Designation: E1162 – 11

Standard Practice for Reporting Sputter Depth Profile Data in Secondary Ion Mass Spectrometry (SIMS)[1]

This standard is issued under the fixed designation E1162; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the information needed to describe and report instrumentation, specimen parameters, experimental conditions, and data reduction procedures. SIMS sputter depth profiles can be obtained using a wide variety of primary beam excitation conditions, mass analysis, data acquisition, and processing techniques (**1-4**).[2]

1.2 *Limitations*—This practice is limited to conventional sputter depth profiles in which information is averaged over the analyzed area in the plane of the specimen. Ion microprobe or microscope techniques permitting lateral spatial resolution of secondary ions within the analyzed area, for example, image depth profiling, are excluded.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *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:*[3]

E673 Terminology Relating to Surface Analysis (Withdrawn 2012)[4]

3. Terminology

3.1 For definitions of terms used in this practice, see Terminology E673.

4. Summary of Practice

4.1 Experimental conditions and variables that affect SIMS sputter depth profiles (**1-4**) and tabulated raw data (where feasible) are reported to facilitate comparisons to other laboratories or specimens, and to results of other analytical techniques.

5. Significance and Use

5.1 This practice is used for reporting the experimental conditions as specified in Section 6 in the "Methods" or "Experimental" sections of other publications (subject to editorial restrictions).

5.2 The report would include specific conditions for each data set, particularly, if any parameters are changed for different sputter depth profile data sets in a publication. For example, footnotes of tables or figure captions would be used to specify differing conditions.

6. Information to Be Reported

6.1 *Instrumentation:*

6.1.1 If a standard commercial SIMS system is used, specify the manufacturer and instrument model number and type of analyzer, such as, magnetic sector, quadrupole, time-of-flight, and so forth. Specify, the model numbers and manufacturer of any accessory or auxiliary equipment relevant to the depth profiling study (for example, special specimen stage, primary mass filter, primary ion source, electron flood gun, vacuum pumps, data acquisition system, and source of software, etc.).

6.1.2 If a nonstandard commercial SIMS system is used, specify the manufacturer and model numbers of components (for example, primary ion source, mass analyzer, data system, and accessory equipment).

6.2 *Specimen:*

6.2.1 Describe the specimen as completely as possible. For example, specify its bulk composition, preanalysis history, physical dimensions. If the specimen contains dopants, for example, semiconductors, report the dopant type and concentration. For multicomponent specimens, state the degree of specimen homogeneity. Describe any known contaminants.

6.2.2 State the method of mounting and positioning the specimen for analysis. Specify any physical treatment of the specimen mounted in the SIMS analysis chamber (for example,

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[1] This practice is under the jurisdiction of ASTM Committee E42 on Surface Analysis and is the direct reponisibility of Subcommittee E42.06 on SIMS.

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[2] The boldface numbers in parentheses refer to the references at the end of this standard.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] The last approved version of this historical standard is referenced on www.astm.org.

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heated, cooled, electron bombarded, and so forth). Note the specimen potential relative to ground. Describe the method of specimen charge compensation used (if any), for example, conductive coatings or grid, electron flooding, etc.

6.3 *Experimental Conditions:*

6.3.1 *Primary Ion Source*—Give the following parameters whenever possible: Composition of beam (if mass filtered, give the specific ion and isotope, for example, $^{16}O^{-}$); angle of incidence (relative to the surface normal); ion beam energy; charge state and polarity; current (including the method used for measurement, for example, Faraday cup); beam diameter (including the method used for measurement); size and shape of sputtered area; primary beam current density for a stationary beam (A/m^2); beam raster size and rate (if used); primary ion dose rate averaged over the sputtered area (ions/m^2·s). If the primary ion beam is pulsed at some point during the profile (such as in a time-of-flight SIMS) details of the pulsing should be described (pulse width, repetition rate, extent of beam bunching, and so forth). In addition, any special alignment or tuning of the primary column should be specified or referenced. State if this is a dual beam or single beam analysis. In the case of dual beam depth profiling (one continuous and the other pulsed), parameters of both primary ion sources should be described in detail.

