Contact Photolithography

Overview

Contact photolithography is performed using a Mask Aligner. A mask aligner has two main tooling structures: the Mask Holder and the Wafer Chuck. The mask holder is machined to have an extremely flat surface, and the photomask is held in place on this surface by vacuum. The wafer chuck, which is also machined to be very flat, holds the wafer in place also by using vacuum. This tooling is carefully mounted so that during operation the surfaces of the two parts are kept parallel to each other. The wafer chuck can be moved up to the mask holder in order to bring the wafer into contact with the photomask using variable force. The wafer chuck surface position can also be adjusted to be as planar as possible with the mask in order to yield the best results; this is called Wedge Error Compensation. Once the wafer and mask are positioned an exposure can be performed by opening a shutter on the Lamp Housing. Inside the lamp housing there is a Mercury (Hg) arc lamp and associated optics which will allow a selected controlled band of UV light to expose the mask and wafer. There is an optical system incorporated into the tooling which can be used to view alignment marks on the wafer through complimentary marks on the photomask. Micrometers on the wafer chuck tooling allow the operator to move the wafer into alignment with the mask before exposure. Mask aligners are typically manually operated but some versions are nearly fully automated.

Design

Contact photolithography has the advantage of exposing the entire wafer surface in one process cycle. While this is efficient it presents some problems. Fabrication of the photomask can be complex and expensive, and alignment of multiple layers is difficult and offers no method of compensation for wafer scaling or warpage issues caused by processing. The shortcomings of contact photolithography should be kept in mind when designing a process; i.e. allow generous alignment tolerances, set realistic resolution goals, etc. Particular attention should be directed to the alignment strategy as the type and quality of alignment marks can have enormous impact on overlay accuracy. Marks can be very difficult to properly visualize through the photomask while keeping adequate spacing between the mask and wafer for alignment. You should explore various designs of marks to determine the best chance for successful alignment in your process.

The resolution achievable in any photolithographic process depends upon multiple factors including resist thickness, substrate film stack, and feature geometries and placement. Typical aspect ratios of height (thickness) to width (Critical Dimension) in photoresist are limited to 3:1. Higher ratios can result in line collapse or unacceptable sidewall slope. Reflectivity of any film stack should be considered, particularly if there is surface roughness. There will be significant impact on the exposure dose, and if there are different film stacks in different locations on the wafer the local dose required can change dramatically. This can be mitigated by introducing Mask Bias, where the mask features are adjusted in size to compensate for these and other optical effects. Printed feature sizes are strongly affected by not only reflectivity but by proximity effects, where the placement of features on the mask relative to open spaces or unexposed areas can alter the final results in unforeseen ways. Often the only way to determine these effects is to experiment and measure various combinations of features and placement before making the final mask.

Typical limitations for resolution and alignment on flat wafers with relatively thin resist are somewhat varying, as many factors contribute to the results. General "Rule of Thumb" values would be CD of >2µm and overlay >2µm. Better results are certainly possible but require careful planning and experienced operators.

Preparation

Successful contact photolithography requires that the photomask, wafers, and tooling be as flat as possible. Mask blanks purchased from CNF are very flat Fused Silica material. You must ensure that your wafers meet your flatness requirements based on the resolution you intend to achieve. CNF does not typically sell Ultra-Flat wafers.

All materials to be used should be cleaned before you begin. Mask cleaning can be performed many ways including by using the **Hot Strip Bath** or the **Hamatech Hot Piranha** tool. Any contamination on the mask will cause non-flatness and degrade your results. Note that the process of making contact between the mask and wafer typically leads to resist contamination on the mask surface, so frequent cleaning of the mask is recommended.

Substrates themselves present two problem areas, the front side edge and the back side. Spin coating of photoresist always results in an edge bead due to surface tension effects. The height of the bead increases with the viscosity of the resist. This bead prevents the coated surface from making good contact with the mask, degrading resolution. This bead can be removed from whole wafers using the **Edge Bead Removal System**. Other substrates will require different methods. The back side of the substrate often has residual resist from the spinning process. This will cause non-flatness of the substrate and also degrades resolution. This can be removed manually but requires practice and patience to avoid damaging the front side resist.

Tools

Selecting the best exposure tool for your process should not be too difficult in most cases. CNF currently has three contact photolithography tools, shown in the chart below.

CNF Mask Aligners

Tool	**ABM**	**MJB4**	**MA/BA6**
Exposure Wavelengths	405-365nm, 254nm, 220nm	405-365nm	405-365nm
Substrate Sizes	Up to 200mm	Up to 100mm	Up to 150mm
Alignment capabilities	Front side video microscope, Back side IR up to 2”	Front side microscope, Back side IR up to 100mm	Front side video microscope, Back side video for 100mm to 150mm

Primary considerations are typically substrate size and exposure wavelength. All three tools can accommodate up to 100mm wafers, with the **ABM** and **MA/BA6** capable of 150mm wafers, and only the **ABM** capable of 200mm wafers. All three tools offer similar exposure wavelengths, with the **ABM** having the only DUV wavelength capabilities. Alignment is often a very important consideration. All three tools have front side alignment microscopes, but they have very different optics and available magnification abilities. All three have some type of back side alignment capability, but again they are all different with different mark requirements. You should investigate these options carefully.

Processing

Consistent processing is critical to repeatable and successful results. Once a resist process has been established it must be carefully duplicated each time the process is performed if similar results are to be expected. Careful monitoring of resist thickness and the development process, as well as control of bake times and temperatures, must become a part of standard operation.

The primary controllable variable on a mask aligner is exposure dose. Like any photolithographic process, characterization is necessary to establish the optimum operating parameters. As the entire wafer is subjected to each exposure, creative methods must be used to perform dose testing efficiently. Typical examples utilize a wafer-sized cover with a section cut out, similar to a pie missing one piece. By rotating the cover on top of the mask through several exposures, multiple doses can be tested on the same wafer. Other methods are also used. The goal in all cases is to get the most information from the least number of samples. Note that all testing must be performed using the same film stack and resist process as the actual device, and that the actual device mask must be used for results to be valid.

The other important variable is the contact method. These are Soft Contact, Hard Contact, Vacuum Contact, and Proximity. Each has a place for use depending on the substrate and process. Each aligner uses different mechanisms for achieving these different methods.

Operator technique is possibly the most important factor in the entire process of manual contact photolithography. As most of the operations are performed by hand, the skill of the individual has direct impact on the final result. The importance of attention to the details of tool operation cannot be overstated. The most frequent issues arise from contamination of substrates and masks. All materials and tool surfaces should be inspected prior to every exposure run, and between substrates being loaded onto the chuck. Often masks are cleaned between wafers to ensure the best result. While some tools have sophisticated wedge error correction tooling, many require the operator to control contact force and determine proper mask to wafer planarization, a common problem area. Achieving good alignment manually is difficult at best and depends entirely on the operator's ability. These procedures all need to be practiced and evaluated to achieve consistent results.

Final Words

Mastering contact mask aligner processing takes time and practice. Results depend on the operator's skill and knowledge. It is recommended that beginners work with an experienced CNF User or group member until their techniques are established. Staff is available for assistance and advice.