

*Surface Characterization of Extreme UV  
Lithography tool Components and Parts by  
using ACS™ Cleaning Process and High  
Performance Residual Gas Analyzer for Sub-  
20nm Technology Nodes*

**BY**

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# ***Abstract***

- QuantumClean® has developed a robust cleaning method to remove Nano contamination from major lithography OEM parts, verifying cleanliness by using the latest high performance Residual Gas Analytical tool and in house techniques. The precision cleaning also known as Atomically Clean Surface™ (ACS) along with RGA technology developed by QuantumClean® is non-aggressive and non-destructive, which gives the customer the confidence the part is clean and ready to install.
- The ACS™ process does not create pits nor does it significantly alter the surface roughness, flatness, or surface condition of the part. This technology is also being used on recycled semiconductor parts which are being used for 14nm and below technology nodes and is yielding positive results. This paper discusses the results and importance of using Residual Gas Analyzer to detect the surface conditions of the parts and components with and without the ACS™ cleaning process.

# *Introduction*

- As technology nodes progress to 10nm and beyond, the requirements for defects get extremely high. Defect variation can cause multiple issues down the line. Extreme ultraviolet (EUV) lithography tools are used to pattern the wafers down to 5nm nodes.
- Extreme Ultraviolet Lithography (EUV) tool components and parts must have zero defects larger than 25nm. Part defects are an accumulation of defects present on the surface of the parts, defects added during the shipping and installation, and defects added due to handling of the parts. This raises the question of whether the parts or component's surface condition contributes to the total number of defects.
- It's extremely important to understand the surface condition of the parts and components. The majority of the times the part meets the defect requirements, but out gasses heavily under vacuum, causing the parts to fail inside the EUV lithography chamber

# Experiment Set-up and Explanation

The high resolution RGA tool is suitable for measuring parts with high sensitivity. RGA is a mass spectrometer attached to a chamber (Figure-1) that is designed for process control & contamination monitoring of vacuum parts. RGA's are used mostly to monitor minute traces of impurities. For lithography OEM parts the critical elements measured are  $H_2O$ ,  $CxHy$  (volatile), and  $CxHy$  (non-volatile).

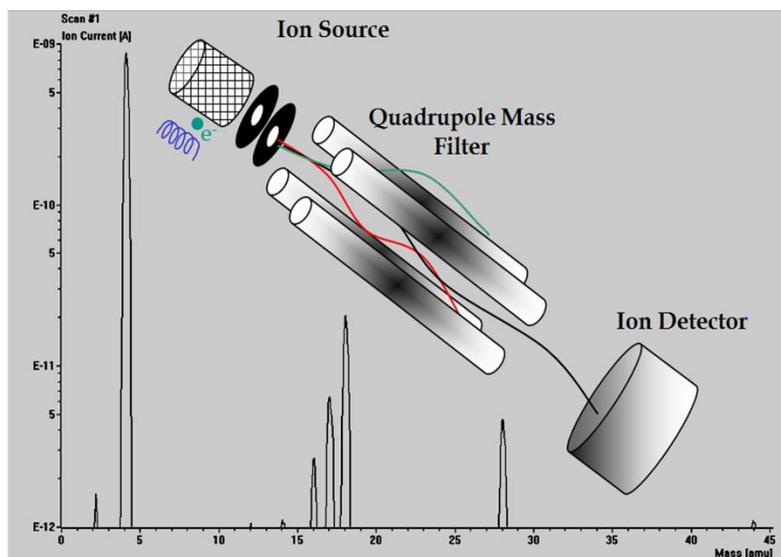


Figure-1

# Experiment Set-up and Explanation

- A background scan is typically run prior to qualification to determine if the tool is within specification.
- The result is then calculated by subtracting the background from the sample results. Figure-2 depicts the background scan

Its important that majority the background peaks are lower than  $5E10^{-8}$  (mBar \* l/s)

