Elemental Scientific

Photomask Metal Contamination Detection with Radian7 ICPMS

Process Chamber with Point Nozzle Scanning

Radian7

Automated Photomask Surface Analysis

Radian7 ICPMS with Photomask Load Ports

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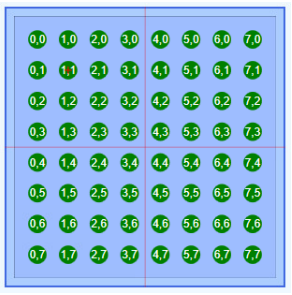
Evaluation of Ultra-Trace Metal Detection Limits on Photomasks Using Radian7 ICPMS

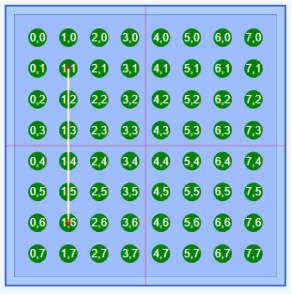
Synopsis

Photomasks play a critical role in defining circuit features in semiconductor lithography. Even single-digit ppt contamination of critical elements such as silver can cause defects. Radian7 ICPMS enables ultra-trace metal detection on photomask blanks (raw quartz) as well as implanted and patterned photomasks through a fully automated scanning process and metals detection by ICPMS. For this work photomask blanks are automatically analyzed using a Radian7 equipped with three SMIF load ports with robotic reticle handling. A variety of scanning patterns and edge exclusion scans adapted to mask type provides detection of spatial distribution of metal and metal nanoparticle contamination on each photomask. Detection limits and recovery efficiency of metal contamination were determined by scanning a blank photomask multiple times. High droplet retention was achieved across all scans, allowing detection of trace metals at single-digit ppt levels, corresponding to E5-E8 atoms/cm^2 on the surface.

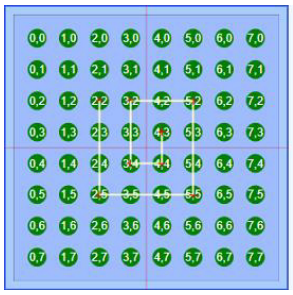
Sector Scanning with Radian7 on Photomasks



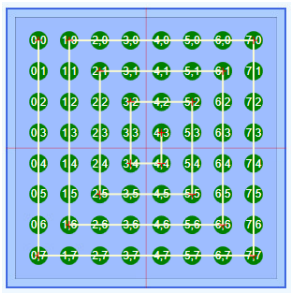
Single Point (1, 1)



Line



Center Section



Whole Mask

Radian7 includes a sector scanning function that allows users to define custom scan geometries such as single points, lines, boxes, or whole surface. Parameters such as edge exclusion, droplet overlap, and scan speed are software-controlled, enabling precise targeting of areas most sensitive to yield-impacting defects. This flexibility supports both routine QA and process development for advanced photomasks.

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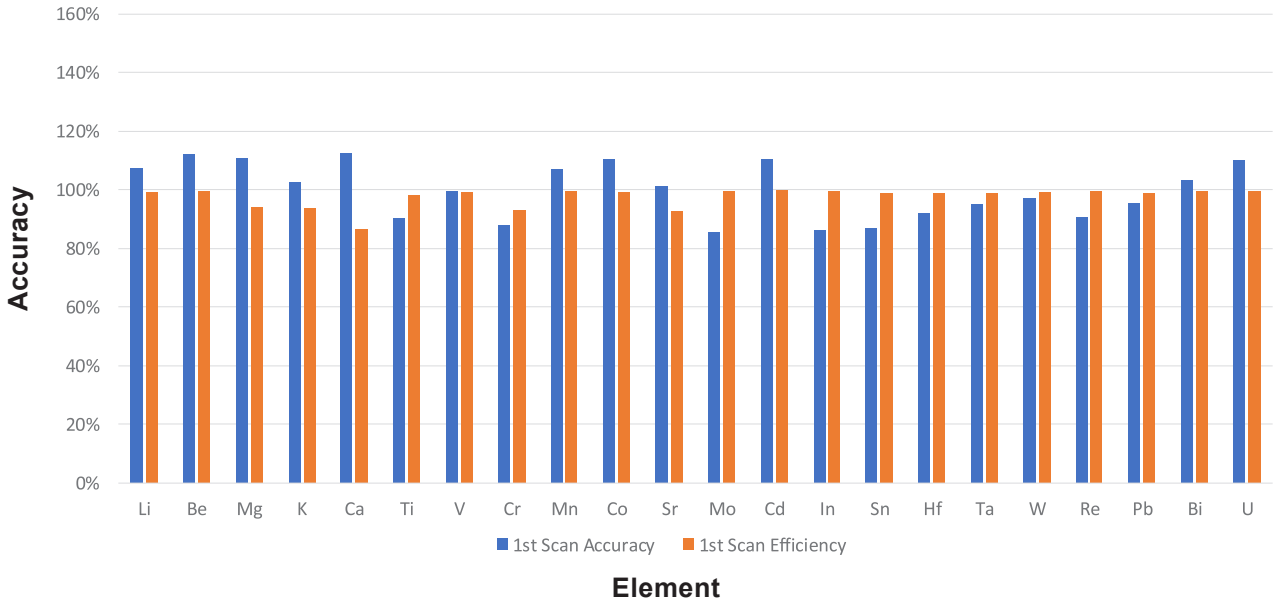
Accurate, Efficient Recovery and Low Detection Limit Analysis

Accurate and Efficient Metals Analysis



Photomasks were spiked with known concentrations of trace metals and scanned under standard RadianVPD operating conditions. The recovered droplets were analyzed by ICPMS, with measured concentrations yielding an average recovery accuracy of 99.7% and a relative standard deviation (RSD) of 9.4%. First-scan recovery efficiency averaged 97.6% with an RSD of 3.4%, demonstrating the system's reliability for quantitative analysis of surface contaminants.

Low Level Detection Limits

Element	On Mask Detection Limit (ppt)	On Mask Detection Limit (atoms/cm²)	Element	On Mask Detection Limit (ppt)	On Mask Detection Limit (atoms/cm²)
Li	0.2	2.2 E+07	Co	0.7	9.4 E+06
Mg	1.5	2.6 E+08	Sr	0.4	3.0 E+06
K	2.0	1.2 E+08	Mo	0.5	3.8 E+06
Ca	2.1	1.1 E+08	Ag	0.1	1.2 E+06
Ti	1.1	7.2 E+07	Cd	0.5	3.6 E+06
V	0.6	9.1 E+06	Ta	0.2	7.4 E+05
Cr	0.8	8.4 E+07	W	0.7	2.7 E+06
Mn	0.7	9.6 E+06	Pb	0.7	2.4 E+06

A blank quartz photomask was scanned seven times using a 500 µL droplet, where the recovered droplets were analyzed by ICPMS. Based on 3 σ statistical analysis of replicate results, the system achieved single-digit ppt detection limits, corresponding to E5-E8 atoms/cm² on the photomask surface. While these results are higher compared to bare silicon wafers due to impurities in the raw quartz, the detection limits are still sufficient to support trace element detection on photomasks.