Achieving Zero PWP

At Atmospheric Pressure and in Vacuum Environment

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INTRODUCTION

The number of particles added to a wafer as it passes through a tool, is expressed in particles per wafer pass or PWP (for a reticle, it is particles per reticle pass or PRP). PWP is a critical parameter for a tool that handles wafers or reticles. There are stringent requirements on PWP for each process node set forth by ITRS as well as the KLA-Tencor customers. In applications, such as EUV and EBEAM inspection, where wafers or reticles are handled in both atmospheric and vacuum environments, achieving PWP for process nodes <22nm is quite challenging and most tools present inconsistent PWP performance. For particle risk retirement of EUV tool in RAPID and, in collaboration with EBEAM Division to improve PWP in EBR tools, RAPID has developed techniques in achieving zero PWP in both atmospheric and vacuum environments. This paper demonstrates methods about how to produce zero PWP performance with an emphasis on vacuum environment.

Test Methodology

To achieve zero PWP, RAPID has developed a unique and effective test methodology that can readily reveal the sources of particles in both atmospheric and vacuum transfer of wafer. In this test methodology, a blank 300mm silicon wafer is used as a test coupon, an atmospheric/vacuum particle test stand (VPTS) is used to collect particles on test coupons as particles are generated by various components and processes. The Surfscan and EBR tools are used to determine the size, distribution, shape, and elemental content of particles. Figure-1 shows the particle test and inspection strategy in RAPID for EUV program.

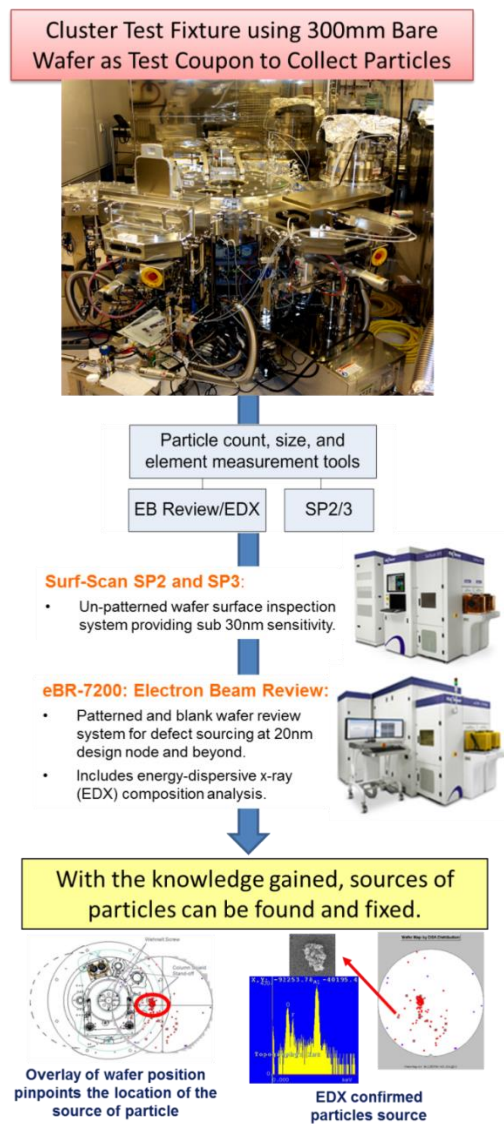

Figure-1, Particle Collection and Inspection Strategy in RAPID

Achieving Zero PWP in Atmospheric Wafer Handler

The low particle handling of wafer and reticle in atmospheric environment is well understood. To achieve zero particles down to 28nm in VPTS, several improvements were made to the EFEM which led to achieving zero PWP, even in 1,000 wafer cycles. The improvements include:

1. All Stainless Steel sheet-metal and frame with polished finish.
2. Trackless Robot
3. Positive laminar flow through HEPA filters, from top to bottom of EFEM.
4. HEPA filters properly sized to prevent particles entering EFEM.
5. Minimized age of gas, to avoid stagnation and recirculation of air anywhere within the EFEM.
6. Perforated surfaces in the flow of air to avoid particle accumulation.
7. No paint, silicone gaskets, or porous gaskets all of which can accumulate and release particles.
8. Quiet, low noise/low vibration assembly to avoid dislodging particles from surfaces.
9. *X*-ray ionizer, which creates far fewer particles than other ionizer types.
10. Edge-effector with low contact/low friction edge gripper
11. All electronics and their cooling fans located below a perforated plate which is below the wafer handling area.
12. L-motion mechanism for the Vacuum Load-lock doors to minimize particles generated by the door actuation.

