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An Alkaline SiO_2 Slurry for Fine Atomizing CMP

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Abstract. A kind of slurry which is applicable for fine atomizing CMP was made and the optimal results were obtained through orthogonal experiments by comparing fine atomizing CMP and traditional CMP. The research results show that the material removal rate of fine atomizing CMP is 52.23% of traditional CMP, and the dosage of the slurry used in fine atomizing CMP only accounts for 10 vol% compared to traditional CMP. The surface roughness after the fine atomizing CMP is 2.5nm which is better than that of the traditional CMP (3.0nm).

Introduction

At present, with the rapid development of Communication and Network, there is an increasing demand for Integrated Circuit (IC). Scaling-down of the chip feature size and increasing of the wafer size promote the IC industry to develop rapidly. And the chip feature size of Ultra Large Scale Integration (ULSI) has reached the deep sub-micron level. Semiconductor Industry Association (SIA) predicts that the feature line width will reach 0.05μm in 2012, which demands the flatness of chip reach the nanometer level. Chemical mechanical polishing (CMP) is recognized as the only global flattening practical technology [1-8].

The equipment and consumables for CMP technology include CMP equipment, polishing slurry, polishing pad, cleaning equipment, detection equipment, etc [9]. The flow velocity of polishing slurry has important influence on the polishing rate and polishing quality. Too low flow velocity will increase friction, make the temperature uneven distribution and reduce the wafer surface roughness. High flow velocity can ensure the consistency of the wafer surface[10]. However, the polishing slurry utilization only reached 20%, and the treatment of the massive slurry is quite troublesome, which will cause environmental pollution after the emission to nature. In order to improve the polishing utilization, we proposed fine atomizing chemical mechanical polishing technology. The special polishing slurry is atomized to uniform micron-grade droplet whose Sauter Mean Diameter (DSM) is 5~15μm. Then the polishing fog is imported to the polishing pad because of the pressure difference.

Experiment

The preparation of the polishing slurry was as follows: Add DI water to White carbon black first, and then mix them with magnetic blender. Meanwhile, add suitable amount of organic alkali and surfactant into the mixture, and then add proper Silicon sol and oxidant. At last, we can get good dispersion polishing slurry which do not form the stratification or precipitation after quietly being placed for 48 hours.

Experiment instrument: Millipore water purification systems; UNIPOL-1502 Polishing Machine; Mettler Toledo XS205DU precision electronic balance; IKA Magnetic blender; CSPM5000 scanning probe microscopy.

We compared the material removal rates of the traditional CMP and the fine atomizing CMP. The necessary conditions for polishing were as follows: The pressure of polishing is 7PSI; the speed of polishing pad is 55r/min; the time of polishing is 5min; the flow velocity of polishing slurry in the traditional CMP is 100ml/min and in the fine atomizing CMP is 10ml/min; the materials are monocrystalline silicon chips (20mm×20mm).

Experimental results and analysis

Table 1 indicates the material removal rates of different conditions through the traditional CMP and fine atomizing CMP.

Table 1: Test conditions and results

level	SiO_2 [wt%] A	Oxidant [wt%] B	organic alkali [pH] C	Surfactant [wt%] D	The MRR of the traditional CMP [nm/min]	The MRR of the fine atomizing CMP [nm/min]
1	28	1	9.5	1.5	150.86	68.84
2	28	2	10.5	2.5	188.84	72.96
3	28	3	11.5	3.5	215.64	95.67
4	30	1	10.5	3.5	171.67	84.12
5	30	2	11.5	1.5	225.21	104.94
6	30	3	9.5	2.5	170.60	83.64
7	32	1	11.5	2.5	240.28	118.03
8	32	2	9.5	3.5	194.64	91.74
9	32	3	10.5	1.5	216.74	113.20

