To search page

Late 1990s

Shorter wavelengths of exposing sources (from the i-line of mercury emission to excimer laser beams)

Process Technology ~

The minimum resolution line width of a pattern transferred onto a wafer in the projection optical system is given by $R = k_1 \times \lambda / NA$ (R: minimum resolution line width, k_1: proportional constant, λ: exposure wavelength, NA: numerical aperture of the projection lens). The technical directions to form a finer pattern are the reduction of k_1 determined by the process, the shortening of the wavelength of the exposing light λ, and the increase of the numerical aperture NA of the lens.

In terms of wavelength shortening, the g-line (wavelength: 436nm) in the visible light region of the spectrum through the extra-high-pressure mercury lamp was used when the reduction projection exposure apparatus, so-called Stepper, appeared in the 1980s. As a result, it was possible to form a pattern of about 0.8μm width on the wafer, and it was applied to the production of 4M-DRAM.

Subsequently, in the early 1990s, ultraviolet i-line (wavelength: 365nm) of the spectrum through the same ultra-high-pressure mercury lamp was used. It was put into practical use together with the development of glass materials for projection lenses with high transmittance that could cope with ultraviolet light. By shortening the wavelength, the minimum resolution line width became less than 0.5μm which was used for production of 16 M-DRAM. After that, it further became possible to achieve a minimum line width of 0.35μm by increasing the NA of the lens and by the improvement of the resist material also. Since the i-line stepper has a lower running cost than the subsequent exposure apparatus, it is applied to the process steps which require only loose line widths definition in the finer device generations, and it has continuously evolved in higher throughput and in the exposure of larger wafer diameters.

In order to pursue further microfabrication, KrF excimer laser (wavelength: 248nm) was put into practical use in the latter half of the 1990s as the next generation light source. The issues of laser output power capable of maintaining the stepper processing capability, wavelength dispersion narrowing for chromatic aberration, etc. were cleared, and the pattern of 0.25μm became resolvable by a KrF stepper.

Changing the exposure wavelength to KrF laser required significant changes of the resist materials as well as the light source and the lens. The intensity of the laser light is lower than that of the conventional i-line, and the capability of the stepper is greatly deteriorated as it is. Unlike conventional photosensitizing mechanisms of resist materials, a chemically amplified sensitivity resist using catalytic reaction of the acid which is generated in the exposure process has been developed and put into practical use, and this problem has been solved. However, the sensitivity varies with a slight amount of basic substance in the atmosphere, so the importance of chemical filtering in the equipment and in the clean room has increased. In addition to this, due to the increase in light energy due to shorter wavelength, accumulation of ammonium sulfate and organic matters on the surface of the stepper optical system parts became a problem, and the cleanliness in the apparatus was also important in this respect.

After that, the KrF stepper evolved into a so-called scanner that transfers a pattern while moving the mask and the wafer synchronously, while maintaining the exposure wavelength. By narrowing the transfer area in a slit shape, the numerical aperture of the projection lens can be made larger, and NA of 0.65 for the stepper was increased to over 0.8 for the scanner, resulting in the capability of 0.1μm resolution.

Meanwhile, the miniaturization of the pattern dimension of the mask as the design original plate also advanced. Although the dimensional precision of the mask has been relaxed by the reduced projection exposure method, as the miniaturization has further progressed in the 1990s, the drawing precision requirement of the mask itself has become more severe. For this reason, mask drawing was carried out with the electron beam, and the electron beam lithography system of ETEC in USA became a quasi-industry standard machine. But after that, Japanese manufacturers such as New Flair Technologies (then Toshiba Machine) made a breakthrough, ultimately surpassing ETEC in the market.

Version 2019/1/13