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38-nm Particle Inspection on Bare Wafer by Side-Scattering Light Detection

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1. Introduction

Particle inspection systems are important to keep cleanliness in LSI production. A system for measuring the micro-roughness of a wafer is also necessary[1),2)]. To date, 38-nm particles have been observed only by the most advanced scanning electron microscope (Hitachi S900). However, a SEM cannot inspect a whole wafer because of its low detection speed. Optical detection could achieve high-speed inspection, but this has been impossible because of optical noise from the wafer surface (Figs. 1 and 2). This paper describes a method for measuring both particles and wafer surface roughness. Our technique overcomes the problem of optical noise by using side-scattering light detection, and it can detect 38-nm particles.

2. Optical noise

The amount of noise can be simulated using a diffraction model of surface roughness. In this experiment, the optical noise level from four wafers[1)], each having different surface roughnesses, was measured (Fig. 3). Simulation results (Fig. 4) were similar to the experimental results, indicating that the diffraction model is good and that the roughness can be measured from the detected light level.

Since Fig. 4 shows that the amount of optical noise decreases as the incidence angle of illumination increases, we used a large incidence angle to reduce the optical noise level. We further reduced the noise by using a detector with small pixels on the wafer. These techniques enabled us to detect 38-nm particles.

3. Inspection apparatus and experimental results

Figure 5 shows the experimental apparatus, which has a large incidence angle illumination laser, an objective lens, and an image intensifier with a small pixel size that can detect individual photons. Figure 6 shows the intensity detected from standard particles (Daw Chemical Co. or Japan Synthetic Rubber Co.) of various sizes and the optical noise from the wafer. The detected light level obeys Mie's theory[3)].

The detection results were verified by SEM as shown in Figs. 7 and 8. Figure 7 shows the inspected image of 38-nm particles. Figure 8(a) shows the SEM image of the same particles as in Fig. 7. This figure confirms that particles are isolated and that their size is 38 nm.

4. Probability of detection

The probability of particle detection is low due to the fluctuation in the number of detected photons when the light detected from particles is composed of under 10 photons. The detected photon number obeys a Poisson distribution[4)], which is used to calculate the probability of detection. Figure 9 shows the probability of detection for particles of various sizes. For example, detection of 38-nm particles on an 8" wafer with a probability of more than 95% requires a 180-Joule Ar laser (488 nm) and a detection pixel size on the wafer of 0.3 μm.

5. Conclusions

The optical noise from a wafer surface is shown to be diffracted light, and the wafer roughness can be measured by the detected light level from the wafer surface. The optical noise is reduced at large incidence illumination. This technique can detect 38-nm particles on the bare surface of a wafer by using side-scattering light detection with a large incidence illumination and a detector with small pixel size. A 180-J laser is needed to reduce the fluctuation in detected photon number, which allows high-probability inspection.

6. Acknowledgement

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7. References

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3) M. Born and E. Wolf, "Principles of Optics," pp. 647-655 (1970).
4) L. Levi, "Applied Optics," pp. 152-154 (1968).

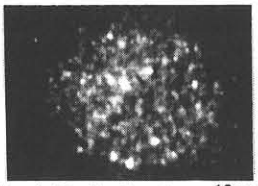


Fig. 1 Optical noise 10μm

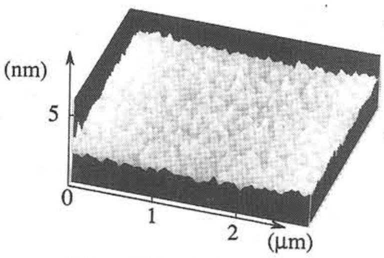
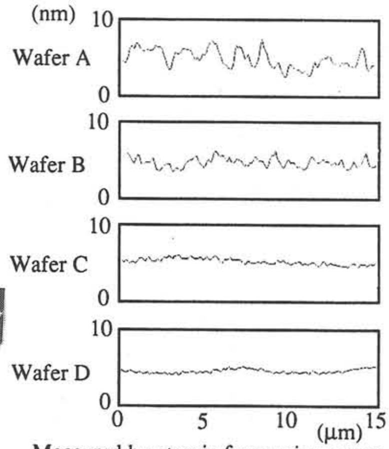


Fig. 2 Micro-roughness
Particle detection is difficult due to surface optical noise



