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Novel Nozzle-Scan Coating Method for Low-k Films

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Introduction

ILD with low-k below 3.0 are strongly required by the high-speed logic and also the low power mobile devices. Spin coating method has been widely used as the low-k film formation[2)] as well as photoresist, antireflection layer. However, there are several problems related to spinning the wafer. One of the problems is the emission of much waste of the solution in the coating process. In this method, utilization efficiency of the polymer is less than 10% and most of them are thrown away. This low utilization efficiency makes the process cost higher. Another spin related problem is the dependence of film thickness on pattern density, in the case of forming films on a patterned wafer. Surface topography affects the supply of solution at the position of the pattern, and furthermore, the wafer spinning enhances this effect leading to variations in film thickness dependent on pattern and radial direction. To solve these problems, a new coating method using a scanning nozzle instead of spinning the wafer was developed. With this method, higher utilization efficiency could be achieved, and good planarity at steps could be also realized. In this paper, coating characteristics and film properties of low-k ILD using the scan coating are described.

Experimental

Fig.1 shows schematics of apparatus used for the scan coating method. The dispenser nozzle is constantly scanning back and forth while the wafer is sent at a predetermined step pitch (=scan pitch) in the direction normal to the nozzle scan direction. The dispensed solution is drawn as parallel lines on the wafer. After that, these lines are laterally spread by the surface tension, and continuous fluid film is formed. Then, this fluid film is baked to evaporate the solvent out and polymerize the film. In this study, the JSR LKD series[3)], methylsilsesquioxane based polymer was used as the solution of low-k film.

Results and Discussion

Table 1 summarizes the scan coating condition of low-k film. Coating time and film thickness can be controlled by scan speed, scan pitch, nozzle diameter, dispense pressure and polymer concentration in solution. In this experiment, the scan speed was 1.0 m/s, scan pitch was 0.9 mm and nozzle acceleration was 150 m/s^2. Under this condition, coating time of 50 s/wafer and efficiency of the polymer utilization of 85% were obtained. Efficiency of the polymer utilization can be raised up to more than 90% by decreasing scan speed and increasing nozzle acceleration.

Properties of low-k films using the scan coating are summarized in table 2 compared to that of the spin coating. Film thickness uniformity is 1.8%, and electrical and mechanical properties of the film are the same as those obtained by the spin coating method.

Fig.2 shows comparison of the planarity of low-k film on a patterned wafer where Al pillars had been formed as via plugs. Comparing the film thickness on the pillar pattern (pattern density: 30 %) and on the wide space, it is found that film thickness variation is less than that of by the spin coating method, and good planarity can be obtained.

Fig.3 shows photographs of the fabricated double level damascene structure by the scan coating method with the pillar process[1)]. The second level Al damascene wire is fabricated after low-k film was coated by the scan coating method on Al pillars which were formed on the first level W damascene wire. Good planarity at the steps by the scan coating method has facilitated the fabrication of second level damascene wire by CMP.

Conclusion

The new nozzle-scan coating method has been developed, and it has been applied to low-k dielectrics film formation. By this method, waste of the solution has been found to be reduced to 1/10 of that of the conventional spin coating. Film properties were found to be the same as the spin coating. The dependence of the film thickness on the pattern density was also greatly improved. Saving polymer and solution is a big impact on the environment problem, which the semiconductor industry is faced with. From these results, it has been concluded that the nozzle-scan coating is a promising method for a future low-k film formation.

Acknowledgments

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Reference

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2) Homma et al., Solid-State Electronics Vol.41, No.7, (1997) 1005
3) R. Nakata et al., Proc. of SSDM, (1999) 506

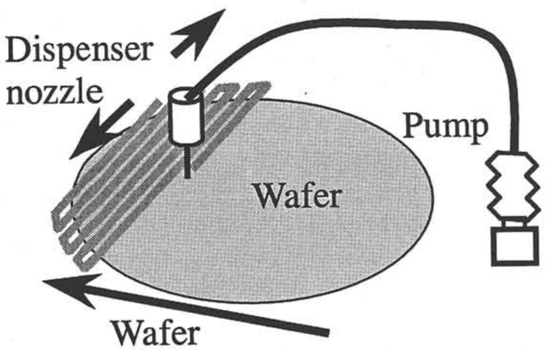


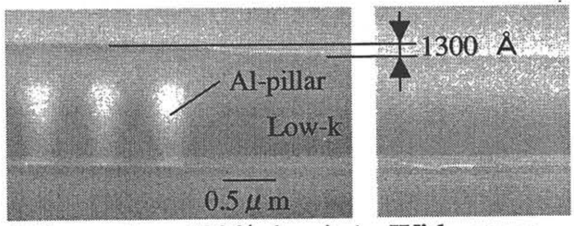
Figure 1 Schematics of apparatus used for the scan coating method

Table 1 Scan coating condition of low-k film

Scan speed (m/s)	1.0
Scan pitch (mm)	0.9
Nozzle acceleration (m/s^2)	150
Shuttle time (ms)	10
Coating time (s/wafer)	50
Utilization efficiency (%)	85

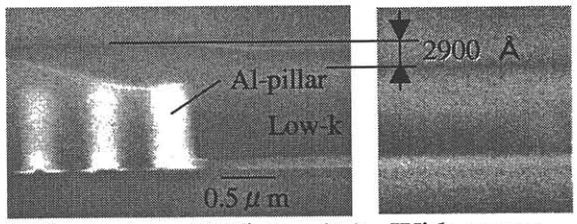
Table2 Comparison of low-k film properties

	Scan coating	Spin coating
k	2.7	2.7
Refraction index	1.32	1.32
Film density (g/cm^3)	1.18	1.18
Young's modulus (GPa)	6.2	6.2
Hardness (GPa)	1.2	1.2
Film stress (MPa)	50	50
Thickness unif. (%, 3 σ)	1.8	1.3



Pillar pattern (30% density) Wide space

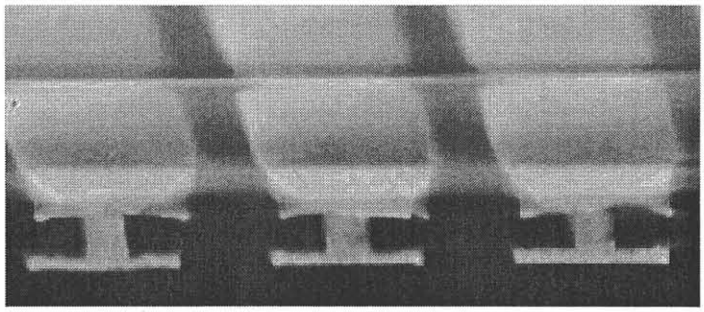
(a) Scan coating



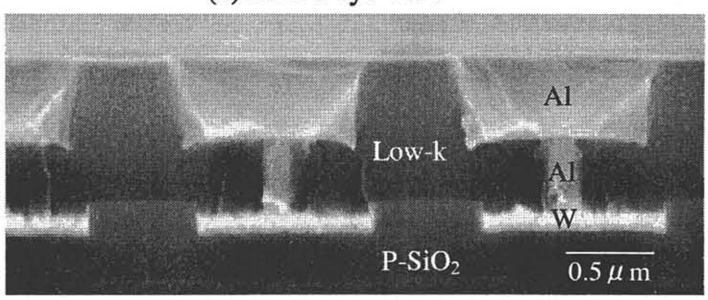
Pillar pattern (30% density) Wide space

(b) Spin coating

Figure 2 Comparison of the planarity on pillar pattern



(a) Bird's eye view



(b) Cross sectional view

Figure 3 Photographs of double level damascene structure