TNO Reticle Handling Test Platform

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ABSTRACT

Particle free handling of EUV reticles is a major concern in industry. For reaching economically feasible yield levels, it is reported that Particle-per-Reticle-Pass (PRP) levels should be better than 0.0001 for particles larger than 18 nm. Such cleanliness levels are yet to be reported for current reticle handling systems.

A reticle handler was built based on a modular concept with three uniform linked base frames. In the first stage of the project a dual pod loading unit, two exchange units for opening inner pods and a reticle flip unit are installed on the base frames. In the near future improvements on cleanliness will be tested and particle detection equipment will be integrated. The system will act as a testing platform for clean handling technology for industry.

Keywords: reticle handling, EUV, particle free, ultra-clean

1 Introduction

Cleanliness of EUV reticles is still a major concern for industry. Since the availability of EUV pellicles is still lacking, added particles (>18nm) to the front side of the reticle will lead to printable defects. Added particles (> 10µm) to the reticle backside lead to overlay errors and tool downtime. Over the last years particle cleanliness of reticle handling has been frequently investigated. Recently, Jonckheere [1] showed that transport and handling still adds particles to the reticle. For an atmospheric EUV AD-t compatible load port a Particle-per-Reticle-Pass (PRP) number between 0.005 and 0.076 was found [2]. Amemiya [3] achieved a PRP number below 0.01 for reticle handling in an experimental vacuum system. For several units of an atmospheric automated handling system for EUV mask pod-in-pod system PRP numbers of 0.01 were reported [4]. In the current ASML NXE lithographic tools, Peters [5] showed an annual reduction in PRP numbers by a factor 10. In 2013 a PRP number of 0.01 was achieved for the NXE:3300B lithographic tool.

From a production perspective Lim [6] reported that the PRP number should be lower than 0.001. According to Peters [5], the customer requirement for full production should be a factor 10 lower, at PRP = 0.0001. When the reported numbers are evaluated, a correction for the particle size should also be taken into account. The ITRS roadmap [7] gives critical defect sizes for the front side of 20nm in 2014 and 16nm in 2016. The experimental data refer to much larger particles. Peters [5] described data on particles larger than 92nm and Amemiya [1] was capable of detecting particles larger than 46nm. The reported data show that the current handling technology is not yet available at the particle free level at the correct particle size required for full production.

In order to bring handling technology to a higher level, TNO has built an atmospheric reticle handler, with the aim of working towards the cleanliness levels of the future. The handler will be used to expand the applied knowledge and technology on particle free design and test new hardware developments. The hardware will

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serve as a demonstrator and development platform for the reticle handling technology for the EUV era. This paper provides a summary of the activities that were performed by TNO during the design and realization of the reticle handler.

2 Design process and philosophy

As a design philosophy, it was chosen to start with a best effort system on particle contamination. The design should initially be based on commercially available sub units. For functionalities that were not available, solutions were developed in house. In future work, contamination sources will be pin pointed within the system and unit by unit improvements will be made until the performance of the system achieves acceptable Levels for full production.

