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2000s

Change of the light source for exposing equipment to argon-fluoride excimer lasers and expanded application of liquid immersion of lenses

~ Process Technology ~

The minimum resolution line width and the resolvable focus range of the pattern transferred by the exposure apparatus are expressed by the following Reyleigh equation.

$R = k_1 \times \lambda / NA$, $DOF = k_2 \times \lambda / NA^2$

(R: minimum resolution line width, DOF: depth of focus, k_1, k_2: proportional constant, λ: exposure wavelength, NA: numerical aperture of projection lens)

The lithography technology at the forefront of microfabrication since the 2000s has been a high NA scanner using an ArF excimer laser (wavelength: 193nm) as a light source. NA is now raised to about 0.9, and it is at a level applicable to 65nm generation products. However, further increase in NA reached the limit, and the large reduction of focal depth DOF could cause a drop in chip yield.

On the other hand, EUV (Extreme Ultra Violet) exposure, which is expected as a light source of the next generation, has been delayed in practical use, with numerous technical problems.

Under these circumstances, a liquid immersion exposure method was introduced as a technique to raise the NA while maintaining the ArF light source. NA is nsin(θ) (n: refractive index of the lens-wafer medium, θ: maximum incident angle of light from the lens to the wafer). In the conventional exposure apparatus in the air, N = 1 and the incident angle of light on the wafer reaches nearly 70°, resulting in NA value of a little over 0.9. The liquid immersion exposure technique is to fill the gap between the lens and the wafer with pure water. The refractive index of pure water for ArF light is 1.44, which is multiplied to NA in the air, thus realizing NA exceeding 1. Currently, scanners with NA of approximately 1.3 have been put to practical use and applied to 45 nm generation products.

One technical problem of liquid immersion exposure is that the resist surface is exposed to pure water, and constituents such as photosensitizer in the resist dissolve out. As a result, the resolution performance of the resist is deteriorated, and the dissolving component contaminates the lens surface. This was solved by applying the protective film on the resist, which was developed by the material manufacturers.

The next generation devices may well be developed by the application of this ArF liquid immersion exposure technology and double patterning technology.

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