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Rapid Thermal Precleaning Using Hydrogen Reduction

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We developed a rapid thermal precleaning technique for using low-temperature hydrogen reduction at 800℃. To reduce the partial pressure of impurities, we used an ultra high vacuum (UHV) cluster tool with precleaning chamber and a Si deposition chamber. We developed an experimental precleaning chamber that improved the gas flow. Precleaning at 800℃ for 1 minute remove oxygen, carbon, and fluorine completely. The contact resistance of poly-Si/bulk was 38.9 Ω with precleaning, and 110.1 Ω without.

1.INTRODUCTION

In ULSI devices, an impurity free of interface is very important for low-temperature epitaxy, low contact resistance, ultra-thin Si_3N_4 capacitor, and ultra-thin gate oxide.[1),2),3),4)] Removing native oxide by HF vapor has been widely studied[4)], but HF vapor cleaning does not remove organic compounds or fluorine.

Hydrogen reduction in conventional Si epitaxy does remove such impurities, but this conventional precleaning uses high temperatures (900～1000℃), because of the high partial pressures of such impurities. To reduce the partial pressures of O_2 and H_2O, we used an UHV cluster tool with an experimental precleaning chamber. We removed oxygen, carbon, and fluorine completely using hydrogen reduction at 800℃ for 1 minute.

2.EXPERIMENT

We used an UHV cluster tool (Fig. 1) and our experimental precleaning chamber (Fig. 2) for hydrogen reduction. Purified hydrogen (O_2: less than 10 ppb; H_2O: less than 95 ppb) flows vertically from a perforated inner bell jar to the wafer. The base pressure of the chamber is 6.7×10^{-6} Pa. The wafer lies on a SiC-coated graphite susceptor and is heated by an IR lamp. We measured the temperature with an IR monitor placed on the bottom of the susceptor.

We deposited silicon films from Si_2H_6/H_2 or Si_2H_6/N_2 in the Si deposition chamber.

3.RESULTS AND DISCUSSION

(1) Low-temperature epitaxy

An n-type (100) wafer was treated with NH_4OH/H_2O_2, HF/H_2O, D.I. rinse and spin dry. After the wet treatment, we loaded the wafer in the precleaning chamber at 6.7×10^{-5} Pa. We heated the wafer at process temperature for 90 seconds, then precleaned it for 1 minute. We used process temperature from 750 to 950℃. The hydrogen flow rate was 50 slm and the pressure was 1.1×10^4 Pa.

After precleaning, we transferred the wafer to the Si deposition chamber. We grew a 100 nm-thick low-temperature Si epitaxial layer at 650℃, Si2H6 flow 10 sccm, H_2 flow 30 slm and 2.7×10^3 Pa. This layer had no defects after being precleaned at 1000 ℃. After growth, the wafer was treated with NH_4OH/H_2O_2, HNO_3, D.I. water, and dry. We grew an additional 5 μm epitaxial layer on the wafer using a cold-wall barrel reactor at 1100℃. If the low-temperature epitaxial layer had defects, the high-temperature epitaxial layer would also have defects. We observed defects after Sirtl etching.

Precleaning at 800℃ does not yield defect (Table 1). We studied the hydrogen flow in the bell jars (Fig. 3 and 4). With our experimented bell jar, we grew high-quality epitaxial layers free of defects

above 800℃. We measured the impurities (O, C, and F) with SIMS depth profiles of a sample precleaned at 800℃ for 1 minute (Fig. 5).

With the conventional bell jar, grew similar layers with precleaning above 950℃.

Because most reaction rates are proportional to partial pressure, removing native oxide at low temperatures requires reducing the partial pressures of O_2 and H_2O and substituting pure hydrogen for the impurities. With our experimental bell jar, purified hydrogen was introduced vertically and gases were substituted efficiently. However for the conventional bell jar, hydrogen was introduced to the wafer laterally and gases were not substituted efficiently. As a result, we removed oxygen, carbon, and fluorine by hydrogen precleaning at 800 ℃ for 1 minute.

(2) Contact resistance

We measured the contact resistance of polysilicon and N+ substrate (P^+ Ion implant, 70 keV, 3×10^{15} cm^{-3}) by the Kelvin method.

Our sample structure (Fig. 6) had a contact hole 550 nm deep, and was shrunk by side wall SiO_2. The final contact hole was 0.2×2.6 μm^2. We treated the wafer with NH_4OH/H_2O_2, HF/H_2O, D.I. rinse and spin dry. After the wet treatment, we precleaned the wafer in our experimental precleaning chamber for 1 minute at temperatures ranging from 800 to 900℃. The hydrogen flow rate was 50 slm and the pressure was 1.1×10^4 Pa.

After precleaning, we transferred the wafer to the Si deposition chamber at 6.7×10^{-5} Pa. We deposited phosphorus-doped amorphous silicon film at 570℃ from $Si_2H_6/N_2/PH_3$ at 1.1×10^3 Pa. Deposited amorphous silicon was 100 nm thick and the phosphorus concentration was 1×10^{21} cm^{-3}. We then annealed the wafer at 850℃ in N_2 for 30 minutes.

We found that the contact resistance was lower for those wafer that had higher-temperature precleaning (Fig. 7). Without precleaning, the contact resistance was 110.1 Ω. Precleaning at 800℃ for 1 minute yielded 38.9 Ω. For higher temperature precleaning, the contact resistance decreased slightly.