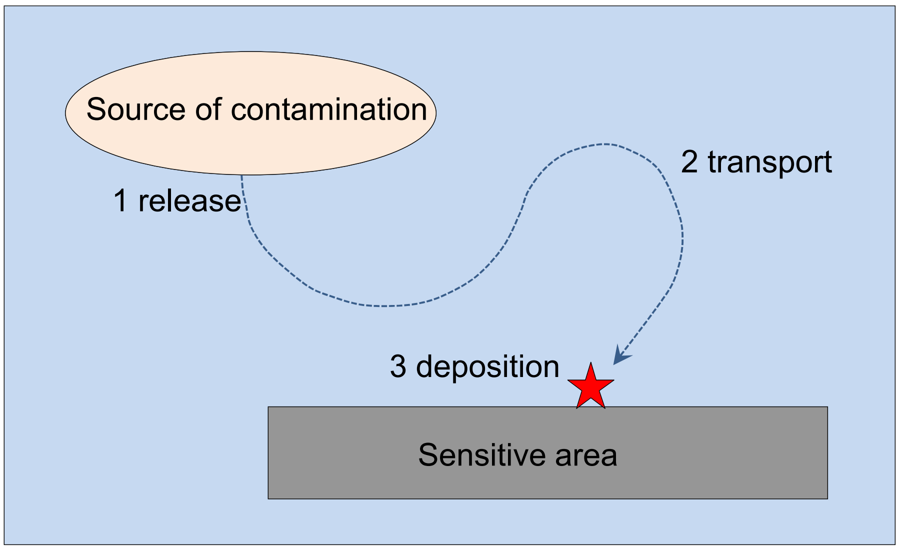

Figure 1: Three stages in a contaminating process [8]

As a base for design, the stages of a contaminating process are taken into account (see Figure 1). This representation assumes a contamination source and a sensitive area. In order to take all elementary stages into account, the contaminant must first be released at the source, then it must be transported from the source towards the sensitive area and finally the contaminant must deposit onto the surface of the sensitive area. In an ideal situation a prevention plan inhibits at least one of these steps. Since total inhibition is scarce at least two out of three steps should be suppressed. In the context of the current paper, the sensitive area is the reticle substrate and particles are considered to be the main type of contamination.

In the design process key functionalities and requirements were first defined. Then possible sources were identified and possible prevention strategies were investigated.

A representative handling and measurement cycle for EUV masks consists of the elementary steps:

- Opening EUV Outer Pod
- Robotic manipulation of an EUV Inner Pod (EIP)
- Opening EIP
- Robotic manipulation of an EUV reticle substrate
- Flipping of an EUV reticle substrate

- Opening Scan Box for the particle inspection tool
- Robotic manipulation of the Scan Box
- ISO-1 minienvironment

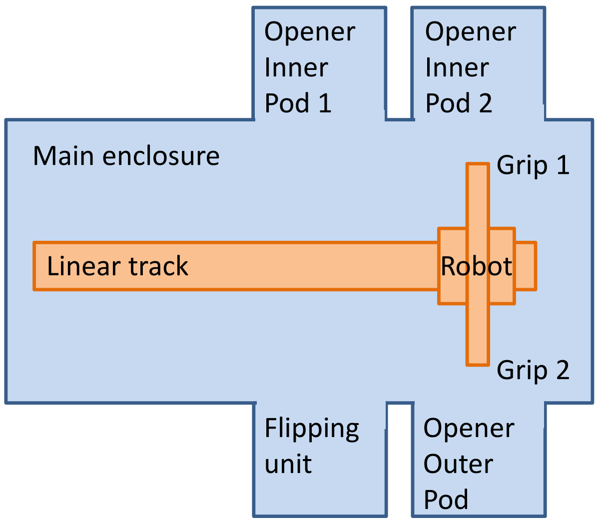

Figure 2: Functional base plan for the reticle handler

These functionalities were placed in a functional base plan (see Figure 2). In order to achieve scalability, a modular lay-out was chosen for the main enclosure where the functional units are placed at the sides. With such a modular design extension with more functional clusters will be possible. The modularity requires a linear track to move a scalar robot towards the position of a functional unit. The robot has a dual gripper; one gripper is capable of manipulation of the EIP and a Scan Box and the other gripper is designed to directly manipulate reticle substrates. The following functional units have been included within the system:

- Opener Pouter Pod - for opening the EUV Outer Pod
- Opener Inner Pod 1 - for opening of the EUV Inner Pod
- Opener Inner Pod 2 - for opening the Scan box which is required for the TNO Particle detection tool, the RapidNano.
- Flipping Unit – for manipulating the orientation of the reticle

Particle sources are locations within the system where particles are generated or released that could lead to the contamination of a reticle. During the design process, all known particle sources within the system, where considered and accounted for. The main mechanism for particle generation in handling equipment is wear. Wear can occur at all locations where contacts are made and broken. Known particle sources are the linear track and a ventilator in the robot. Typical other locations are points of contact with the gripper. Contact of the inner pod or scan box with the opener and the contact points of the flipping tool with the reticle are other sources of particle contamination.