Achieving Zero PWP in Vacuum

PWP tests in VPTS demonstrated that achieving zero PWP in vacuum is quite challenging. The main sources of particles in vacuum were found to be the following in the order of significance as shown:

1. Transfer Valves (a major source of particles)
2. Misalignment of atmospheric and vacuum robots (a major source of particles)
3. Sticky contact-points on the vacuum-robot end-effector (a major source of particles)
4. Mechanically coupled vacuum robot arm
5. Low quality surface finish of in-vacuum surfaces.
6. Clamped-down glass viewports
7. Vented screws, especially when vented holes face down toward wafer.
8. Lack of Vent diffusor and roughing port location optimization.
9. Lack of vent and pump-down process optimization.
10. Wafer in line-of-site to Turbo-pump which generates ballistic particles.
11. Absence of inspection of particles on the in-vacuum surfaces.
12. Poor handling and assembly process without sniffing and removing particles generated.

To achieve zero PWP in vacuum, all above sources of particles had to be addressed and resolved. For example, a transfer valve was tested in atmospheric pressure vs. vacuum which revealed the extent of particle problem in vacuum. See Figure-2.

Particles Collected while Valve Operating in Atmospheric Pressure

Adders			Test Order	Wafer Paths
≥28nm	≥65nm	≥100nm		
0	0	0	4	LL2-2_PM3, Cycle 10,000x
3	2	2	3	LL2-2_PM3, Cycle 10,000x

Total number of particles ≥28nm = 0

Particles Collected while Valve Operating in High Vacuum

Adders			Test Order	Wafer Paths
≥28nm	≥65nm	≥100nm		
83	70	62	4	LL2-2_PM3, Cycle 10,000x
115	88	67	3	LL2-2_PM3, Cycle 10,000x

Total number of particles ≥28nm = 83

Figure-2, Particles collected on test coupons from a transfer-valve as tested in atmospheric pressure vs. in vacuum.

The test showed particles generated by the valve did not transfer to wafer at atmospheric pressure but did in large quantities within vacuum. This is mainly because the falling speed of a 1 um particle in atmospheric pressure is ~50 um/sec…it takes the particle 20 seconds to fall just 1mm! This gives a very low probability for the particle to reach the wafer during transfer.

By making major modifications to the vacuum transfer-valve, the number of particles generated, even during 1,000 valve cycles, was reduced to nearly zero! See Figure-3.

The key modifications that were made to the valve are listed below in the order of significance:

1. Replacing the aluminum seat with polished stainless steel.
2. Replacing the Viton-seal with unfilled bonded seal.
3. Reducing valve closing pressure to minimum value that assured a good seal.
4. Eliminating robbing of seal surface against the valve seat.
5. Eliminating any loosely attached coatings.
6. Eliminating vented screws and replacing them with non-vented screws equipped with particle trap.

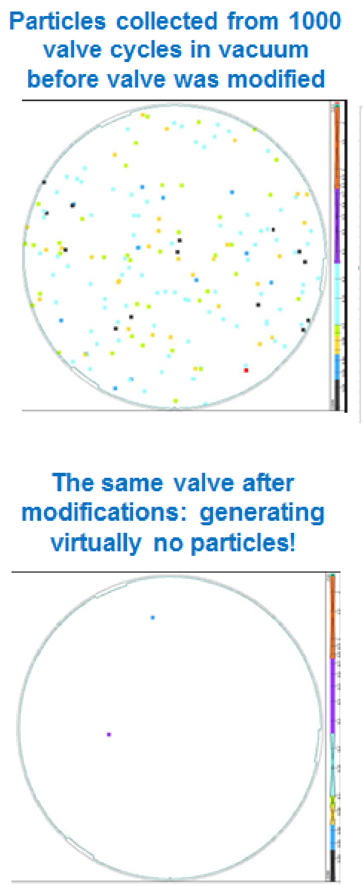

Figure-3, Surfscan particle maps of adders before and after modifications were made to a transfer-valve.

Conclusion

After nearly 18 months of effort in finding and addressing the sources of particles in a state-of-the-art atmospheric/vacuum wafer handling tool, near zero PWP ≥ 28nm was repeatedly achieved. Figure-4 shows the results of full PWP tests on 3 wafers, 25 cycles each:

Test Order	Wafer Paths	Particle Adders		
		28 to 65nm	65 to 100nm	≥100nm
-	Foup Witness	0	0	0
2	PWP_Align_LL2-2_PM4, 25X	0	0	0
3	PWP_Align_LL2-2_PM4, 25X	1	0	0
4	PWP_Align_LL2-2_PM4, 25X	0	0	0

One Particle in this PWP test

Zero Particle in 25 PWP Cycles

Figure-4, Full PWP results of 3 test wafers

These PWP results show that it is feasible to achieve zero PWP for particles down to 28nm in vacuum. Further test results will provide better statistical data with higher confidence level on achieving zero adders.

Future work

Sealing materials used in dynamic seals are a major source of particles in vacuum. Selection and optimization of sealing materials for zero particle generation is currently underway in RAPID.

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Key words

PWP, PRP, Particles per Wafer Pass, Particles per Reticle Pass, EFEM, Vacuum, Transfer Valves, EUV, Dynamic Seals