6.3.2 *Secondary Ion Mass Spectrometer*—Give the following parameters whenever possible: analyzed area versus total sputtered area (for example, image field/selected area aperture size for stigmatic ion microscopes; raster/electronic signal gating for ion microprobes, and so forth); collection angle (angle between surface normal and secondary ion collection optics); the spectrometer energy acceptance/bandpass within the secondary ion energy distribution used during depth profiles (particularly important if energy discrimination is used to remove polyatomic ion interferences); reflectron voltages, pulsing conditions, and post-acceleration voltages for time-of-flight instruments; mass resolution ($M/\Delta M$ where ΔM is the peak width at a specified fraction of the maximum intensity (such as, 50 % or 10 %) for an ion peak of mass M); method used to perform selected ion monitoring during sputtering (for example, electrostatic or magnetic peak switching procedures for double focusing instruments); the type of specimen charge compensation used if any (for example, changes in sample potential biasing during depth profile). If any electron flood gun is employed, specify electron current or dose (electrons / m^2).

6.3.3 *Secondary Ion Intensity Measurement*—Specify the type of detector (for example, electron multiplier, Faraday cup) and detector bias used including the counting (integration) time used for each measurement of each ion of interest. For analog detection, give the detector system time constant. For pulse counting detection, give the pulse pair resolution including dead time corrections. For rapidly rastered primary beams, correct intensities (counts/second) to instantaneous values by multiplying by the ratio of total sputtered area to the analyzed area (important procedure to help assess possible detector saturation limitations (**5**)).

6.3.4 *Vacuum*—Specify pressures in the primary column, specimen chamber and mass spectrometer prior to and during sputter depth profiling, including the type of vacuum pumping. Also give the composition of the residual gas, if available. If flooding of the sample surface region or backfilling of the analysis chamber with reactive gases (for example, oxygen) is used give the details of the procedure including the partial pressure of the reactive gas.

6.4 *Quantification by Data Reduction:*

6.4.1 *Concentrations*—If any elemental concentrations are presented, state clearly the methodology used for quantification (**6 and 7**). In addition, specify the details of any external or internal standards used including methods for normalization in comparing ion intensities in reference materials to ion intensities in specimen depth profiles. A commonly used method makes use of Relative Sensitivity Factors derived from measurements of ion-implanted reference materials to calculate impurity concentrations in similar matrices (**8**). Specify reference materials made by ion implantation according to ion species, isotope, dose, energy, matrix, and reference data used to calculate peak concentration of the implant in the reference material. Report analytical precisions for multiple determinations of concentrations.

6.4.2 *Depth Scales*—Specify the methods used (if any) to relate elapsed sputter time to a depth sputtered (that is, depth scale calibration). Possible techniques include measurements of: times to remove reference material films of known thickness, ion implant standards with peak concentrations occurring at calculated depths (for example, by TRIM of SRIM simulation (**9**)), or crater depths via various stylus profilometry or interferometry techniques. Report any nonuniform sputtering of the specimen, if observed.

6.5 *Display of SIMS Sputter Depth Profile Figures:*

6.5.1 *Raw Ion Intensity Versus Sputtering Time (or Fluence) Profiles*—The left hand vertical axis should be ion intensities measured in arbitrary units (analog detection), or in instantaneous counts per second (pulse counting, see 6.3.3). The intensity axis can be either linear or logarithmic depending upon suitability relative to the dynamic range of the profile. The scale selected should be clearly indicated. The bottom horizontal axis should be the sputtering time reported in time units or fluence (coulomb/m^2 or ions/m^2). If the primary ion parameters are changed during the profile in a manner that affects the sputter rate, the time axis must be adjusted accordingly.

6.5.2 *Quantified Depth Profiles*—If elemental concentrations or depth scales are quantified as described in 6.4.1 and 6.4.2, use the following procedure. The right hand vertical axis can be reported in units of atomic percent, weight percent, or atoms per cubic metre/centimetre, whichever is most convenient or appropriate. The top horizontal axis can be indicated in units of depth (typically nanometres or micrometres). An example of the format is shown in Fig. 1 for a ^{11}B implant profile in silicon.

