Translation of Particles to Wafers during Spin Coating

Chuck Extrand, Sung In Moon & Loxie Monson
Entegris, 101 Peavey Road, Chaska, MN 55318
Email: chuck_extrand@entegris.com

INTRODUCTION

The inadvertent deposition of contaminants on silicon wafers during processing can damage or destroy integrated circuits. One potential source of contaminant translation is the spin coating, which is used widely in semiconductor manufacturing to deposit layers of photo-resist. This coating process is well understood and has been successfully analyzed and modeled (1-6).

In addition to deposition of photo-resist, spin coating is also used as a tool to analyze levels of contaminants that are generated by liquid handling components and filters. In this type of test, a liquid or solvent stream passes through a component or sub-system and then a small volume is deposited onto a spinning, unpatterned wafer. After the liquid spins down and evaporates, the surface of the wafer is examined for added contaminants, such as particles.

This technique can generate valuable data, but has some limitations. As the process parameters are not well understood, the resulting data is empirical, meaning it may be difficult to compare data generated at other times or by other researchers using different liquids or equipment. Moreover, without a fundamental understanding of the process, it is impossible to relate the contaminant levels on the wafer to the concentrations present in the liquid.

APPROACH

To analyze the technique described above, we used polystyrene (PS) and silicon oxide (SiOx) nano- and micro-spheres dispersed in water, propylene glycol monomethyl ether acetate (PGMEA) or isopropyl alcohol (IPA) at bulk particle concentrations (c_p) of ~ 0.1-1 x 10^9 cm^{-3}. Dispersions of these model particles were deposited onto wafers at various spin speeds (ω). The number of particles per area (N) was counted with optical microscopy or with a laser particle counter. Particle data was analyzed with the following equation, which we derived starting from the fluid mechanics analysis of Emslie, Bonner and Peck (1). The resulting number of particles per area (N) is related to particle concentration in the bulk liquid (c_p) via the spin speed (ω) of the wafer and the liquid properties,

$$N \approx (3\mu/\rho\omega^2 t)^{1/2}c_p \qquad (1)$$

where ρ, μ and t are the density, viscosity and drying time of the liquid.

RESULTS

Figure 2 shows the number of particles per area (N) plotted against the concentration (c_p) of 1010 nm SiOx particles in IPA at room temperature (~20°C). N increased with c_p. For a given concentration, the N decreased with the spin speed (ω). In Figure 3, the same data are plotted as $N/(3\mu/\rho\omega^2 t)^{1/2}$ versus c_p, according to eq (1). When analyzed in this manner, the data from the various spin speeds collapsed onto a single line with a slope approximately equal to unity. Thus, the model well describes the experimental data. Other particle-liquid combinations behaved similarly.

CONCLUSIONS

We were successfully able to model transfer of particles from chemicals to the surface of wafers during spin coating. Thus, knowledge gained here can be used to better evaluate products as well as allow for prediction of product performance in semiconductor processes. This model and experimental method also could be used along with laser particle scanners to address the metrology gap that currently exists in liquid particle counting.

REFERENCES

(1) A.G. Emslie, F.T. Bonner and L.G. Peck, *J. Appl. Phys.* **29**, 858 (1958).
(2) B.D. Washo, *IBM J. Res. Dev.* **21**, 190 (1977).
(3) D. Meyerhofer, *J. Appl. Phys.* **49**, 3993 (1978).
(4) W.J. Daughton and F.L. Givens, *J. Electrochem. Soc.* **129**, 173 (1982); 2881 (1982).
(5) S.A. Jenekhe, *Polym. Eng. Sci.* **23**, 830 (1983).
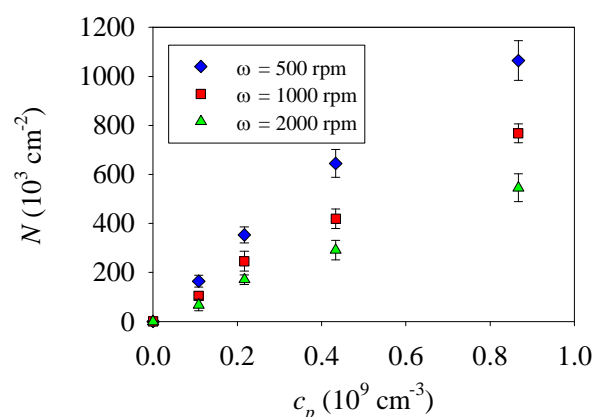(6) C.W. Extrand, *Polym. Eng. Sci.* **34**, 390 (1994).

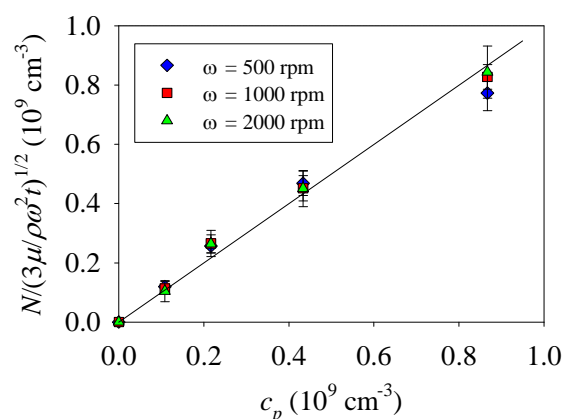Figure 1. Number of 1010 nm SiOx particles per area (N) *versus* concentration (c_p) in IPA at ~20°C.

Figure 2. Same data plotted as $N/(3\mu/\rho\omega^2 t)^{1/2}$ *versus* c_p. The solid line has a slope of one as predicted by eq (1).