In order to achieve particle free handling, either solutions for minimizing particle generation and release or transport of particles must be suppressed. Particle generation by contact of the gripper and the reticle is minimized by choice of the gripper materials. Furthermore, the design of the gripper was aimed at using low contact forces and zero friction elements for the moving parts. Finally, metrology for smooth and accurate contacting is incorporated into the gripper and the EIP openers. The smoothness and high accuracy of the system prevent slipping and shocks during the initial contact. In this way, peak forces during the initial stages of contacting are avoided.

Preventing the generation and release of particles from the linear track and robot ventilator was not possible since these items are constructed from available technology. The risks on particle deposition on the reticle were mitigated by suppression of the transport mechanism of the particle, isolating it from the sensitive areas of the reticle. This isolation is achieved by means of a laminar down flow within the reticle handler. By keeping the reticle upstream of the identified particle sources the particles are transported towards the exiting filters and cannot reach the reticle. The suppression of the transport is effective only when a homogeneous down flow can be realized. Therefore, the homogeneity of the flow in the main chamber was calculated by CFD during the early design phase, which ultimately led to the optimization of the geometry of the system.

3 Design and realization

From the functional base plan (see Figure 2) a simplified main enclosure set-up was modelled to reduce simulation time. Fluent (flow modeling software?) was used to calculate flow profiles in this main chamber. The base air velocity assumed within calculations was 50 cm/s.

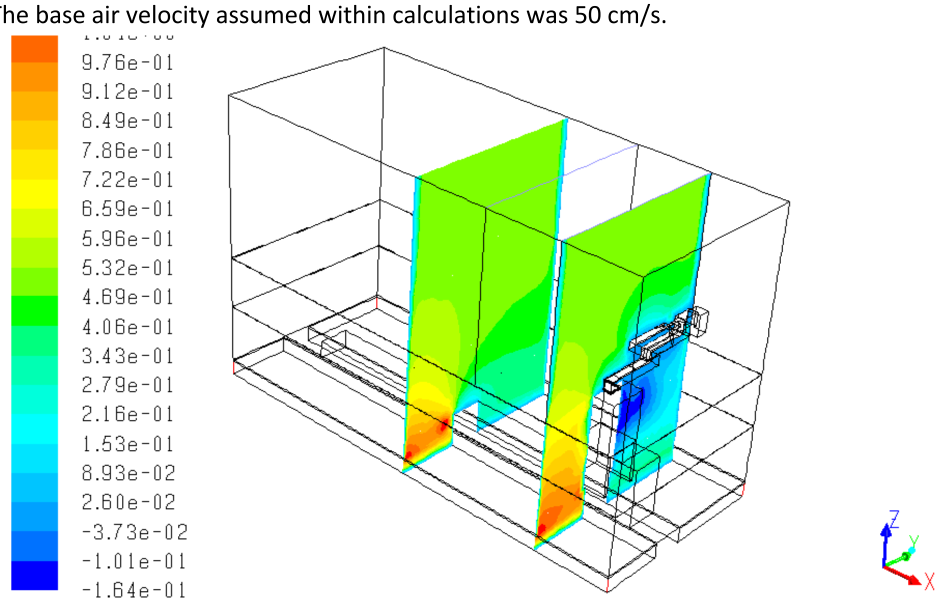

Figure 3: CFD calculations for the main chamber

As expected, the flow in the main chamber was in a downward direction in nearly all regions. The exception is the region underneath the robot arm. Here, a wake with an upward velocity was predicted (see Figure 3). A more detailed study of the flow velocity vectors (see Figure 4) showed that the wake area covered 50% of the distance between arm and chamber bottom. The flow vectors pointed towards the robot column but no circular velocity profile was predicted. The position of reticle substrate was high enough to isolate it from the wake area. As long as no significant particle sources are present in the region of the wake sufficient confidence is present on preventing particle transport from wake area towards the reticle substrate.

