Method for an integrated single photo-mask for dual and multiple exposure lithography

Disclosed is a method for an integrated single photo-mask for dual and multiple exposure lithography. Benefits include improved throughput and improved performance.

Background

Multiple exposure lithography is expensive in terms of cost, throughput time, and overlay registration accuracy in the photo-mask and silicon wafer processes.

Conventional technology relies on the fabrication of separate photo-masks for each exposure required in the multiple exposure lithographic technique. For example, alternating phase shift mask technology has two separate masks for poly-silicon gate patterning, phase mask and trim mask. The total cost of poly-gate patterning increases due to fabricating two masks and the rework rate that results from the tight registration requirement between the two masks. By juxtaposing all or some of the separate patterns for multiple exposures onto one mask, the manufacturability issues of cost, throughput time, and registration are improved.

Several techniques can be implemented to minimize the effects of interaction and coupling between the integrated mask patterns and mask structures. The pattern files can be resized. Existing correction patterns can be modified. Additional patterns or substructures designed to compensate total mask process bias and/or coupling effects can be introduced. For example, the electron-beam fogging ring for the chrome-level critical dimension (CD) uniformity correction can be modified to compensate the total mask process bias for the integrated mask (see Figure 1).

Two masks used for double exposures are the dark-field phase mask and the bright-field trim mask. The electron-beam fogging compensation ring is a layout with four-sided large peripheral patterns around the phase mask to improve CD uniformity.

General description

The disclosed method uses the integration of dual or multiple photo-masks for double or multiple exposure lithography into a single photo-mask for resolution enhancement techniques. The integrated mask for multiple exposure lithography can incorporate masks of various types, including:

- Chrome-on-glass binary mask
- Embedded/attenuated phase shift mask
- Alternating phase shift mask
- Active optical proximity correction mask

The alternating phase shift mask (altPSM) includes:

- Exposed phase edge
- Hidden phase edge
- Undercut chrome
- Sidewall chrome

The process-compatibility issue of integrating diverse mask structures or types on a single plate is resolved by introducing additional mask processing, modifying the existing process, and correcting the lithography or design.

The key element of the method includes a single photo-mask approach for multiple exposure lithography by accommodating dissimilar mask architectures.

Advantages

The disclosed method provides advantages, including:

- Increased throughput due to integration of photo-masks into a single mask
- Improved performance due to overlay registration accuracy in the multiple lithographic exposures
- Improved cost performance due to integrating multiple exposures in optical lithography into a single mask

Detailed description

The disclosed method is a multiple exposure, single mask approach that integrates patterns onto one plate's lithographic area within constraints, such as stepper's field constraint or pellicle size constraint. For mask types with compatible processes, the integrated mask can be easily manufactured without extra process steps in the mask fabrication process. For mask types with originally different process configurations, additional mask writing steps can be introduced to process separate portions of the photo-mask's device areas for each exposure.

An alternative approach is to maintain one full process flow without extending to multiple write and etch process steps. The impact of extra processes on the patterning area with dissimilar mask structures must be negligible or correctable by lithography or design.

The coupled-mask structure can be modified. Specifically, for altPSM double exposure technology, two masks are required to enable the resolution enhancement: dark field phase mask and bright field trim mask (see Figure 2). The phase mask has three fabrication process layers: chrome etch to generate conventional chrome-on-glass (COG) structure, anisotropic glass etch to generate phase shifting structure, and isotropic glass etch to generate undercut beneath the chrome for inherent image imbalance correction. The trim mask receives only the COG process.

To simplify the single dual mask process for dual exposure, the two masks' patterns are combined onto one plate. The electron-beam fogging ring around the dark field phase mask is revised to minimize the impact to the bright field trim mask from large-scale interaction. Owning to pattern density imbalance in mask process, the second-layer process data is revised so that the trim mask portion does not receive anisotropic glass etch. The plate is processed through the same three-layers process as for the phase mask. In this way, the trim mask portion of the dual mask receives minimal coupling effect from the phase mask and its electron-beam fogging ring at first-layer COG process. The trim mask has an undercut structure generated from the third-layer process as applied to the phase mask.

Two masks used for the integrated single dual mask are the dark-field phase mask and the bright-field trim mask. The electron-beam fogging compensation ring is a layout with three-sided large peripheral patterns around the phase mask. The compensation ring in between the trim mask and the phase mask is minimized to accommodate the limited space between the areas of two masks (see Figure 3).

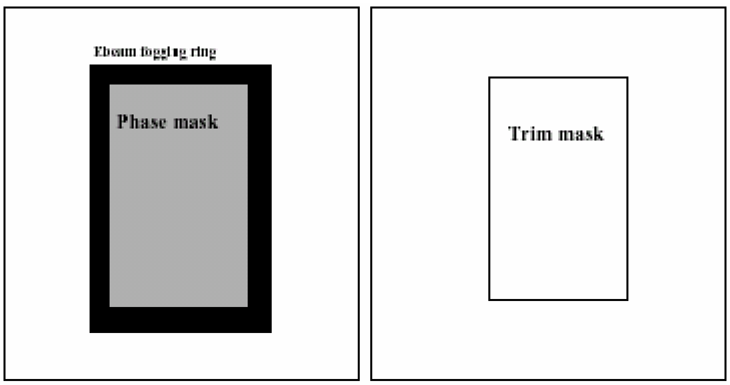

Fig. 1

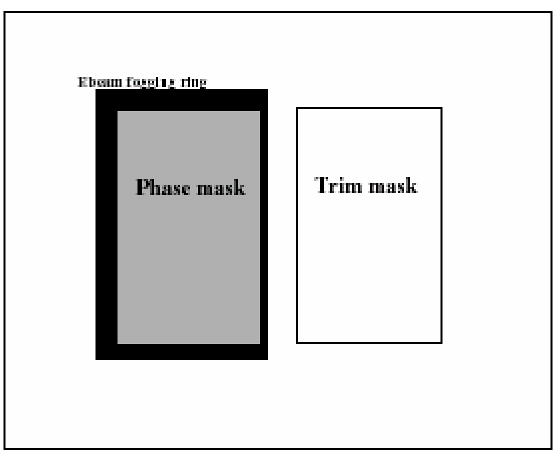

Fig. 2

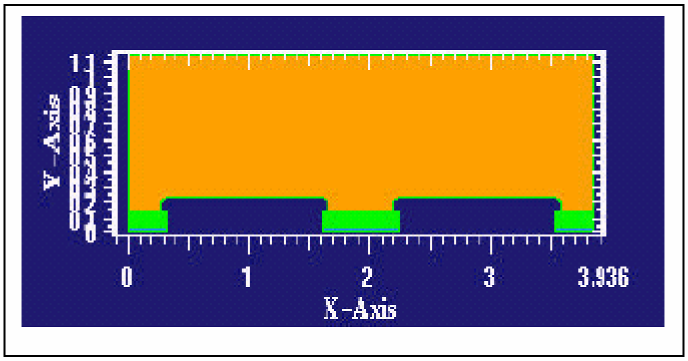

Fig. 3

Disclosed anonymously