4. CONCLUSIONS

We developed an ultra high vacuum cluster tool with a rapid thermal precleaning chamber. We performed low-temperature hydrogen precleaning in our experimental precleaning chamber at 800℃ for 1 minute. We confirmed with SIMS depth profiles that precleaning removed O, C, and F impurities on a silicon surface.

5. REFERENCE

1) M.Miyazaki et al., IEEE Electron Dev. Lett., 11, 10 (1990) 448.
2) M.Nakano et al., Dig. Tech. Papers, 1992 VLSI Symp. (1992) 16
3) H.Morita et al., Dig. Tech. Papers, 1989 VLSI Symp. (1989) 75
4) N.Miki et al., IEEE Trans. Electron Dev. ED-37 (1990) 107

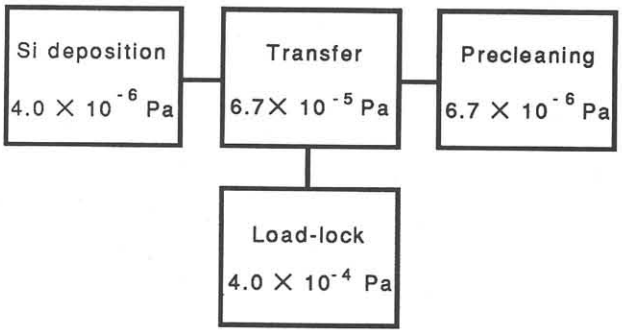

Fig.1 UHV cluster tool.

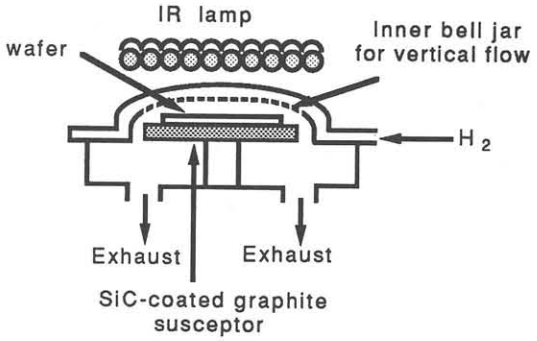

Fig.2 Precleaning chamber.

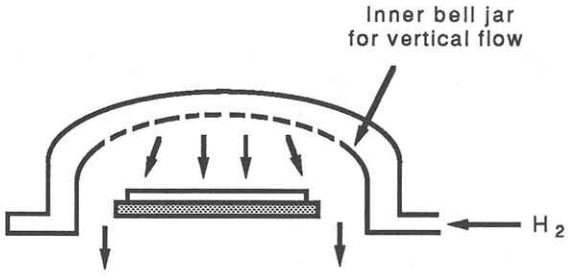

Fig.3 Gas flow with inner bell jar.

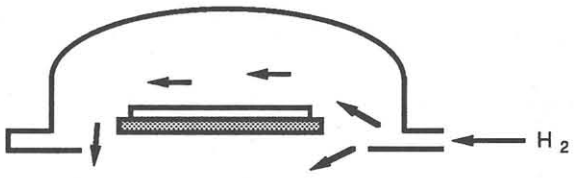

Fig.4 Gas flow without inner bell jar.

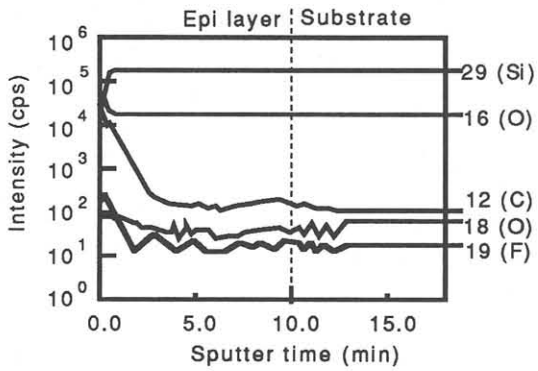

Fig.5 SIMS depth profiles of epitaxial layer precleaned at 800℃ for 1 minute.

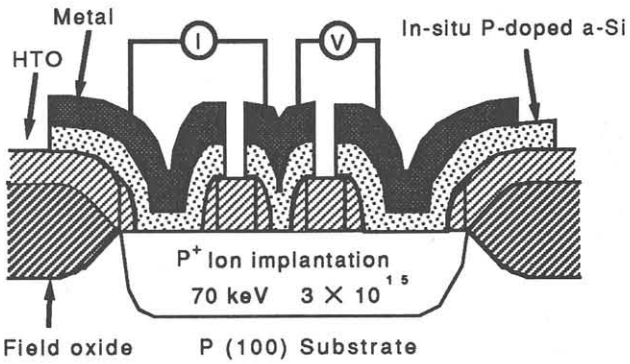

Fig.6 Sample structure.

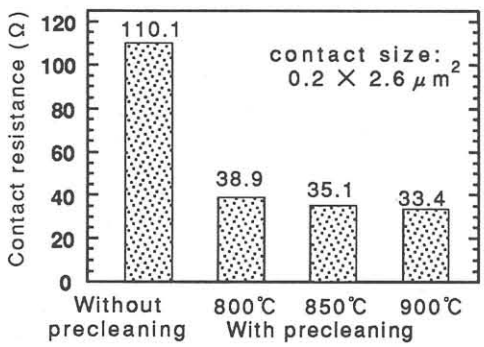

Fig.7 Contact resistance.

Table 1 Crystalline quality.

Gas flow	Precleaning temperature [℃]			
	750	800	900	950
Vertical	X	O	O	O
Lateral	X	X	X	O

Precleaning condisions: H 250 slm , 1.1X10^4 Pa, 1 min.

O No defect X Defective