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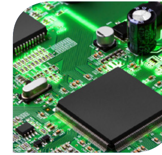

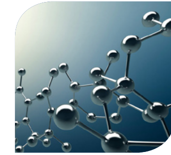

Characterization of Surface Metallic Contamination using TXRF and SurfaceSIMS.XP

In order to control contaminants, it is necessary to identify and quantify them. Utilizing both TXRF and SurfaceSIMS.XP provides the total solution with the best value for surface contamination measurements on semiconductor surfaces.

Ultra-clean surfaces are critically important to the successful processing of semiconductor devices. Likewise, eliminating or reducing Al and other metal surface contamination on silicon wafers is a very critical part of IC processes. To control contaminants, it is necessary to identify and quantify them. Choosing an appropriate measurement technique is important for providing accurate and consistent results. Utilizing both TXRF and SurfaceSIMS.XP (XP = extended profile) provides the total solution with the best detection limits and value for surface contamination measurements.

The present application note highlights some important advantages of using SurfaceSIMS.XP (XP = extended profile) and TXRF to determine surface Al contamination on processed Si wafers.

Features of TXRF

- Survey technique; detection of elements from Na to U.
- Non-destructive, automated analysis in a clean room environment.
- Whole wafers 200 - 300 mm. Smaller wafers down to 50 mm may be also mounted for analysis.
- Large analysis area (10 mm diameter) at a glancing angle below critical angle.
- Detection limits ranging between 1e9-1e10 atoms/cm^2 for most metals.
- Long-term precision: <20% RSD.
- Derived fromASTM Method (F1526-95)
- Applicable substrates: Si, SiO_2, SiC, GaAs, sapphire, InP, and others.

As a survey technique, TXRF provides high sensitivity multi-element surface contamination measurements at a low cost.

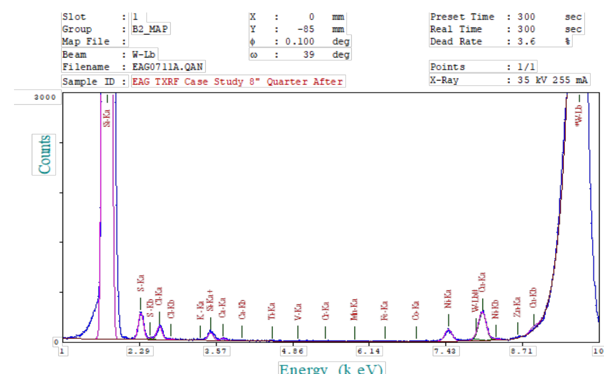

Figure 1: TXRF spectrum of metallic impurities on Si wafer

Features of SurfaceSIMS.XP

- Element-specific detection of all elements and isotopes, especially light elements (H-S) where TXRF has poor detection efficiency.
- ASTM methods (F1617-98) for Al, Na, K and Fe contamination on silicon and epi substrates.
- Measurement of near surface depth distributions, providing both surface and in-depth detection of contamination.
- Small analysis areas (minimum 50x50 μ^2) - very useful for device applications and for navigating measurements between airborne particles.
- Detection limits ranging between 1e8-1e9

atoms/cm^2 for most metals.

- Long-term precision: ~10% RSD.
- Applicable substrates: Si, SiO_2, SiC

SurfaceSIMS.XP provides (1) areal densities of surface contaminants and (2) information about the near-surface depth distribution of contaminants. This represents an important advantage over TXRF, and VPD-ICPMS.

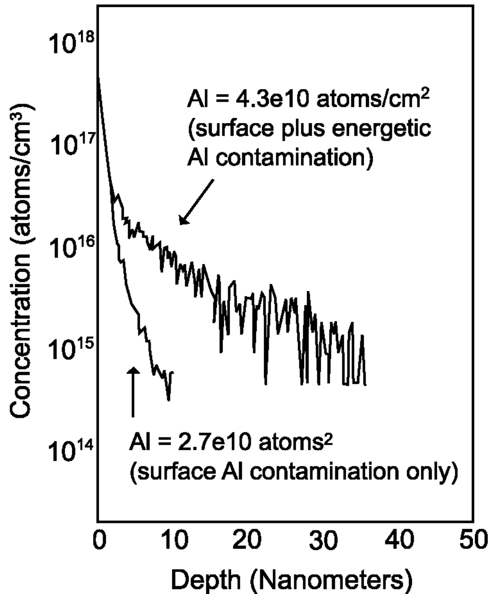

Figure 2: SurfaceSIMS.XP depth profiles of Aluminum in Si

SurfaceSIMS is an ASTM approved method for measuring Na, Al, K and Fe contamination on silicon substrates (ASTM F 1617). On bare Si wafers, SurfaceSIMS provides very similar results over several measurement decades, comparable to other surface metal contamination measurement techniques such as TOF-SIMS and VPD-based techniques. SurfaceSIMS results are reported as contaminant areal densities (atoms/cm^2).