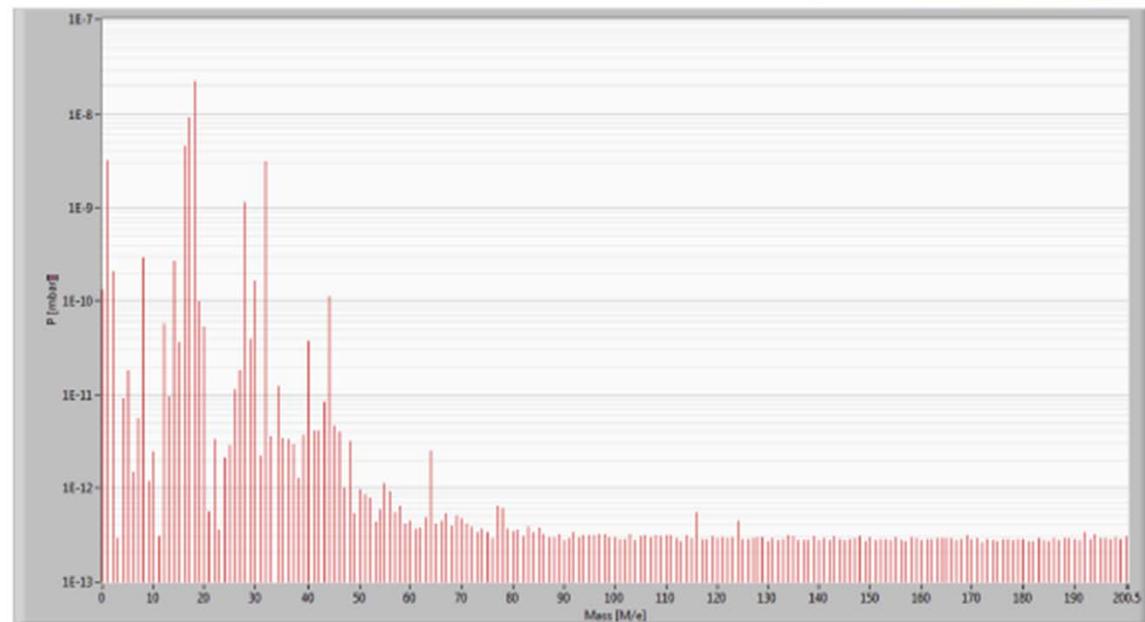


Figure-2

# Experiment Set-up and Explanation

- Different types RGA chambers used for our experiments. Figure 3a, 3b, and 3c shows tool set up of Main RGA chambers with different configurations
- Box in Box also known as BIB is used for small parts which are placed in the BIB inside the main RGA chamber for accurate out-gassing readings

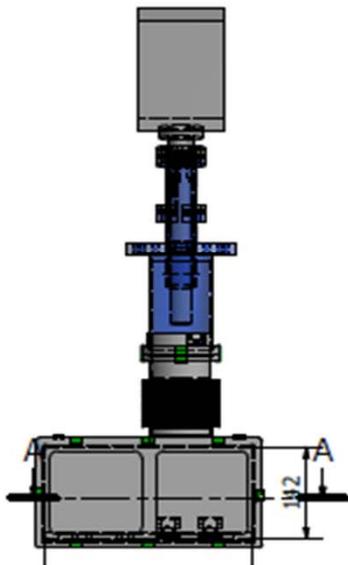


Figure-3a (Side View)

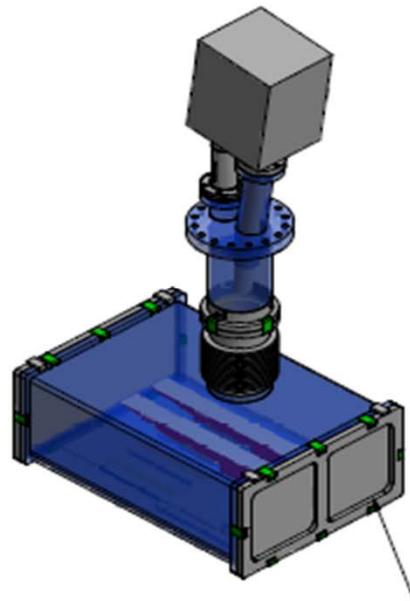


Figure-3b (Box Set-up)

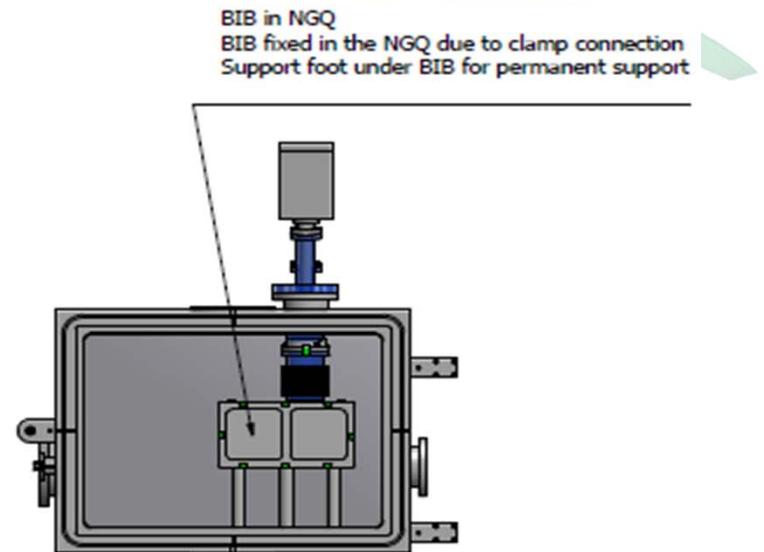


Figure-3c (Main Chamber with BIB View)