Measured by atomic force microscope (Digital Instruments, NanoscopeII)

Fig. 3 Surface roughnesses

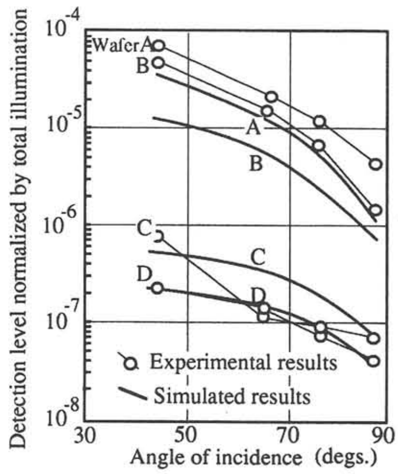


Fig. 4 Optical noise level

Simulation results are similar to experimental results, which indicates that roughness can be measured from the detected light level.

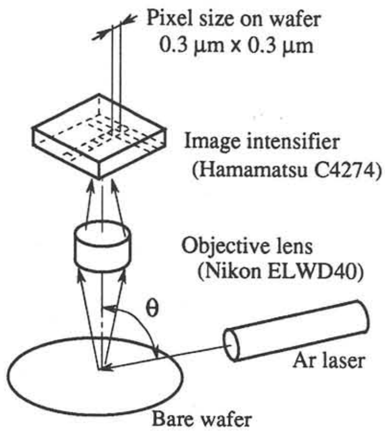


Fig. 5 Experimental apparatus

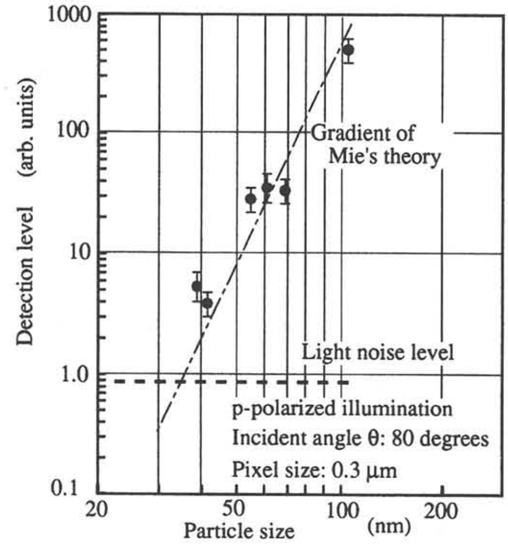


Fig. 6 Particle detection level
A 0.3-μm pixel size on wafer can detect 38-nm particles.

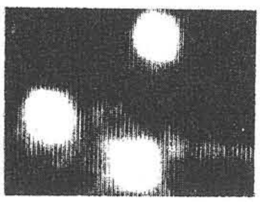
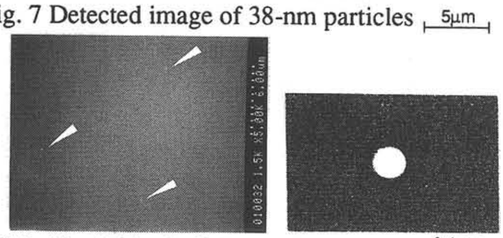


Fig. 7 Detected image of 38-nm particles 5μm



(a) Position in Fig. 7 5μm (b) One particle 0.1μm

Fig. 8 SEM images
38-nm particles are verified by SEM.

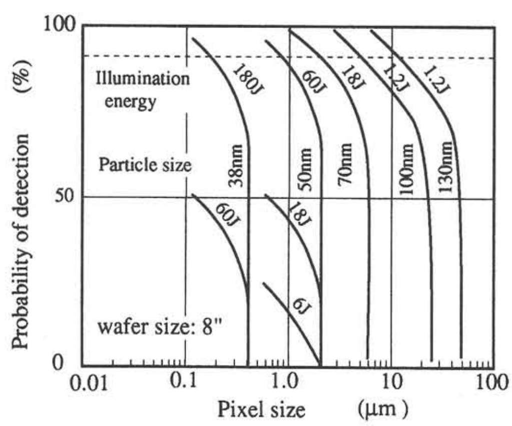


Fig. 9 Probability of detection
180-J illumination is necessary to achieve high-probability inspection of 38-nm particles.