SurfaceSIMS.XP is an extension of the SurfaceSIMS method where the same analytical conditions are used, but data is reported in the form of a complete SIMS depth profile. It not only provides surface area densities (atoms/cm2) but also detects any non-silicon residual film covering a processed wafer. When processed wafers are covered with a thin residue other than native Si oxide, TOF-SIMS, and VPD-based techniques may not be suitable methods for contamination measurement. These methods will provide incorrect results if the metal contaminants are buried, and analyses are terminated too early (TOF-SIMS), or if recovery yields are too low due to inappropriate extraction chemistry (VPD). However, since SurfaceSIMS.XP is a depth profiling technique, it has distinct advantages in certain cases, and should be the method of choice for the analysis of many processed Si wafers.

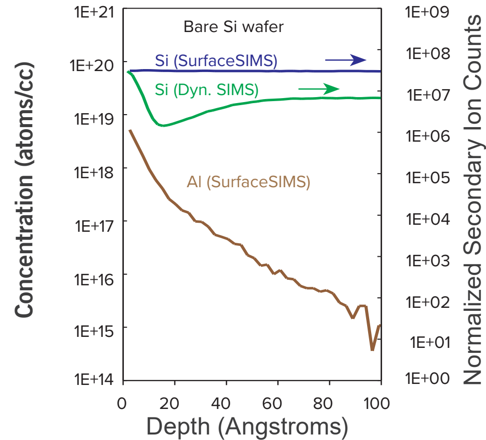

Figure 3: Al contamination on a bare silicon wafer measured with SurfaceSIMS.XP. Si is also measured with SurfaceSIMS.XP and conventional dynamic SIMS. The Si profile measured with dynamic SIMS shows the presence of a native oxide on the Si surface as seen in the SIMS surface transient region. The flat Si profile obtained by SurfaceSIMS.XP shows that the transient effect is eliminated by oxygen flooding which maintains surface oxidations despite sputtering.

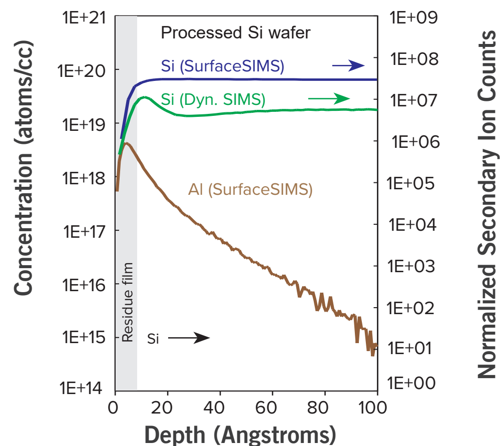

Figure 4: Al contamination on a processed silicon wafer. The Si profile indicatesthe presence of a thin residual layer on the silicon surface. Al appears to be at the interface instead of the top surface. Incomplete oxidation of the buried Si surface is observed by the temporary increase in the Si count rate in the dynamic SIMS profile. For such processed samples, only SurfaceSIMS.XP will be able to provide accurate and consistent contamination measurements.

Typical Detection Limits of Selected Elements (10^{10} atoms/cm^2) on Silicon					
Elements	**TXRF**	**SurfaceSIMS.XP**	**Elements**	**TXRF**	**SurfaceSIMS.XP**
Li	*	0.001	V	2	0.01
B	*	0.1	Cr	0.7	0.03
C	*	100	Mn	0.6	0.05
N	*	300	Fe	0.3	0.05
F	*	40	Ni	0.3	0.5
Na	*	0.01	Cu	0.3	0.3
Mg	*	0.05	Zn	0.8	0.5
Al	*	0.05	As	3	0.5
P	*	1	Mo	*	0.1
S	50	2	Rh	20	0.7
Cl	20	20	Sb	20	0.7
K	40	0.01	Sn	*	0.1
Ca	10	0.05	Ta	3	0.1
Ti	2	0.05	W	10	0.2

* These elements cannot be detected by TXRF or cannot be measured at practical levels. In some cases, spectral interferences prevent detection at low levels.

SIMS at EAG

When controlling contaminants SurfaceSIMS.XP is best complimented with TXRF. Total Reflection X-ray Fluorescence (TXRF) utilizes extremely low-angle X-ray excitation of a polished wafer surface to obtain the concentration of surface metallic contaminants. A highly surface-sensitive technique, TXRF is optimized for analyzing surface metal contamination on semiconductor wafers such as Si, SiC, GaAs or Sapphire.

EAG is the global industry standard for SIMS analysis, offering the best detection limits, along with accurate concentration and layer structure identification. EAG's depth and scope of experience and commitment to research and development in the SIMS field is unrivaled. EAG has the largest range of Secondary Ion Mass Spectrometry instruments worldwide (more than 40), staffed by exceptionally qualified scientists. EAG also has the world's largest reference material library of ion-implanted and bulk-doped standards for accurate SIMS quantification.

EAG's SIMS scientists are specially trained and adept at understanding our client's analytical needs and optimizing analyses to address their concerns and interests most effectively. Today, SIMS analysis is widely used to help customers across a variety of industries for research and development, quality control, failure analysis, troubleshooting and process monitoring. EAG provides personal service throughout the process to allow a complete understanding of the SIMS lab test results.

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