Enabling Advanced Lithography:

The Challenges of Storing and Transporting EUV Reticles

White paper

INTRODUCTION

Extreme ultraviolet (EUV) lithography is expanding into high-volume production as the semiconductor industry continues to push the envelope of ever-shrinking design dimensions. For advanced nodes at and below 7 nm, EUV lithography is an enabling technology for streamlining the patterning process. Reliable patternmaking at such a fine scale requires ultraclean reticles.

Like all reticles, those used for EUV lithography rely on reticle pods for safe storage and to protect them during lithographic patterning, inspection, cleaning, and repair. The protective pod must last for many years without introducing unwanted contamination or physical damage.

Pods designed for 193 nm immersion lithography are not sufficient to protect EUV reticles. The unique requirements of EUV lithography pose additional constraints and demands on pods, making the EUV reticle pod a highly specialized piece of equipment with multiple critical components.

This paper explains the challenges inherent in designing pods for EUV lithography and proposes solutions that will allow more fabs to implement advanced lithography nodes at their facilities.

PROTECTING EUV RETICLES

The finer the lithographic patterns, the greater the risk reticle contamination poses. Potential contamination sources include both foreign particles and chemical residues. Reticle coatings are delicate and easily damaged. Anything that touches a reticle, whether it is an expected part of the process such as a robot arm in the fab or an unexpected contaminant such as a human hair, has the potential to cause damage.

Immersion lithography relies on pellicles to act as “dustcovers” that protect reticles from particle contamination during pattern exposure. Pellicles need to be optically transparent, which in the case of EUV lithography means that they must be transparent to light in the EUV spectrum with wavelengths around 13.5 nm. Most existing pellicle film materials absorb EUV light, but the semiconductor industry is starting to implement EUV-specific pellicles (see Figure 1).

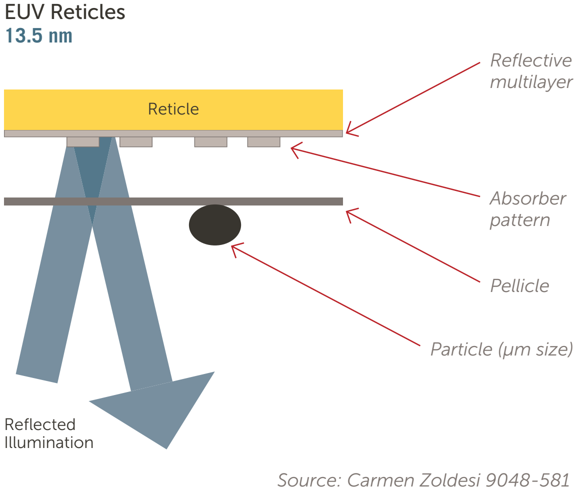

Figure 1. Incorporating a pellicle into an EUV reticle.

Until pellicles become standard for EUV lithography, EUV pods need to protect reticles that do not include a pellicle. The NXE tools for EUV lithography require a dual-pod configuration consisting of an inner metal pod under vacuum and an outer pod with access to the ambient environment. The inner pod is only opened when the pod is inside the tool.

The dual-pod configuration is standard practice for EUV lithography, and such pods are commercially available. Just because they are readily available, however, does not mean that they are a commodity product. EUV pod designs (see Figure 2) continue to evolve to meet demands for performance and lithography throughput.

Figure 2. Dual-pod configuration for EUV lithography showing outer pod (left) and inner pod (right).

Despite the protection that the dual-pod configuration conveys, the potential for contamination is significant. For this reason, EUV pods must be developed with contamination risk mitigation in mind. Especially for reticles that do not include a pellicle, the inner pod is the primary source of both protection and potential contamination.

Pod design considerations cover both the geometry of the inner and outer pods and the materials from which they are made.

MATERIAL CLEANLINESS

All surfaces that contact or surround a reticle, including those of the pod, must remain ultraclean to avoid introducing unwanted contamination in the form of particles or airborne chemical vapors.

Polymers that outgas create undesirable chemical contamination that can deposit on the reticle surface. Pod materials should, therefore, be chosen to minimize the potential for outgassing potential. The inner pods are made of metal, which does not outgas. Outer pods, however, are polymer-based, just like single reticle pods used in non-UV lithography.

Shrinking design guidelines make contamination-free environments more crucial, as the presence of even small contaminant particles is more likely to cause inaccurate pattern transfer and yield loss.

ENSURING MECHANICAL PROTECTION

The pod must safely contain the reticle during transportation both within a fab and between facilities, such as shipping from a mask house to an integrated device manufacturer (IDM) via air or ground. There is a delicate balance between the need to secure the reticle in the pod and the need to minimize mechanical damage from too high a contact force. If restraining force is too low, the reticle will not be able to withstand the mechanical acceleration and vibrations that occur during transportation and will sustain damage.