From the experimental conditions, it is known that the material removal rate is 52.23% of traditional CMP's. And the velocity of the fog is 10ml/min in the fine atomizing CMP which only accounts for 10% of that in the traditional CMP. Table 2 indicates the analysis aiming at material removal rate after fine atomizing polishing. And $\bar{y}$ shows the mean value of n times test results; *Kij* says the sum of the first *i* (*i*=1,2,3) level in the first *j* column; ω_{ij} says the effect of the first *i* (*i*=1,2,3) level in the first *j* column, the following type said: $\omega_{ij}=\frac{K_{ij}}{n}-\bar{y}$, n=the times of the first *j* listed first *i* level; R_j says the range. $R_j=(\omega_{ij})_{\max}-(\omega_{ij})_{\min}$.

Table 2: Analysis and calculation that aiming at the material removal rate after fine atomizing polishing

Factor	SiO_2 A	Oxidant B	organic alkali C	Surfactant D	
K_{1j}	237.47	265.84	244.22	286.98	$\bar{y}=\frac{1}{n}\sum_{i=1}^{n}y_i$
K_{2j}	272.70	269.64	270.28	269.48	
K_{3j}	317.82	292.51	313.49	271.53	=92.00
ω_{1j}	-12.84	-3.39	-10.59	3.66	
ω_{2j}	-1.10	-2.12	-1.91	-2.17	
ω_{3j}	13.94	5.51	12.50	-1.49	
R_j	26.78	8.90	23.09	5.83	

We can get the following information from the ω_{ij}:

(a)The effect is increased with the increase of A, B and C, respectively. But the effect of factor D first decreased and then increased. The max appears when the content of surfactants is 1.5%.

(b)The size of R_j can judge the primary factors and secondary factors to indexes. Aiming to the effect of material removal rate, the factor A plays an ultimate role and factor D does the minimum role.

The wafer surface roughness is 9.51nm before polishing. The surface roughness is 2.5nm after the fine atomizing CMP. And in the same conditions, the surface roughness is 3.0nm after the traditional CMP. Fig. 1 shows the surface morphology of the monocrystalline silicon chips after the traditional polishing. Fig. 2 shows the surface morphology of the monocrystalline silicon chips after the fine atomizing polishing.

