low, which means that a plurality of layers having significantly different etching rates are arranged in the thickness direction of the film. When the film is processed by dry etching, the cross-sectional profile of a pattern is degraded due to differencial side etching, leading to a degradation of dimensional accuracy.

Embodiments of the invention seek to provide a photomask blank which may have such a conductivity that the photomask blank may be used in the EB lithography system adapted to emit EB at a high current density, and includes a chromium-containing film which may be patterned using a thin photoresist film, to form a fine-size photomask pattern of satisfactory cross-sectional profile at a high accuracy.

When a chromium-containing film is processed by dry etching, the cross-sectional profile of the resulting pattern is largely affected by the composition of the chromium-containing film. Where the dry etching is anisotropic, as shown in the schematic view of FIG. 4, a chromium-containing film pattern 52 has a profile that its line width is a faithful representation of the line width of an etching mask pattern 53 of etching mask film or resist film in a thickness direction of the film. Where the dry etching is isotropic, as shown in the schematic view of FIG. 5, a chromium-containing film pattern 52 has a profile that its line width is constricted at the center in a thickness direction of the film, relative to the line width of an etching mask pattern 53. In FIGS. 4 and 5, a film or transparent substrate 51 is under the chromium-containing film.

To form a fine-size pattern accurately in a chromium-containing film which serves as a light-shielding film of a photomask, for example, the chromium-containing film must have a sufficient conductivity for use in an imaging system and a high etching rate. Where the

side etching state is exaggeratingly depicted as steps in FIG. 6, actual side etching is not so extreme and becomes a continuous moderate variation. Anyhow, it is difficult to accurately transfer the shape of an etching mask pattern 53 to the chromium-containing film 52. In FIG. 6, a film or transparent substrate 51 is under the chromium-containing film.

When an underlying film, for example, a film of a material containing silicon and being free of a transition metal or a material containing silicon and a transition metal, or a transparent substrate is patterned using the chromium-containing film pattern as an etching mask, there arises an etching bias. That is, a substantial size deviation arises between the pattern of the film serving as etching mask and the pattern of the underlying film or substrate to be etched, leading to a degradation in pattern transfer performance.

Regarding a photomask blank comprising a transparent substrate and a chromium-containing film thereon, the inventor has found that when the chromium-containing film is constructed as a multilayer structure of chromium compound layers formed of a chromium compound containing chromium and nitrogen, or chromium, nitrogen and oxygen, and each chromium compound layer may have a chromium content of at least 30 at% and a total content of chromium, nitrogen and oxygen of at least 93 at%, and meets the formula (1):

$$3Cr \leq 2O + 3N \qquad (1)$$

wherein Cr is a chromium content (at%), O is an oxygen content (at%), and N is a nitrogen content (at%), then the chromium-containing film may have the highest etching rate and cleaning resistance; when the chromium-containing film includes at least one chromium compound layer meeting a first

etching mask film being formed of a silicon-containing material.

In a preferred embodiment, the chromium-containing film has an optical density of 1.5 to 2.6 with respect to the exposure light.

In a preferred embodiment, the sum of optical densities of the chromium-containing film and the phase shift film with respect to the exposure light is 2.5 to 3.5.

In a preferred embodiment, the sum of optical densities of the chromium-containing film, the phase shift film, and the etching mask film with respect to the exposure light is 2.5 to 3.5.

In a preferred embodiment, the chromium-containing film is disposed on the transparent substrate through the optical film, and the optical film includes a light-shielding film formed of a material containing silicon and being free of a transition metal or a material containing silicon and a transition metal.

ADVANTAGEOUS EFFECTS OF INVENTION

The photomask blank of the invention includes a chromium-containing film which meets the desired optical density, may have a high etching rate in dry etching, and may be effective for reducing the load on a photoresist film which is used as an etching mask when a pattern of the chromium-containing film is formed by dry etching, contributing to a thickness reduction of the photoresist film. Since the chromium-containing film maintains conductivity, it may be effective for preventing the photomask blank from a charge buildup in the EB lithography system, achieving a high writing accuracy. Since the chromium-containing film has a minimal variation of etching rate in thickness direction, the pattern after etching may be of improved cross-sectional profile,

leading to a high transfer performance of a photomask pattern. As a result, using the photomask blank of the invention, a fine-size photomask pattern can be formed at a high accuracy. This may achieve both an improvement in productivity of photomasks and a reduction in size of the pattern formed on a processable substrate by pattern transfer using the photomask.

BRIEF DESCRIPTION OF ACCOMPANYING DRAWINGS

FIG. 1 is a cross-sectional view of a photomask blank in a first embodiment of the invention.

FIG. 2 is a cross-sectional view of a photomask blank in a second embodiment of the invention.

FIG. 3 is a cross-sectional view of a photomask blank in a third embodiment of the invention.

FIG. 4 is a schematic view of a cross-sectional profile of a pattern formed by anisotropic dry etching.

FIG. 5 is a schematic view of a cross-sectional profile of a pattern formed by isotropic dry etching.

FIG. 6 is a cross-sectional view of a chromium-containing film having three chromium compound layers having different etching rates stacked, after dry etching.

DESCRIPTION OF PREFERRED EMBODIMENTS

The photomask blank of the invention is to be processed into a photomask suitable for pattern transfer using exposure light of wavelength up to 250 nm, especially up to 200 nm, typically KrF excimer laser of 248 nm, ArF excimer laser of 193 nm or F_2 laser of 157 nm. For the photomask suitable for pattern transfer using exposure light of wavelength up to 250 nm, for example, light of wavelength 257 nm is used in defect inspection, and light of wavelength 405 nm (solid-state laser diode) is used in readout of alignment marks.