# ***RGA Set-up and Explanation***

- Parts placement:
  - For experiment purposes, parts placement is critical and there should be minimal contact with the chamber
  - Note: Overloading and poor part placement runs the risk of virtual leak
- Importance of Box in Box (BIB) setup:
  - The variety of chambers gives flexibility to provide better chamber loading on product depending on size, quantity and substrate. It is important to use the correct chamber for the product based on the RGA values of the parts
- Baseline integrity check and validation:
  - RGA requires a specified schedule for validation, integration, and background
- Importance of background scans:
  - A background scan is run to verify that the chamber is within specification prior to running qualifications.
  - If the background scan fails, the RGA goes through a thorough clean process to make sure it reaches base pressure in a timely fashion with proper background levels

# *Process Flow/Description*

- Different types of parts are received by QuantumClean® from Lithography OEM suppliers and sub-suppliers
- Parts size can vary from few millimeters to a meter in length
- QuantumClean® provide two types of services;
  - Parts cleaning process followed by RGA scans
  - RGA scans only (Parts already cleaned by 3<sup>rd</sup> party suppliers)
- Figure 4a and 4b depicts Clean-1 and Clean-2 processes used by QuantumClean® to clean the suppliers parts prior to RGA scans
- Clean-1 is used for stringent cleaning which helps to remove organics and inorganic materials from the surface of the part
- Clean-2 is used for parts that needs the removal of Hydrocarbon elements
- QuantumClean® cleans and scans a diverse selection of Lithography OEM parts with varying substrate, geometry and complexity, using both Clean -1 and Clean - 2 cleans. Figure 5 depicts different parts

