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Novel Dry Cleaning Using AHF-Alcohol with the New "Hot" Cluster Tool

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We have succeeded in the development of a novel dry cleaning technique by using AHF(Anhydrous Hydrofluoride)-alcohol with the new "hot" cluster tool for the first time. And, we compared the contact resistance of W-polycide/W-polycide between our system and the batch cluster tool. Using our system, the minimum contact resistance and the minimum standard deviation were obtained. Our AHF-Alcohol cleaning and the new "hot" cluster tool are advantageous for production of future high performance ULSI's.

1. Introduction

In recent ULSI technology, reduction of parasitic resistance has been important role to obtain high performance. As reducing in the lateral size of LSI's, contact holes become narrow, and as reducing in the vertical size of LSI's, reduced thermal budget problem become dominant.

Several batch cluster tools with dry cleaning were proposed to obtain lower contact resistance under a reduced thermal budget condition [1].

We have succeeded in the development of a novel dry cleaning technique by using AHF(Anhydrous Hydrofluoride)-alcohol with the new "hot" cluster tool for the first time. And, we compared the contact resistance between our system and the batch cluster tool.

2. Experimental

2-1. The single wafer cluster tool.

Figure 1 shows the single wafer cluster tool we developed. The base pressure of the system was 5E-6 Torr. AHF and alcohol vapor were introduced to the precleaning chamber. N_2 was used as a carrier gas of alcohol. Si_2H_6 was used as a Si source gas and H_2 was used as a prebaking gas. The resistance heating susceptor of the CVD chamber was originally designed, and was a single piece plate of SiC coated graphite. The ramping rate was 300℃/minute. The temperature was held constant at 500 ℃. A wafer was treated with AHF-alcohol vapor in the precleaning chamber under a condition of 50 Torr then transferred to the CVD chamber through the vacuum load-lock. The low-pressure AHF-alcohol cleaning make possible a wafer transfer in low-pressure. In the CVD chamber, the temperature of the wafer was increased to 800 ℃ within 1 minute and H_2 treatment was done for 1 minute under the condition of H_2 50 slm and 15 Torr, then the temperature was decreased to 500 ℃ within 1 minute and amorphous silicon was deposited under the condition of Si_2H_6 50 sccm, N_2 200 sccm, 5 Torr and 500℃. The whole treatments were done within 5 minutes.

2-2. The batch cluster tool.

Figure 2 shows the batch cluster tool, which was consist of a atmospheric HF vapor cleaner, a N_2 load-lock and a vertical LPCVD reactor. At the N_2 load-lock, the oxygen concentration was 0.5 ppm and the H_2O concentration was 95 ppb. The oxygen concentration of HF vapor cleaner was 80 ppm. A wafer was loaded to the vapor HF cleaner, then a wafer was treated with HF-H_2O vapor from 3～5 v/o HF aqueous solution vessel for 1 minute. After the cleaning, a wafer was transfered to a wafer boat in a N_2 load-lock. A boat with 25 wafers were loaded to a LPCVD reactor at 450 ℃. Amorphous silicon was deposited under the condition of Si_2H_6 50 sccm, 500 ℃ and 0.2 Torr. Whole treatments were done within 6 hours.

2-3. The contact resistance measurements.

We evaluated the contact resistance of W-polycide/W-polycide contact for the both systems and also wet HF cleaning. Figure 3 shows the sample structure of W-polycide/W-polycide contact.

Lower polycide was consist of 600 A WSi_2 and 400 A polysilicon. Upper polycide was consist of 800 A WSi_2 and 400 A polysilicon.

The maximum heat treatment was 850 ℃ for 40 minutes. We measured the contact resistance for 69 holes per each size from 0.45 to 1.0 μm in

diameter by Kelvin cross-bridge test structures.
The 1000 chain contact resistance of 0.5μm diameter was also evaluated for 69 chips.

3. Results and discussion

3-1. The low-pressure AHF-alcohol cleaning.

Figure 4 shows the relationship between oxide etched thickness and ethanol-N_2 flow rate. The etching condition was AHF 50 sccm, ethanol-N_2 500 sccm, 50 Torr and for 2 minutes. The etching ability was increased as increasing in ethanol-N_2 flow rate.

3-2. The atmospheric HF-H_2O vapor cleaning.

Figure 5 shows the relationship between oxide etched thickness and etching time. As increasing in the etching time, the etched thickness was increased. Within 40 seconds, the linear relationship was observed.