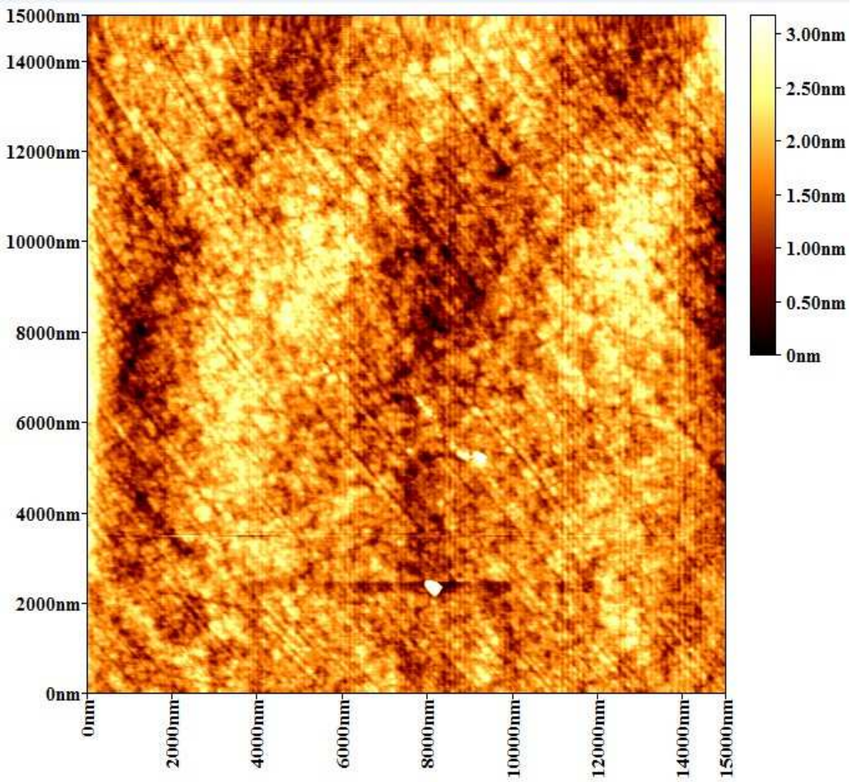

Fig. 1: The surface after the traditional polishing

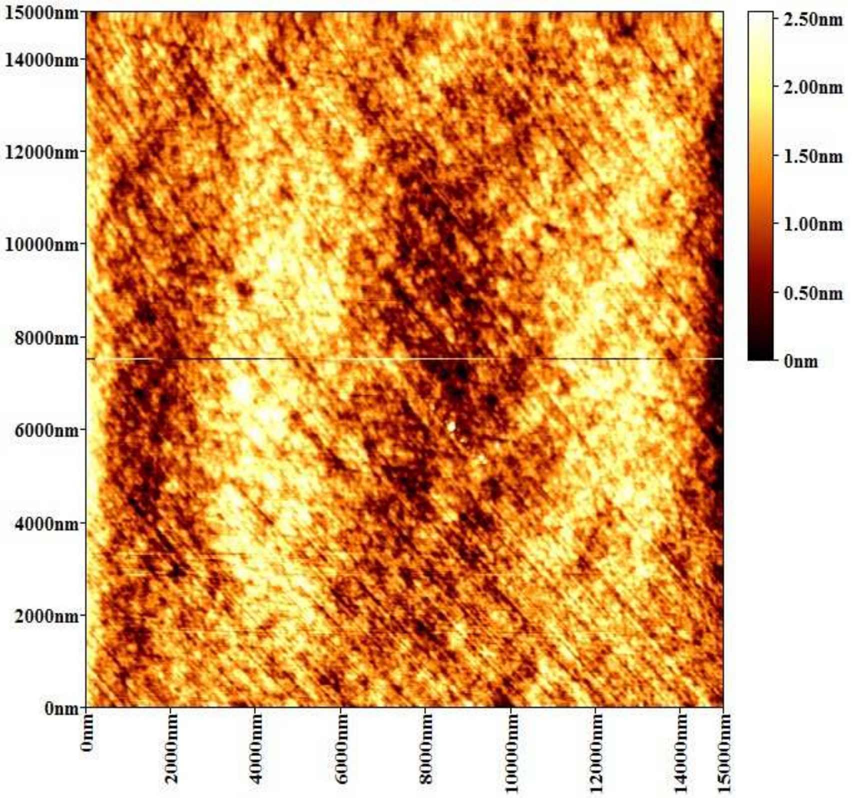

Fig. 2: The surface after the fine atomizing polishing

The surface quality of the wafers through the fine atomizing CMP is better than the one through the traditional CMP and the reasons may have two points, as follows:

(a) In the fine atomizing CMP, the special slurry is atomized to the micron-grade liquid grains which cluster less abrasive particles than the traditional slurry. So the scratch of the polishing surface caused by a lot abrasive particles clustered can be avoided;

(b) At the same time, in the fine atomizing CMP, the rapid absorption function of the micron-grade liquid grains in polishing interface and highly active chemical reactions lead the speed and strength of the chemical reactions to far outweigh the traditional CMP of importing the slurry in the fluid. These alleviate the contradictions of surface roughness and the material removal rate to a certain extent.

Conclusion

The material removal rate through fine atomizing CMP is 52.23% of that through traditional CMP, and the dosage of the slurry used in fine atomizing CMP only accounts for 10 vol% compared to traditional CMP. The surface roughness after the fine atomizing CMP is 2.5nm which is better than that of the traditional CMP (3.0nm). The components ratio of the best material removal rate (118.03nm/min) is the following: SiO_2 accounts for 32 wt %, PH is 11.5, surfactant accounts for 2.5 wt % and oxidant accounts for 1 wt %.

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