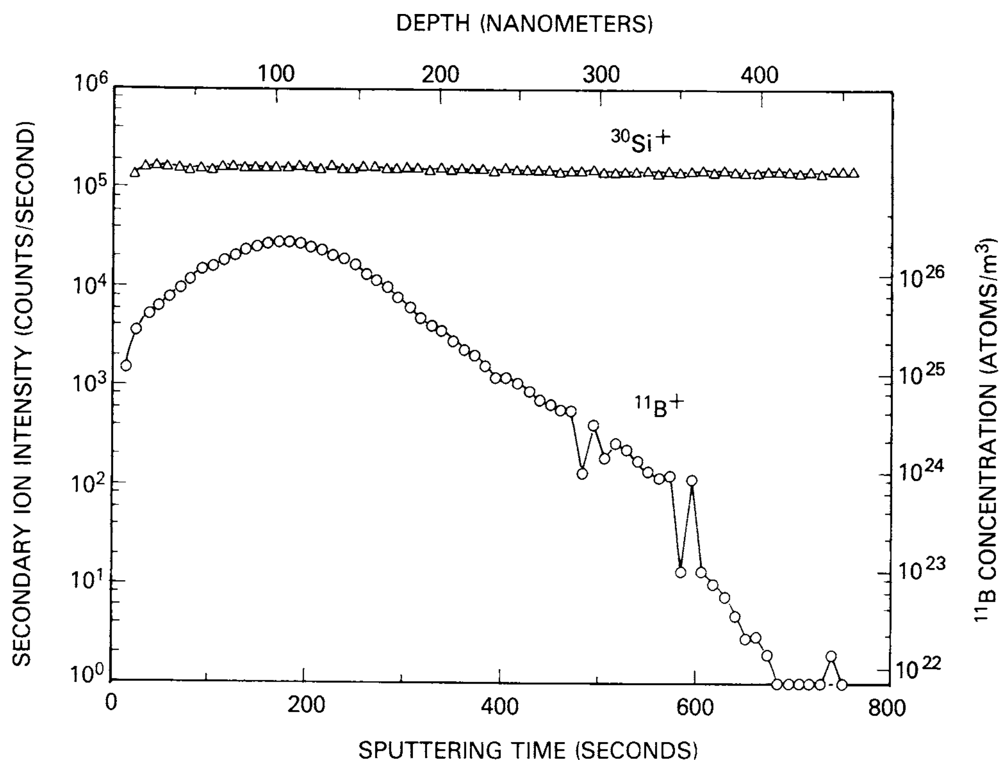

FIG. 1 SIMS Sputter Depth Profile of Boron in Silicon

REFERENCES

(1) Hofmann, S., "Quantitative Depth Profiling in Surface Analysis," *Surface and Interface Analysis*, Vol 2, 1980, p. 148.

(2) Zinner, E., "Depth Profiling by Secondary Ion Mass Spectrometry," *Scanning* , Vol 3, 1980, p. 57.

(3) Wittmaack, K., "Depth Profiling by Means of SIMS: Recent Progress and Current Problems," *Radiation Effects*, Vol 63, 1982, p. 205.

(4) Williams, P., "Secondary Ion Mass Spectrometry," *Applied Atomic Collision Physics*, Vol 4, 1983, p. 327.

(5) Traxlmayr, U., Riedling, K., and Zinner, E., "On the Dead-Time Correction of Ion Counting Systems During Gated Raster SIMS Measurements," *International Journal of Mass Spectrometry and Ion Processes*, Vol. 61, 1984, p. 261.

(6) Werner, H.W., "Quantitative Secondary Ion Mass Spectrometry: A Review," *Surface and Interface Analysis,* Vol 2, 1980, p. 56.

(7) Wittmaack, K., "Aspects of Quantitative Secondary Ion Mass Spectrometry," *Nuclear Instruments and Methods,* Vol 168, 1980, p. 343.

(8) Wilson, R.G., Stevie, F.A., and MAgee, C.W., *Secondary Ion Mass Spectrometry—A Practical Handbook for Depth Profiling and Bulk Impurity Analysis*, John Wiley & Sons, New York, 1989, pp. 3.1-1–3.1-7.

(9) Ziegler, J.F., Biersack, J.P., and Littmark, U., *The Stoping and Range of Ions in Solids*, Pergamon Press, New York, 1985, http://www.srim.org.

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