



Standard Test Method for Measuring Surface Sodium, Aluminum, Potassium, and Iron on Silicon and EPI Substrates by Secondary Ion Mass Spectrometry¹

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1. Scope

1.1 This test method covers the determination of total sodium, aluminum, potassium, and iron on the surface of mirror-polished single crystal silicon and silicon epi substrates using secondary ion mass spectrometry (SIMS). This test method measures the total amount of each metal, because this test method is independent of the metal's chemistry or electrical activity.

1.2 This test method can be used for silicon with all dopant species and dopant concentrations.

1.3 This test method is especially designed to be used for surface metal contamination that is located within approximately 5 nm of the surface of the wafer.

1.4 This test method is especially useful for determining the surface metal areal densities in the native oxide or chemically grown oxide of polished silicon substrates after cleaning.

1.5 This test method is useful for sodium, aluminum, potassium, and iron areal densities between 10^9 and 10^{14} atoms/cm². The limit of detection is determined by either the BLANK value or by count rate limitations, and may vary with instrumentation.

1.6 This test method is complementary to:

1.6.1 Total reflection X-ray fluorescence (TXRF), that can detect higher atomic number Z, surface metals such as iron, but does not have useful ($<10^{11}$ atoms/cm²) detection limits for sodium, potassium, and aluminum on silicon.

1.6.2 Electron spectroscopy for chemical analysis and Auger electron spectroscopy that can detect metal surface areal densities down to the order of 10^{12} to 10^{13} atoms/cm².

1.6.3 Vapor phase decomposition (VPD) of surface metals followed by atomic absorption spectroscopy (AAS) or inductively coupled plasma mass spectrometry (ICP-MS) of the VPD residue, where the metal detection limits are 10^8 to 10^{10} atoms/cm². There is no spatial information available and the VPD preconcentration of metals is dependent upon the chemistry of each metal.

1.7 *This standard does not purport to address all of the*

safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process²

E 673 Terminology Relating to Surface Analysis³

3. Terminology

3.1 All terms in this test method are in conformance with those given in Terminology E 673.

4. Summary of Test Method

4.1 Specimens of mirror-polished single crystal silicon are loaded into a sample holder. The holder is transferred into the analysis chamber of the SIMS instrument.

4.2 A primary ion beam, typically O₂⁺, is used to bombard each specimen with a sputter rate less than 0.015 nm/s (0.9 nm/min).

4.3 The area of analysis may be different for different instruments and may range from 100 μm × 100 μm to 1 mm × 1 mm.

4.4 Depending upon instrumentation, a molecular oxygen jet or leak may be focused on the analysis area.

4.5 The positive secondary ions ²³Na, ²⁷Al, ³⁹K, and ⁵⁴Fe are mass analyzed by a mass spectrometer, and detected by an electron multiplier (EM) or equivalent high-sensitivity ion detector as a function of time until the signals reach background levels or 1 % of the initial signal rates of each element. The instrumentation must be able to discriminate the elemental ion signals from molecular interferences.

4.6 A BLANK silicon sample is used to evaluate whether the lower limit of detection arises from molecular ion interferences, elemental instrumental backgrounds, or count rate limitations. The matrix positive secondary ion count rate for silicon (²⁸Si, ²⁹Si, or ³⁰Si) is measured by a faraday cup (FC) or appropriate detector during, or at the end of, the profile. If

¹ This test method is under the jurisdiction of ASTM Committee F-1 on Electronics and is the direct responsibility of Subcommittee F01.06 on Silicon Materials and Process Control.

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² Annual Book of ASTM Standards, Vol 14.02.

³ Annual Book of ASTM Standards, Vol 03.06.