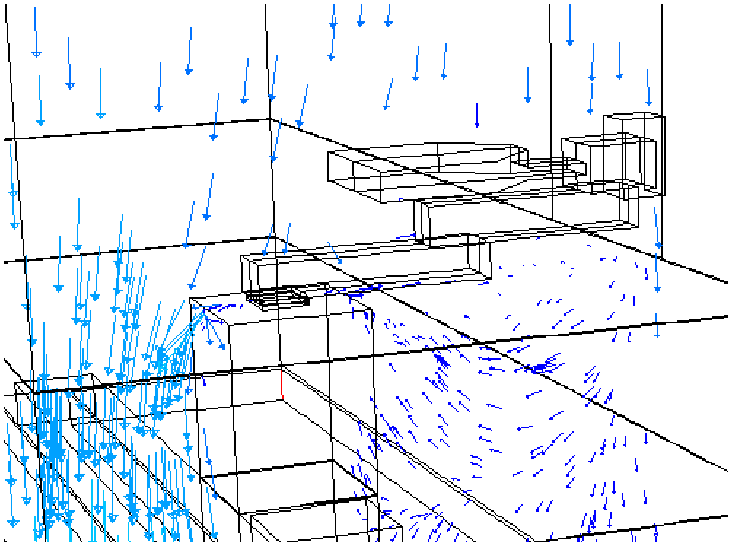

Figure 4: Detailed flow velocity vectors in wake area

Based on these calculations the final design of the main chamber was made (see Figure 5). Functional units were placed at the sides each provided with a filter fan unit to guarantee particle free air flow.

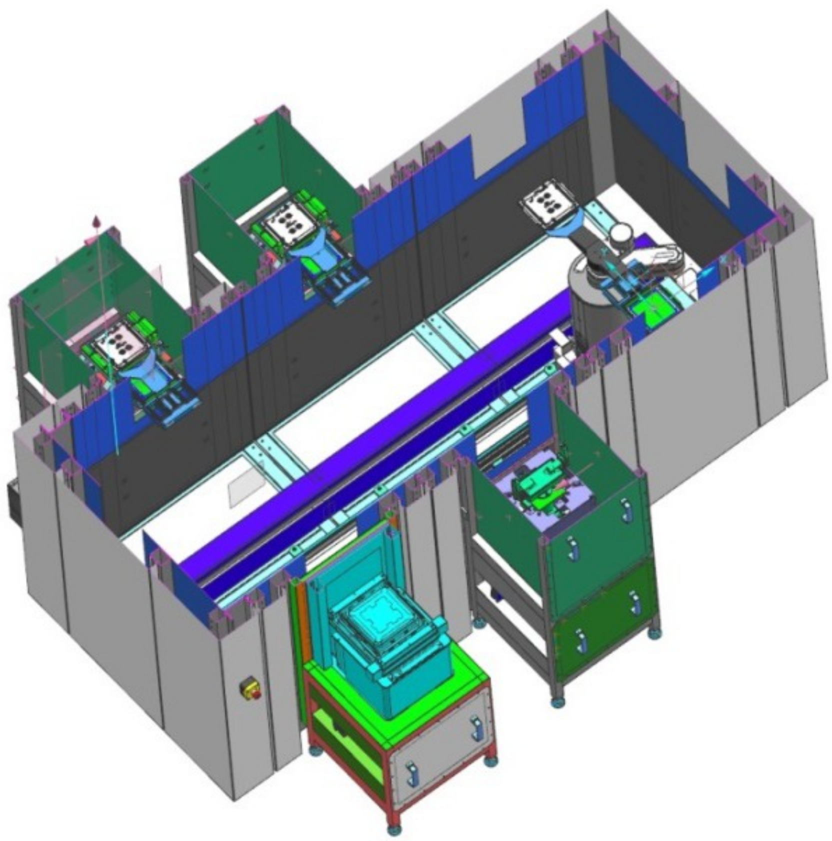

Figure 5: TNO reticle handler, drawing of phase 1

Figure 6: Reticle handler exterior, no covers (left), main enclosure interior (right)