3-3. Contact resistance of Poly-Si/Poly-Si.

At first, We evaluated the Kelvin contact resistance of Polysilicon/Polysilicon. The contact hole diameter was 0.5μm. The Kelvin contact resistance of wet HF treatment with a spin dryer and a conventional vertical reactor was 76.4Ω, that of the batch cluster tool was 28.8 Ω and that of the single wafer cluster tool was 28.7 Ω.

These cluster tools are advantageous for Polysilicon/Polysilicon contact. The reasons for the larger contact resistance of wet HF treatment are considered as follows, native oxide growth and/or organics contamination during the transfer after the cleaning.

3-4. Contact resistance of W-polycide/W-polycide.

Figure 6 shows the relationship between the Kelvin contact resistance and hole areas for each treatments. The contact resistance of Wet HF treatment was largest among these treatments. The reason is the same as mentioned above.

The contact resistance of the single wafer cluster tool was minimum for every hole sizes. Table 1 shows the Kelvin contact resistance, the contact resistivity and the standard deviation for each hole sizes. The standard deviation of the single wafer cluster tool is also smallest for every hole sizes. The reason for the excellent results of the single wafer cluster tool is considered as follows, lower oxygen and H_2O concentration in load-lock and shorter hold time in load-lock prevent a wafer contamination.

In case of the batch cluster tool, a first wafer must hold in the boat at the N_2 load-lock for 90 minutes untill the boat is full of wafers, because of the combination of the single wafer HF-H_2O vapor cleaning and the batch CVD reactor of 25 wafers. During the hold time, a wafer contamination may occur.

From the literature [2], the ideal contact resistivity is introduced as 1E-7 Ωcm^2, taking the experimental condition into consideration. Using the single wafer cluster tool, the resistivity is closest to the ideal value. And as the contact hole size decreased, the resistivity increased. This phenomena may relate to a etching problem.

The resistance of 1000 contact holes with 0.5μm diameter was also evaluated for 69 chips (Table 2). Using our system, the minimum resistance and the minimum standard deviation were also obtained.

4. Summary

We compared the contact resistance of W-polycide/W-polycide between the single wafer cluster tool, the batch cluster tool. Also, conventional system of a wet HF cleaning and a vertical LPCVD reactor was evaluated as reference.

The Kelvin contact resistance, the 1000 contacts resistance and the standard deviation were smallest in case of the single wafer cluster tool.

Lower oxygen concentration of H_2O concentration of the load-lock and shorter wafer hold time at the load-lock of the single wafer cluster tool prevent a wafer contamination.

The AHF-alcohol cleaning and the single wafer cluster tool are advantageous for production of future high performance ULSI's and for production stability.

5. References

[1] C. Werkhoven et al., IEDM Tech. Dig., pp. 633,1992.
[2] R. Liu et al., IEEE Electron Device, vol. 37, No. 6, pp. 1535, 1990.

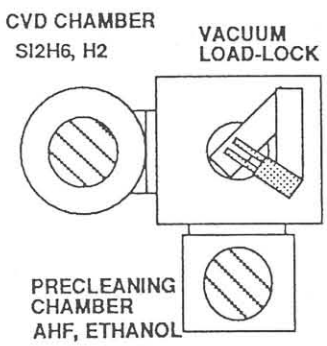

Figure 1 The single wafer cluster tool.

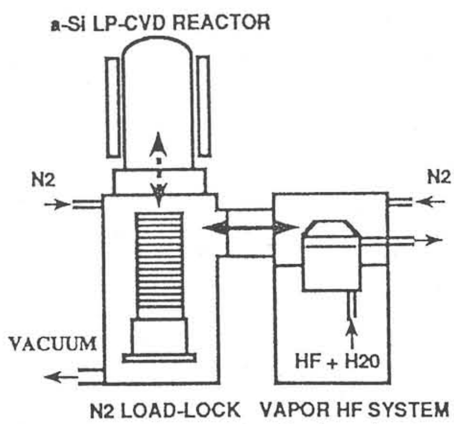

Figure 2 The batch cluster tool.

