were boron-doped CZ-Si (100) in 200 mm diameter with a resistivity of 1.8 ohm-cm, an interstitial oxygen concentration [Oi] of 1.4 x10^{18} atoms-cm^{-3} (old ASTM). The nitrogen concentration [N] was 0.6-1.4x10^{14} atoms-cm^{-3} by secondary ion mass spectroscopy (SIMS). Wafers annealed in a hydrogen atmosphere at 1200°C for 1 hour using a commercial vertical furnace. The Epi layer of Si was deposited on substrate wafers, boron-doped CZ-Si (100) in 200 mm diameter with a resistivity of 10-20m ohm-cm. Thickness and resistivity were 5 um and 1.5 ohm-cm. Both N-HA and Epi wafers were annealed in an Ar atmosphere at 800 °C or 1000 °C for 10 hours after annealing at 800 °C for 1 hour. To evaluate generation lifetime of minority carriers for both wafers in the subsurface (in the depth of 3-5 um from the surface) by MOS C-t method, the MOS structure had 94-98 nm thick oxide and 500-1000 nm thick Al gate in an area of 2 mm diameters, and which back surface has Au gate.

Next, we investigated that the dependence of [Oi] and [N] on the gettering ability in the subsurface. As shown in Table 1, PWs were boron-doped CZ-Si (100) in 200 mm diameter with a resistivity of 1.5-22 ohm-cm, [Oi] of 0.85-1.4x10^{18} atoms-cm^{-3} (old ASTM) and [N] was 0.13-8.4x10^{14} atoms-cm^{-3} by SIMS. Wafers were annealed in a hydrogen atmosphere at 1200°C for 1 hour using the furnace. Wafers were contaminated with Ni in the concentration of 1 x10^{12} atoms-cm^{-2} from the wafer surface, and then was driven in the bulk region in an Ar annealing at 800 °C for 1 hour. These wafers were annealed in an Ar atmosphere at 800 °C for 10 hour. The Ni concentration in the subsurface and the bulk region was measured by graphite furnace atomic absorption spectrometer (GFAAS). The density and unit intensity of the laser scattering tomography defects (LSTDs) were measured by LST (Mitsui Mining and Smelting Co., Ltd., MO-401 [5]).

Table 1 Sample properties

Sample	$[O_i]$ atoms/cm^3	[N] atoms/cm^3	resistivity ohrm-cm
1	1.0×10^{18}	0.13×10^{14}	1.6
2	1.0×10^{18}	1.4×10^{14}	1.5
3	0.85×10^{18}	8.4×10^{14}	1.5
4	1.4×10^{18}	0.6×10^{14}	1.8
5	1.4×10^{18}	3.6×10^{14}	22

3. Results and Discussion

These generation lifetimes of N-HA wafers are longer than these of Epi wafers as shown in Fig.1. It is indicated that hydrogen annealed Si wafer has few defects in the surface region.

Figure 2 shows Ni concentrations in subsurface and bulk region of N-HA, contaminated with Ni and then annealed in Ar atmosphere. Increasing oxygen and nitrogen concentrations decreases the Ni concentration in the subsurface layer. On the other hand, increasing oxygen

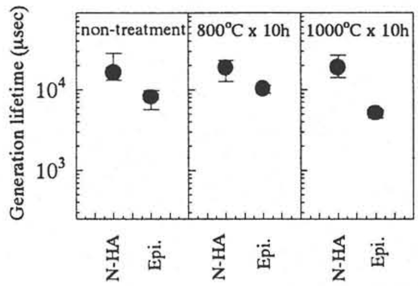

Fig. 1 Generation Lifetime of N-HAs and Epi wafers(revers bias : 5V, temperature : 60°C).

and nitrogen concentrations increases the Ni concentration in the bulk region as shown in Fig. 2. Figure 3 shows that the relationship between relative volume of LSTD, is proportional to density and root square of intensity of LSTD in the bulk region and Ni concentration in the subsurface

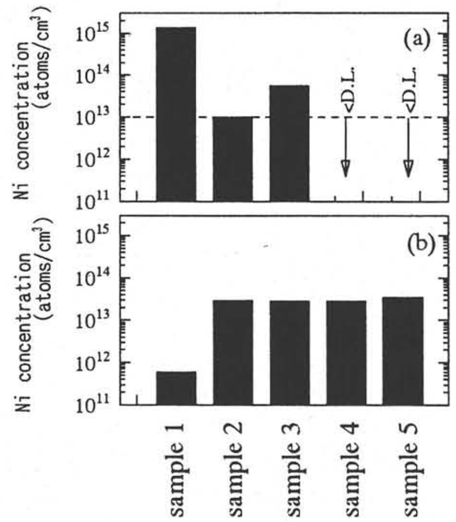

Fig. 2 Ni concentration in (a) subsurface region (7.5μm) and (b) bulk region.

layer. LSTD scattering intensity is proportional to the square of the volume of subsurface defects [5]. Ni concentration in the subsurface layer, thus, decreases lineally with increasing the LSTD volume in the bulk region as shown in Fig.3. It suggests that LSTDs in the bulk region play a role in gettering sites in hydrogen N-HA wafers. Hydrogen annealed Si wafers with a oxygen and a nitrogen concentration have good gettering efficiency as well as Epi wafers.

4. Conclusions

We found that N-doped and hydrogen annealed Si wafer has fewer defect than Epi wafer in the subsurface. Doped nitrogen in Si crystal for N-doped and hydrogen annealed wafer increases the LSTD density in bulk region and also decreases Ni concentration in the subsurface layer. N-doped and hydrogen annealed Si wafer has thus effective gettering ability.

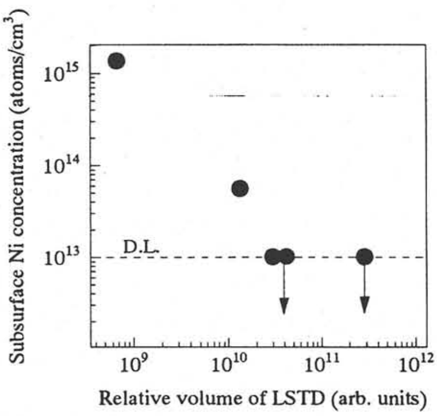

Fig. 3 Dependance of nickel concentration in subsurface regions on relative volume of LSTD.

5. References

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