Too high a restraining force from the contact pins causes excessive contact marks on the reticle. As glass is scratched off the reticle edges, the glass particles become contaminants that can cause lithography defects. From the viewpoint of particle generation, the lower the contact force, the better.

So long as the pod holds the reticle strongly enough that it remains securely in place, fewer contact points mean fewer opportunities for the pod to contribute to particle contamination. The size of the contact points matters as well. Larger contact area translates to lower contact stress when the pod closes.

The selection of pod materials is also critical for minimizing contact marks. Ideal pod materials resist abrasion when positioning reticles and when opening and closing the pod.

PURGING THE POD

Regular purging of the outer pod is required to remove moisture inside and maintain a clean, dry environment for the reticle. The purge gas, either extremely clean dry air (XCDA) or nitrogen, enters the outer pod through inlet ports.

While most of the gas exchange during purging occurs in the outer pod, some gas does flow in and out of the inner pod during either purging or vacuum pumping and venting inside the NXE tool. The inner pod incorporates filters to allow the exchange of gas molecules with minimal particle entry into the inner pod. When closed, the inner pod needs to be sealed such that nearly all the air exchange occurs through the filters rather than through any leaks in the seal.

In an ideal design, the filter conductance — a measure of the ability for air to flow through the filter — should be much greater than the seal conductance, so that at least 90% of the air entering the inner pod enters through the filters.

Filters in the inner pod must be permeable enough to allow sufficient air flow but also robust enough to withstand cleaning. Achieving the proper balance requires careful choice of filter materials and geometry.

If a particle enters the reticle through the seal between the cover and the baseplate, keeping the reticle-to-baseplate gap dimension as low as possible ensures that the particle remains at the outer edge of the reticle rather than migrating to the active area where it can cause yield loss (see Figure 3).

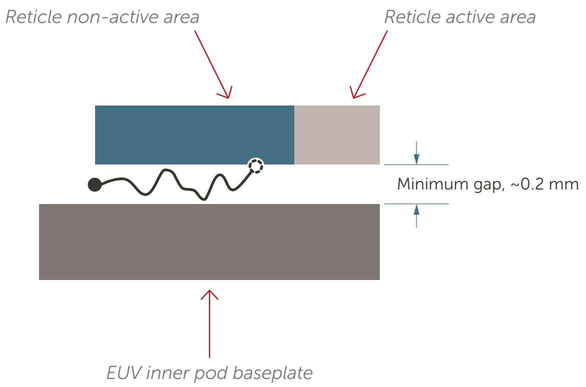

Figure 3. Particle capture in the gap between the reticle and the inner pod baseplate.

EQUIPMENT COMPATIBILITY

Much of the lithographic process is automated, and the robotic arms that handle the pods require tight tolerances for pod dimensions. There is little room for drift in the dimensions, and pods must be compatible with standard robotic interfaces. Because pods are designed to last seven to ten years, new equipment needs to be backward-compatible with existing pods.

The expected long lifetime of pods means that they will experience thousands of open/close cycles over many years. Using materials that resist wear both minimizes particle contamination and extends the useful life of the pods.

Reticle pod optical windows must be compatible with automated equipment. Cameras in the lithography tools need to see inside the pod to properly detect the reticle, putting strict requirements on the reflectivity and flatness of windows in the pod.

ACCOMMODATING PELLICLES

Because reticle pods are intended to last many years, they must meet the needs of current and future EUV lithography. Today's pod designers, therefore, should consider a version that includes space to accommodate a pellicle as well as a version for use without a pellicle. It is possible to modify the inner pod by adding a pellicle pocket in a way that still meets the overall size and weight requirements of the pod.

Designing a pellicle-compatible pod requires close collaboration between the pod manufacturer, pellicle supplier, and lithography tool manufacturer. Automated equipment assumes a tight range of weight for the inner pod, which means that the similar weight of material removed to create the pellicle pocket must be added elsewhere in the pod. The pellicle geometry must be considered when locating contact points and windows in the inner pod.

Pellicles are fragile. During the lithography operation, vacuum purging and venting causes pressure changes inside the inner pod. Such differential pressure must be controlled below a certain threshold so that excess deflection will not damage the pellicle. Properly placed windows in a pellicle-compatible inner pod provide visibility so that the lithography tool can detect pellicle damage.

EUV tools must be able to process reticles with or without pellicles and distinguish between the two types. Accidentally placing a reticle with a pellicle into a pod without a pellicle pocket would cause irreversible damage to the pellicle. Inner pods should incorporate design features that the cameras inside EUV tools can scan to optically determine the pod type, alleviating the risk of mis-identifying the pod.

SUMMARY

EUV reticle pods are highly specialized pieces of equipment that fulfill a critical role in EUV lithography. They must protect the reticle during use, storage, and transportation while not introducing additional contamination or damage. Pods must be compatible with lithography equipment and be able to maintain a clean, dry atmosphere for the reticle. Precisely designed dual-pod configurations achieve these goals for reticles both with and without pellicles, ensuring the future of EUV lithography.

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