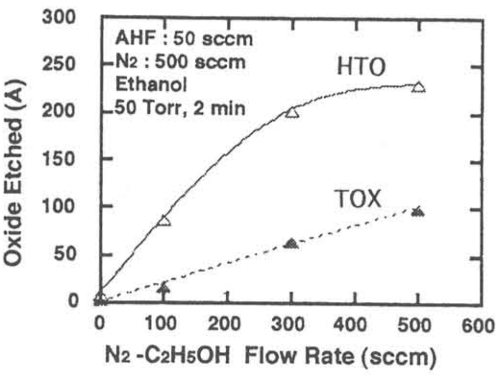

Figure 4 The relationship between oxide etched thickness and ethanol-N_2 flow rate.

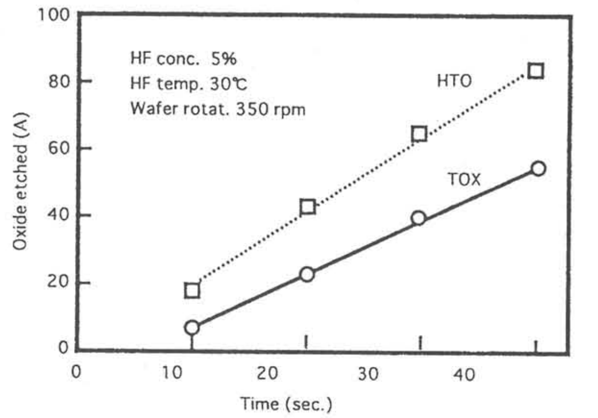

Figure 5 The relationship between oxide etched thickness and etching time.

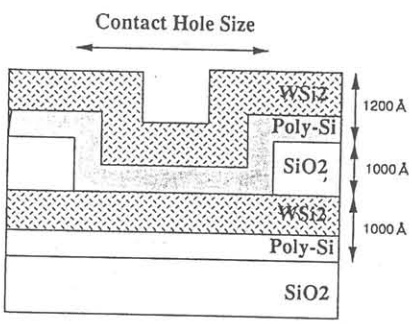

Figure 3 A sample structure for a contact resistance measurement.

Hole size (μm)	Wet HF cleaning			Batch cluster			Our system		
	Resistance (Ω)	Resistivity (Ωcm2)	1 Sigma (%)	Resistance (Ω)	Resistivity (Ωcm2)	1 Sigma (%)	Resistance (Ω)	Resistivity (Ωcm2)	1 Sigma (%)
1.00	676.1	5.3E-6	20.9	30.7	2.4E-7	23.1	18.1	1.4E-7	11.7
0.80	1419	7.1E-6	16.0	56.4	2.8E-7	19.0			
0.70	2102	8.0E-6	12.9	87.3	3.3E-7	25.9	42.5	1.5E-7	8.5
0.65	2418	8.0E-6	15.2	101.7	3.4E-7	29.8			
0.60	2614	7.3E-6	18.2	113.7	3.2E-7	19.1			
0.55	3003	7.2E-6	13.3	141.4	3.4E-7	20.3			
0.50	3373	6.8E-6	21.1	176.8	3.5E-7	19.9	92.7	1.9E-7	6.7
0.45	3946	6.3E-6	18.7	263.4	4.2E-7	19.4	154.0	2.5E-7	12.8

Table 1 The Kelvin contact resistance, the contact resistivity and the standard deviation for eath hole sizes.

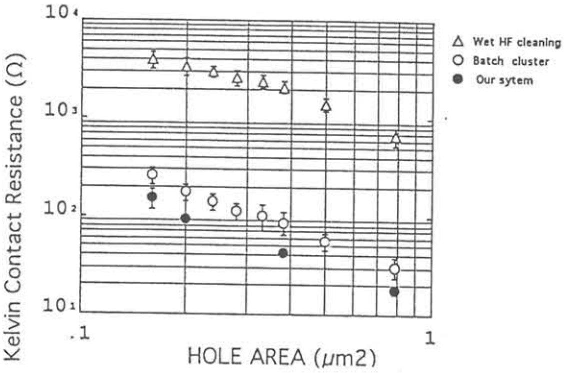

Figure 6 The Kelvin contact resistance vs. the contact hole area. The hole diameter of 0.5 μm is equivalent to the hole area of 0.2 μm².

Pretreatment	Resistance (Ω)	1 Sigma (%)
Wet HF	3.02E+6	14.4
Batch cluster	1.90E+5	9.1
Our system	1.78E+5	1.8

Table 2 The resistance of 1000 contact holes with 0.5 μm diameter and the standard deviation.