# Basic Process Flow

## Clean-1 and test Process Flow

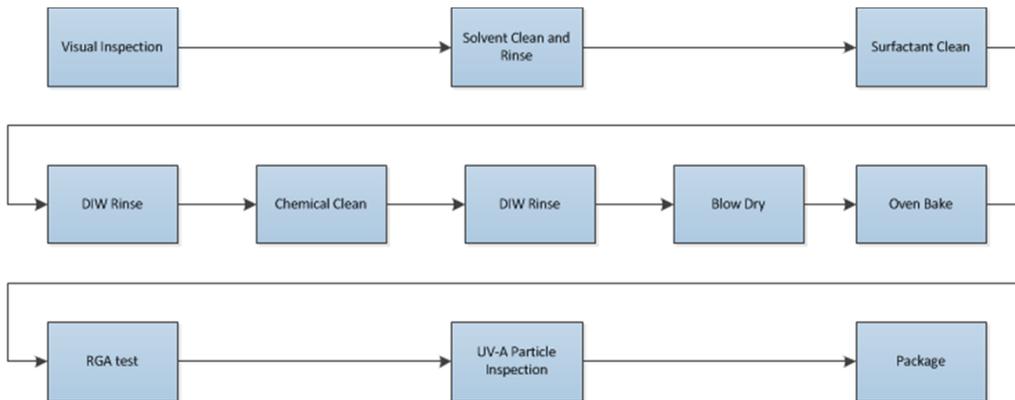


Figure 4a

## Clean-2 and Test Process Flow

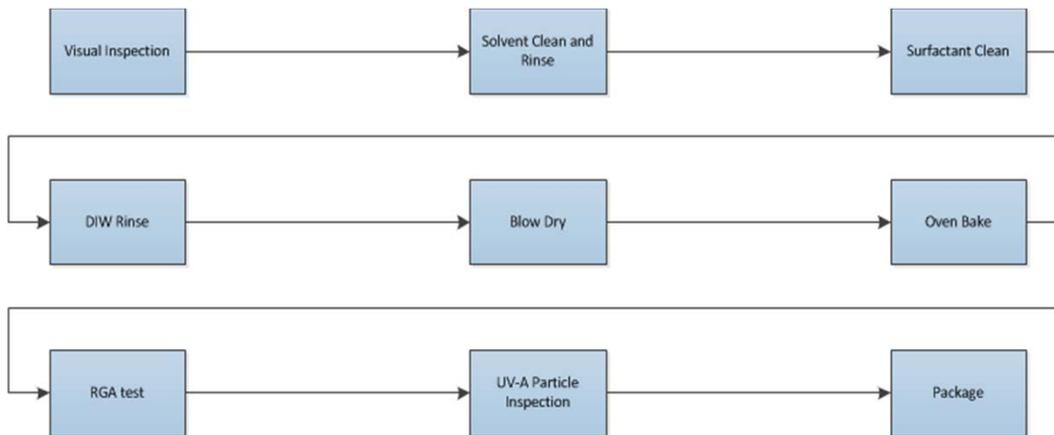


Figure 4b

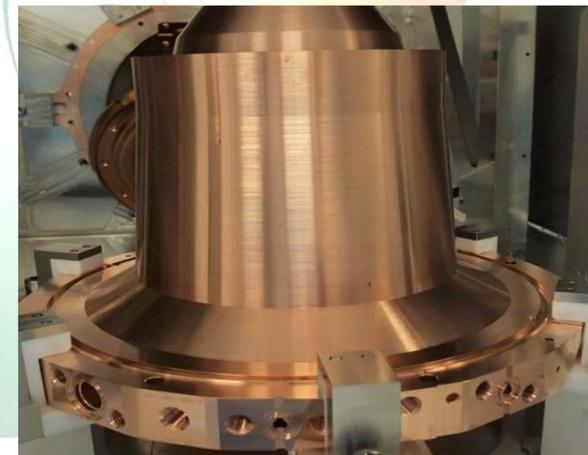
# Example Parts



100mm in Size



200mm in Size



300mm in Size

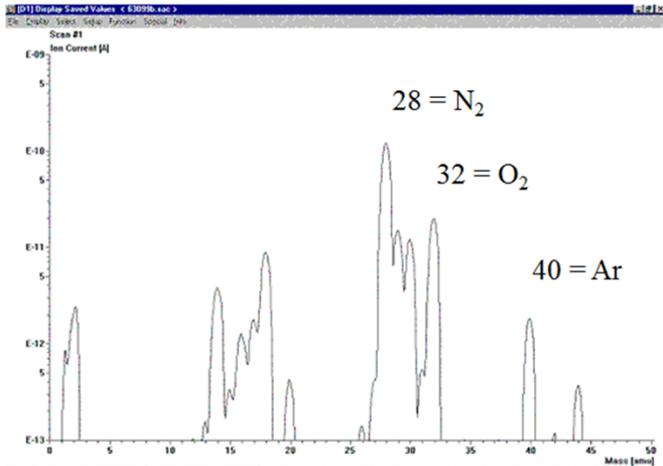
# ***Results and Discussions (Cont'd)***

## **Challenges faced during the entire process**

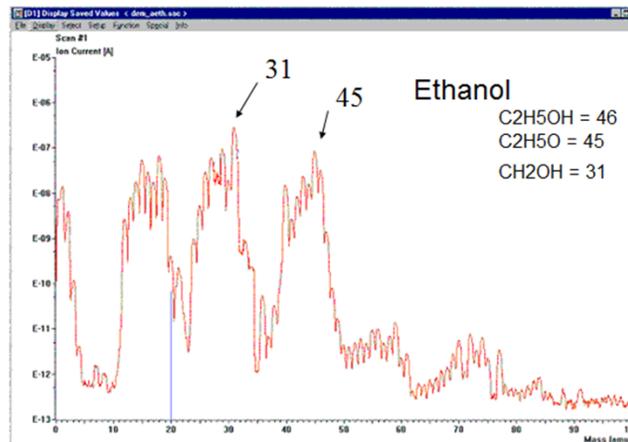
- Incoming parts from Lithography OEM part suppliers come with high AMU elements ranging from 1 to 200 which will not allow the RGA to get to the base pressure.
  - Example: Parts with Heli-coils
- It is important to understand all the failing AMU elements
- Due to QuantumClean's technical capability and capacity, we identify the majority of failures associated with respect to parts
- Figure-6 depicts different scans that identifies different elements out-gassed during the RGA scan process
- However, if the parts are processed in a batch, it becomes difficult to identify a part causing the high failures