Figure 6, left shows pictures of the exterior of the reticle handler. On the far end the EUV Dual pod opener is present. The other side unit contains an Opener for EIP's. Figure 6 (right) gives a picture of the interior. In the front, the robot with dual arms is visible. The linear track cannot be seen from this point of view.

Figure 7: EUV Dual Pod load port (left), Reticle flip unit (right)

Figure 7 (left) shows the EUV Dual Pod load port. This unit opens the EUV outer pods and presents the EIP to the pod gripper. Figure 7 (right) shows the flipping unit. This unit rotates a reticle substrate. This way the reticle is flipped from front side down orientation in the EIP to front side up orientation for the scan box to be able to scan the front side in the Rapid Nano particle scanner.

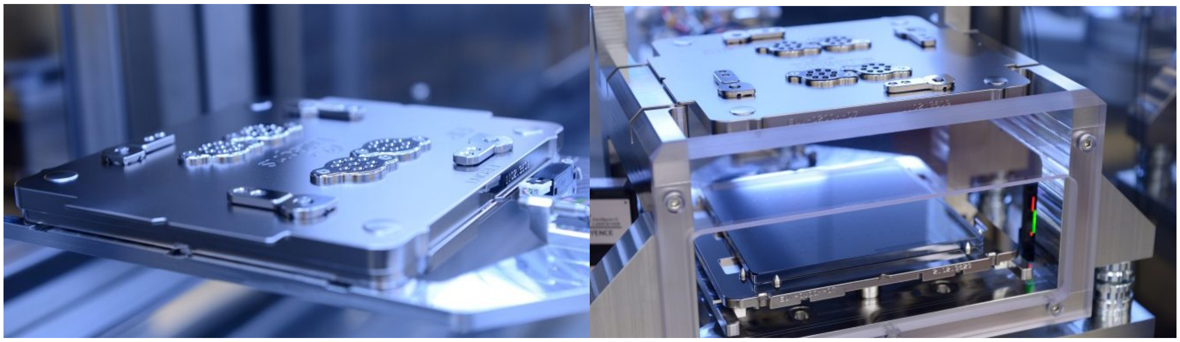

Figure 8: EUV IP on gripper (left), EUV IP on EIP opener (right)

The EUV Inner Pod is picked up by the robot (see Figure 8, left) and the EIP transferred towards the Inner Pod Opener (see Figure 8, right). In the Inner Pod opener unit the lid of the EIP rest on a frame and the pod is opened by lowering the robot.

