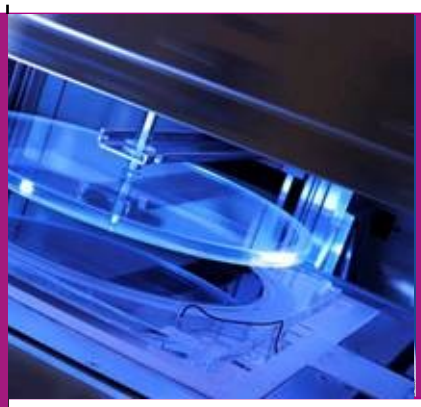
BALAZS™ nanoanalysis

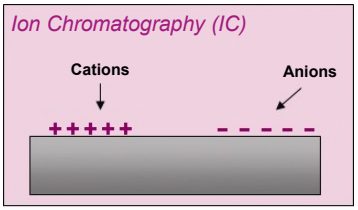
# Wafer Surface Testing

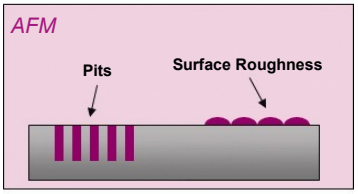


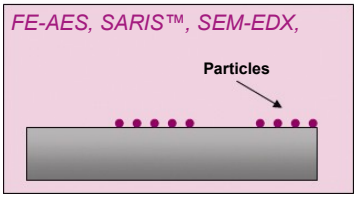
## For Improving the Lifespan of Integrated Circuit (IC) Chips

The ideal single crystal silicon surface is modeled as a perfect silicon crystalline lattice which is terminated with Si-Si or Si-H bonds. Real world silicon surfaces are oxidized silicon species covered with particles, adventitious organic materials, metallic and ionic contaminants and significant levels of silicon lattice defects. High yields in semiconductor processing require consistent surface quality of the starting material and processed surface such as after a cleaning step, CMP or ion implantation.

### Surface Molecular Contamination (SMC)




- Molecular acid:
  Forms pits and haze - $NO_x$ and $SO_x$ can be from inside or outside air; $H_2SO_4^{2-}$, $HCl^-$, $HF^-$, $H_3PO_4^{3-}$, and $HNO_3$ may be vaporization products from cleaning and etch baths; may cause roughness can gate oxide (GOI) failure when the gate oxide thickness is around 2 nm.
- Molecular base:
  Causes hazing - generally from insufficient rinsing and AMC (airborne molecular contamination) and caused by a high concentration ($10^{13}$ - $10^{15}$ atoms/cm$^2$) of any anions and cations on the Si surface.
- Molecular condensable (organics):
  Causes pseudo-increase in apparent native oxide film thickness from adsorption of outgassed organics from the environment (cleanroom materials) and wafer packaging such as carriers; molecular surface density of sub-ng/cm$^2$ equivalent to 1x$10^{13}$ molecules/cm$^2$ can contribute to film delamination.
- Molecular dopant: Results in counter-doping; common sources are AMC -MC and AMC-MD, such as boron from HEPA filters


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*Table 1. Wafer surface molecular contamination (SMC) tests*

| Analyte | Technique | Sample Type | Sample Size | Results |
|---|---|---|---|---|
| **Trace Elements** | VPD-ICP[1, 2] | Bare, oxide, BPSG, SiN and other wafers | Up to 450mm | See note [1] and [2] |
| | TXRF | Bare, oxide, BPSG, SiN and other wafers | Up to 300mm | Wo or Mo anode [3] |
| **Dopants** | DSE-ICP-MS | Bare or witness wafers | Up to 450mm | Boron and Phosphorus |
| **Organics** | TD-GC-MS | Witness wafers | Up to 300mm | Organics |

1. 16 elements: Al, Ca, Cr, Co, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, Ti, V and Zn.
2. 35 elements: Al, As, B, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Fe, Ga, Ge, Hf, In, K, Li, Mg, Mn, Mo, Mn, Na, Ni, Pb, Sb, Sn, Sr, Ta, Ti, W, V, Y, Zn and Zr
3. 13 elements: Ca, Cl, Co, Cr, Cu, Fe, K, Mn, Ni, S, Ti, V, and Zn

## Defect Density Determination by Etching

Etch pit density determination for process wafers and epi film are industry standard measurements used to improve yields of semiconductor devices. Blanket films or entire wafer surfaces are processed utilizing various chemistries to enhance defects followed by optical quantification of the defect which has been developed. This methodology has made the transition to photovoltaic substrates and is useful in determining the quality of the purchased substrate stock material.

Selection of the etch solutions allows enhancement of defects through the use of isotropic or anisotropic etchants. These etchants will enhance the different categories of defects which may be critical to a particular process step. Balazs™ NanoAnalysis can advise process engineers as to the type of etchants which are most suitable to a particular yield issue.

## Surface Roughness Determination by Atomic Force Microscopy (AFM)

### Materials Evaluation

- Surface roughness on as-received silicon wafer surfaces
- Evaluation of $R_a$ for thin film materials prior to and after processing (includes chemical and physical etching)
- Grain size and shape analysis
- Power spectrum

### Quality Control

- Surface profiles of thin film and thick coatings
- Metrology of semiconductor devices, LEDs and PV thin films
- Surface finish of glass and metal substrates
- Ion implantation
- Thermal annealing furnace

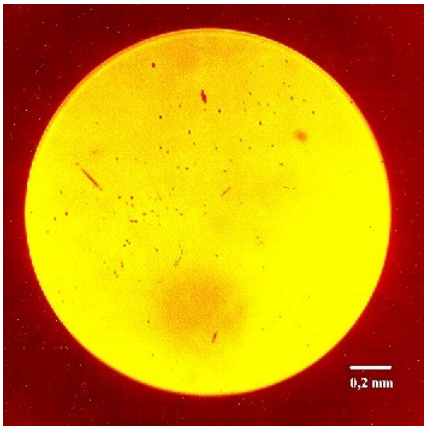


*Figure 1. Etched wafer - the small dark dots are the hillocks produced by defects*