# Figure 6: Depicts Different Scans

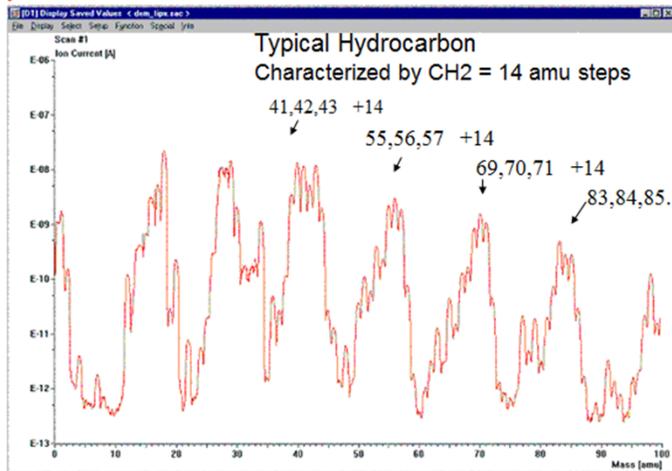
## Air Leak



## Solvents



## Pump Oil



Parent Gas	Relative Mass	Ions Formed	amu
Ethylene	28	C <sub>2</sub> H <sub>4</sub>	28
		C <sub>2</sub> H <sub>3</sub>	27
		CH <sub>3</sub>	15
		CH <sub>2</sub>	14
Carbon monoxide	28	CO	28
		O	16
		C	12
NO <sub>2</sub>	30	C <sub>2</sub> H <sub>5</sub>	29
		C <sub>2</sub> H <sub>4</sub>	28
		C <sub>2</sub> H <sub>3</sub>	27
		CH <sub>3</sub>	15
Ethane		CH <sub>2</sub>	14
		CH <sub>2</sub>	14
Oxygen	32	O <sub>2</sub>	32
		O	16
Argon	40	Ar	40
	36	Ar	36

Parent Gas	Relative Mass	Ions Formed	amu
Hydrogen	2	H <sub>2</sub>	2
		H	1
Helium	4	He	4
	16	CH <sub>4</sub>	16
		CH <sub>3</sub>	15
Methane		CH <sub>2</sub>	14
		CH <sub>2</sub>	14
Ammonia	17	NH <sub>3</sub>	17
		NH <sub>2</sub>	16
Water	18	H <sub>2</sub> O	18
		OH	17
		O	16
Fluorine	19	F	19
Hydrogen fluoride	20	HF	20
		F	19
Neon	20, 22	Ne	20, 22
Nitrogen	28	N <sub>2</sub>	28
		N	14

Parent Gas	Relative Mass	Ions Formed	amu
Hydrocarbons	various	HC	various
		C <sub>5</sub> H <sub>11</sub>	71
		C <sub>5</sub> H <sub>9</sub>	69
		C <sub>4</sub> H <sub>9</sub>	57
		C <sub>4</sub> H <sub>7</sub>	55
		C <sub>3</sub> H <sub>7</sub>	43
	C <sub>3</sub> H <sub>5</sub>	41	

ACETONE

HCl

# ***Results and Discussions (Cont'd)***

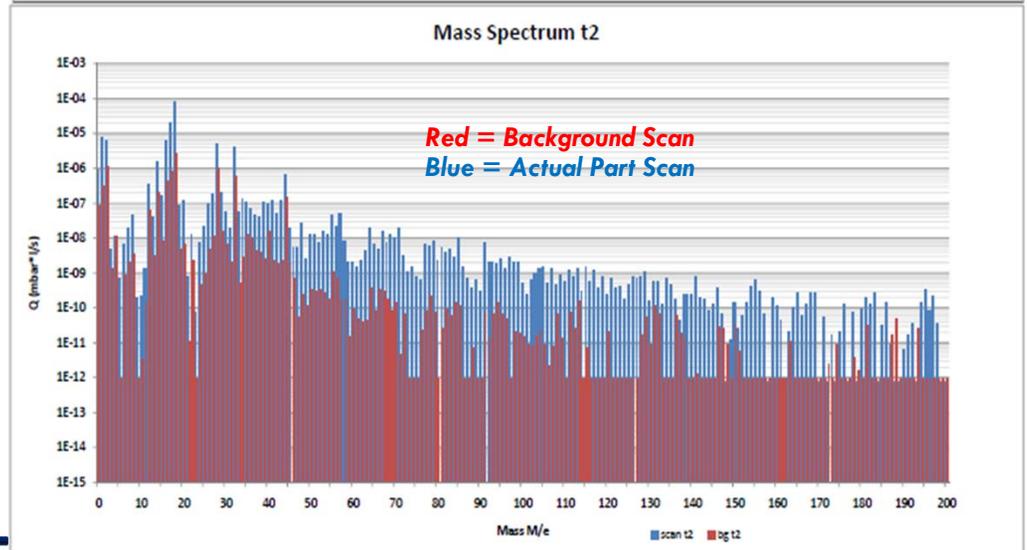
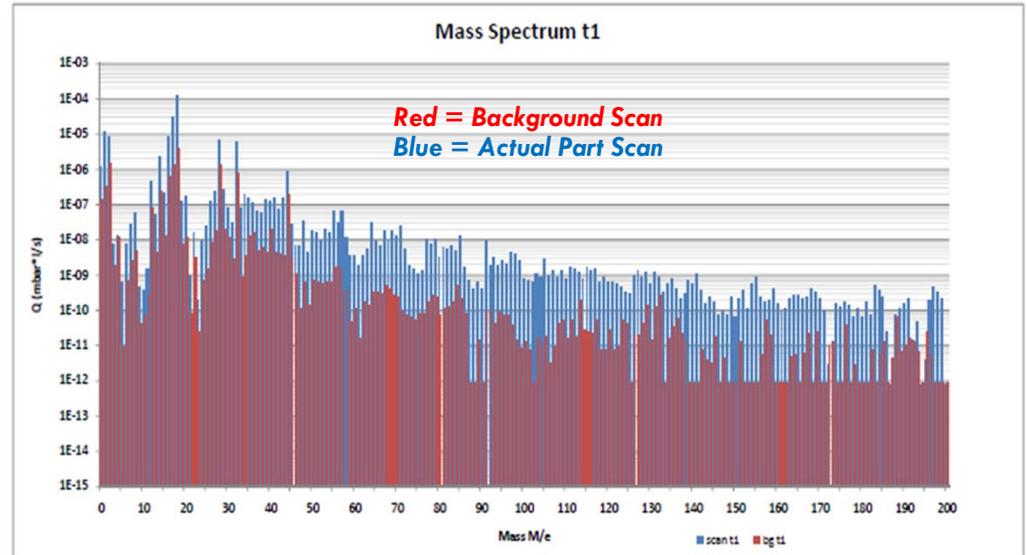
## **Challenges faced during the entire process**