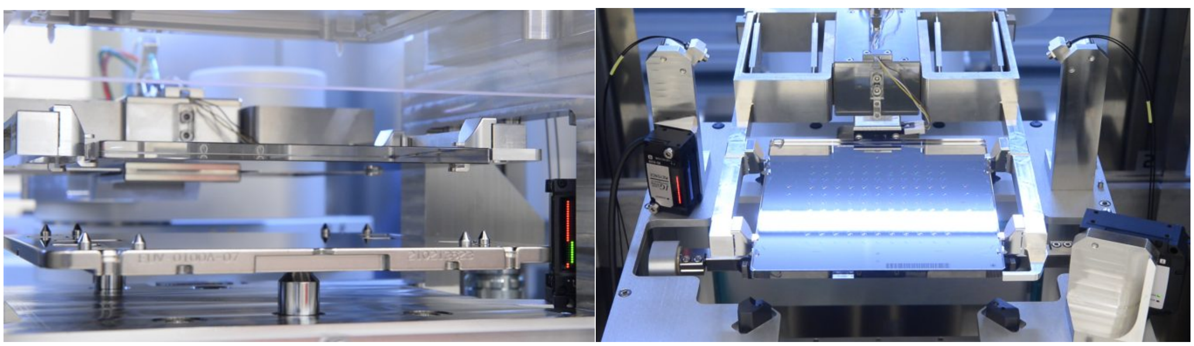

Figure 9: Reticle on gripper in EIP (left), reticle substrate on gripper (right)

The robot arm is rotated and the reticle gripper picks up the reticle substrate (see Figure 9, left) and transferred the reticle substrate towards the flip unit (see Figure 9, right).

4 Further work

In order to determine the cleanliness of the system the PRP number will be determined. A method to determine the correct procedure has been published before [9]. At the first stage, we are aiming at an initial PRP level of at least 0.01. Therefore, a high number of handling cycles must be performed.

First a relevant cycle must be defined. The cycle is described in terms of the functional base plan (see Figure 2). In the cycle all stations will be used at least once. From the EIP openers to the flipping tool and the EUV Dual Pod load port. TNO will be using RapidNano [10] for particle inspection. The RapidNano uses a Scan Box to protect the reticle substrate against particles during measurement which will be loaded in the reticle handler. Therefore, the cycle starts and ends at the Opener for the Scan Box ("Opener Inner Pod 2" in Figure 2). For the measurement cycle, the reticle substrate will be placed in the scan box. The Scan box will be unloaded by the robot through the Outer Pod opener and manually loaded in the RapidNano. When the contribution of loading a reticle substrate into the Scan box can be performed with a better PRP number than 0.1, at least 650 cycles must be performed to achieve sufficient statistics.

It is not expected that the current system will perform better than PRP=0.01. This is mostly due to lack of knowledge on the bottlenecks and the unknown particle sources within the system. In coming year, a step by step improvement program will be carried out. First isolation tests will lead to a breakdown of particle budgets in the reticle handler. The units that contribute most to the particle contamination will then be improved by changes in design, material or way of operation.

In the future other functional units will be connected to the reticle handler. These other functional units are related to metrology, reticle library or a clean vacuum load lock. In addition, it is planned to connect the next generation of RapidNano, which will be capable of detecting 20 nm particles on reticle substrates. This inspection tool is now being designed to be coupled to the reticle handler for automatic loading of the Scan Box. This development will lead to a fully automated handling module for reticle substrates from the EUV Dual Pod towards the RapidNano. When the combined tools are in place a test platform is available for testing customer tools on particle cleanliness on either new functional units that can be connected to the reticle handler or for simply measuring contamination levels test reticles.

5 Conclusion

The first stage of the TNO Reticle Handler system is realized and fully operational. The system is based on a generic, scalable, modular concept with a load port for EUV Dual Pods, opener units for EUV Inner Pods and a flipping tool for reticle substrates in side units. A scalar robot on a linear track moves the EUV Inner Pod and the reticle substrate between the different side units.

The design is based on a best effort with currently available units. In order to minimize the risks on particle contamination of the reticle substrates a series of measures have been taken. Particle generation in the gripper has been minimized by material choice. In the design friction free moving elements are used and the operation mode has feedback loops optimize smooth movements of gripper and reticle substrate.

Particle transport towards the reticle substrate is minimized by using an ISO 1 mini-environment. The flow profiles in the chamber have been calculated with CFD. Design was checked on homogeneity of flow and the absence of upward flow components around possible particle sources.

In the next months improvement projects will start on cleanliness and adding more units to the handling core, including the next generation of RapidNano (detecting capability of>20 nm), metrology equipment, library units and a clean vacuum load lock.

6 Literature

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