- QuantumClean® would rework the parts if they are cleaned by us and only ship parts that are clean and have passed the RGA requirements
- Note: QuantumClean® only ships 100% passing parts to customers
  - The QuantumClean® first time yield is >95% on clean and scan product for the past 4-years, however the failures are reworked in house to achieve 100% conformance
- Parts for RGA scan only will go to the customer with the failing report if the scan fails
  - RGA scan only test passes 75% on average over 4 years
- QuantumClean® has no control on the incoming part cleanliness
- The challenge QuantumClean® faces is what's incoming on the parts, since no C of A's are attached to these parts

# Results and Discussions (Cont'd)

- Figure 7a shows a part receiving only RGA scan by QuantumClean®

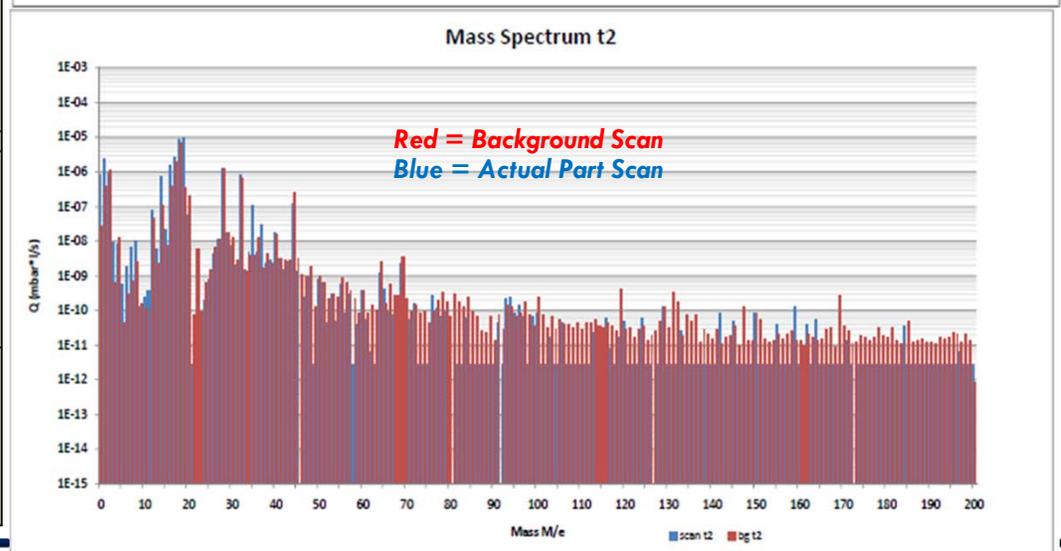
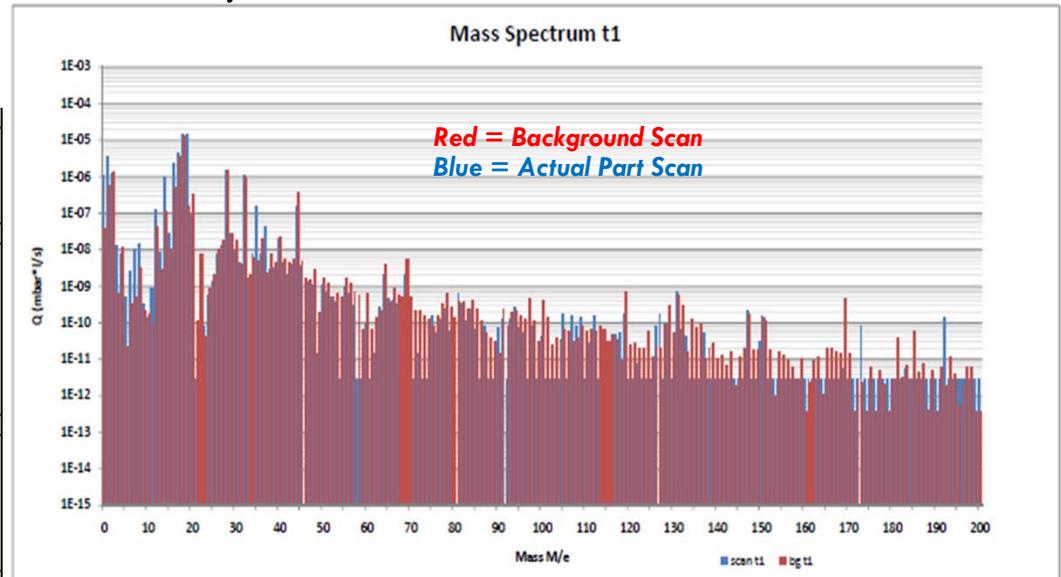
Outgassing report Lithography OEM RGA Scan						1756
<b>Qualification only</b>			<b>Qualification based on mass levels</b>			
Start scan	11-8-2014 12:58	Customer ID	XXXXXX			
Batch nr	1756	Operator ID	FM			
Travellers ID	XXXX	Planner ID	FM			
Date Background: 10-06-12		Date sample: 11-08-14				
Area system: 25000 cm2		Area sample 0 cm2				
Remarks RGA Scan TEST ONLY						
<b>Background</b> 10-06-12		<b>Batch nr 1741</b>				
t1 (hours)	Ptot	3.24E-08 mBar		Seff	326.20 l/s	
5:00:09	IC tot	1.18E-08 A		Ratio	2.74 mBar/A	
	Q (mBar.l/s)	LDL (mBar.l/s)	Q/cm2 (mBar.L/s.cm2)			
Water	5.37E-06	1.07E-05	2.15E-10			
CxHy (45-100)	1.74E-08	3.48E-08	8.97E-13			
CxHy (101-200)	1.93E-09	3.88E-09	7.73E-14			
t2 (hours)	Ptot	2.31E-08 mBar		Seff	326.20 l/s	
10:00:19	IC tot	7.78E-09 A		Ratio	2.97 mBar/A	
	Q (mBar.l/s)	LDL (mBar.l/s)	Q/cm2 (mBar.L/s.cm2)			
Water	3.42E-06	8.83E-06	1.37E-10			
CxHy (45-100)	9.83E-09	1.93E-08	3.85E-13			
CxHy (101-200)	1.10E-09	2.19E-09	4.38E-14			
<b>Sample</b> 11-06-12		<b>Batch nr 1756</b>				
Sample is background subtracted						
t1 hours	Ptot	5.30E-07 mBar		Seff	326.20 l/s	
5:00:09	IC tot	2.29E-07 A		Ratio	2.31 mBar/A	
	Q (mBar.l/s)	Target (mBar.l/s)	Pass/fail	Q/cm2 (mBar.L/s.cm2)		
Water	1.20E-04	1.58E-05	Failed	No area known		
CxHy (45-100)	5.59E-07	3.42E-08	Failed	No area known		
CxHy (101-200)	4.59E-08	2.78E-09	Failed	No area known		
Waterratio	215.4	54.0	-			
WARNING: LDL level > Target level						
t2 hours	Ptot	3.58E-07 mBar		Seff	326.20 l/s	
10:00:19	IC tot	1.55E-07 A		Ratio	2.31 mBar/A	
	Q (mBar.l/s)	Target (mBar.l/s)	Pass/fail	Q/cm2 (mBar.L/s.cm2)		
Water	7.92E-05	1.58E-05	Failed	No area known		
CxHy (45-100)	4.28E-07	3.42E-08	Failed	No area known		
CxHy (101-200)	3.17E-08	2.78E-09	Failed	No area known		
Waterratio	185.9	54.0	-			



# Results and Discussions (Cont'd)

- Figure 7b shows multiple scans for a part cleaned and RGA scanned by QuantumClean®

Outgassing report Lithography OEM RGA Scan				1840
<b>Qualification only</b>		<b>Qualification based on mass levels</b>		
Start scan	16-7-2014 19:48	Customer ID	XXXX	
Batch nr	1840	Operator ID	FM	
Travellers ID	XXXX	Planner ID	FM	
Date Background:	15-07-14	Date sample:	16-07-14	
Area system:	25000 cm2	Area sample	0 cm2	
Remarks	CLEAN AND RGA SCAN TEST			
<b>Background</b>		<b>Batch nr</b> 1836		
t1 (hours)	Ptot	6.76E-08 mBar	Seff	326.20 l/s
4:50:10	IC tot	6.13E-08 A	Ratio	1.10 mBar/A
	Q (mBar.l/s)	LDL (mBar.l/s)	Q/cm2 (mBar.l/s.cm2)	
Water	1.59E-05	3.19E-05	6.38E-10	
CxHy (45-100)	3.89E-08	7.77E-08	1.55E-12	
CxHy (101-200)	4.83E-09	9.66E-09	1.93E-13	
t2 (hours)	Ptot	4.23E-08 mBar	Seff	326.20 l/s
9:50:20	IC tot	1.63E-08 A	Ratio	2.60 mBar/A
	Q (mBar.l/s)	LDL (mBar.l/s)	Q/cm2 (mBar.l/s.cm2)	
Water	8.79E-06	1.76E-05	3.52E-10	
CxHy (45-100)	2.34E-08	4.69E-08	9.37E-13	
CxHy (101-200)	3.04E-09	7.88E-09	1.58E-13	
<b>Sample</b>		<b>Batch nr</b> 1840		
Sample is background subtracted				
t1 hours	Ptot	1.19E-07 mBar	Seff	326.20 l/s
4:50:10	IC tot	1.37E-08 A	Ratio	8.73 mBar/A
	Q (mBar.l/s)	Target (mBar.l/s)	Pass/fail	Q/cm2 (mBar.l/s.cm2)
Water	< LDL (<3.19E-5)	1.50E-05	Not detectable(Passed)	< LDL
CxHy (45-100)	< LDL (<7.77E-8)	3.41E-08	Not detectable(Passed)	< LDL
CxHy (101-200)	< LDL (<9.66E-9)	2.75E-09	Not detectable(Passed)	< LDL
Waterratio	< LDL	54.0	-	-
WARNING: LDL level > Target level				
t2 hours	Ptot	8.11E-08 mBar	Seff	326.20 l/s
9:50:20	IC tot	1.03E-08 A	Ratio	7.86 mBar/A
	Q (mBar.l/s)	Target (mBar.l/s)	Pass/fail	Q/cm2 (mBar.l/s.cm2)
Water	< LDL (<1.76E-5)	1.50E-05	Passed	< LDL see GSA072211
CxHy (45-100)	< LDL (<4.69E-8)	3.41E-08	Passed	< LDL see GSA072211
CxHy (101-200)	< LDL (<7.88E-9)	2.75E-09	Not detectable(Passed)	< LDL
Waterratio	< LDL	54.0	-	-
WARNING: LDL level > Target level				



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# ***Results and Discussions (Cont'd)***

- Figure 7a shows the table and scan charts for two interval “t1” and “t2”. The “t1” in the first part of the table depicts 5 hours of background scan followed by “t2,” which depicts another 5 hours of background scan
- The 2<sup>nd</sup> part of the table shows the data collected from the part/s scanned at “t1” and “t2” intervals. The key elements that are collected in this chart are H<sub>2</sub>O (moisture), CxHy (volatile), CxHy (non-volatile) elements.
- It's clear from Mass Spectrum “t1” and “t2” that this part failed heavily for all the elements including Moisture, Carbon, Boron, Oxygen, Nitrogen, Methanol, CxHy (volatile), CxHy (non-volatile) and Pump oils elements
- Now imagine this part being installed into a EUV lithography tool. The amount of time, expense, and loss of production time involved in detecting this failing part inside the vacuum chamber is astronomical
- Figure 7b depicts the same part cleaned by QuantumClean<sup>®</sup> first and then running through the RGA scans. The table and scan data depicts the condition of the part which will pass inside the EUV lithography tool the first time and every time
- The key to the success is the cleaning and baking of the parts by using QuantumClean<sup>®</sup> proprietary ACS<sup>™</sup> cleaning process

# *Conclusion and Summary*

- This paper presents the importance of parts cleaning using the QuantumClean® ACS™ process for parts used in the Lithography tools mainly EUV tools
- It also places emphasis on the processes used to clean, bake, and analyze the parts prior to installing the parts inside the Lithography vacuum chambers
- Failure to do so can impact the tool performance and integrity along with loss of production time
- QuantumClean® is a preferred cleaning supplier for large Lithography OEM manufacturers
- With QuantumClean® capabilities, we can help all our customers reduce their CoO by providing superior clean parts along with analytical data supporting our cleanliness