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Standard Guide for Reporting of Ion Beam Parameters Used in Surface Analysis[1]

This standard is issued under the fixed designation E 1577; 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 guide covers the information needed to characterize ion beams used in surface analysis.

1.2 This guide does not cover all information required to perform a sputter depth profile (see referenced documents), specify any properties of the specimen except its surface normal, and discuss the rationale for choosing a particular set of ion beam parameters **(1)**.[2] This guide does assume that the ion flux has a unique direction, that is, is an ion beam, rather than a wide spectrum of velocity vectors more typical of a plasma.

1.3 *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 673 Terminology Relating to Surface Analysis[3]

E 684 Practice for Approximate Determination of Current Density of Large-Diameter Ion Beams for Sputter Depth Profiling of Solid Surfaces[3]

E 996 Practice for Reporting Data in Auger Electron Spectroscopy and X-Ray Photoelectron Spectroscopy[3]

E 1127 Guide for Depth Profiling in Auger Electron Spectroscopy[3]

E 1162 Practice for Reporting Sputter Depth Profile Data in Secondary Ion Mass Spectrometery (SIMS)[3]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this guide, see Terminology E 673.

4. Summary of Guide

4.1 This guide describes ion beam parameters to be reported so that experiments can be reproduced and understood.

5. Significance and Use

5.1 Ion beams are utilized in surface analysis in two ways. First, they can generate signals from the specimen, for example, in SIMS and ISS. Second, they can remove material from the specimen surface while a surface analytical technique determines the composition of the freshly exposed surface. This process is called sputter depth profiling. Ideally, this guide requires reporting all characteristics of the ion beam that can possibly affect the results so that the measurement can be reproduced.

6. Information to be Reported

6.1 *Ion Gun Instrumentation*—Specify the manufacturer, type, and model of the ion gun (as well as of the analytical spectrometer). Report the base pressure of the spectrometer vacuum chamber, the pressure in the vacuum chamber during the ion gun operation, and any information on the gas pressure within the ionization chamber of the ion gun. If a mass filter is used, note its characteristics.

6.2 *Recommended Ion Beam Parameters*— The following ion beam parameters may vary in both space and time. Report such variations. For example the ion beam may be pulsed as is sometimes done in static SIMS. If so, report the pulse duration and repetition rate (Hz). The spatial uniformity of the ion beam can be monitored by measuring the ion current with a Faraday cup whose aperture diameter is much smaller in size than the ion beam diameter **(2)**. If a Faraday cup is used whose aperture is larger than the ion beam diameter, temporal variations of the ion beam current can be observed.

6.2.1 *Composition*—Report species present and their charge states, for example, Ar^{+} and Ar^{++}, as well as their relative concentrations. If a neutral trap is used, report its use and its location.

6.2.2 *Kinetic Energy* (keV)—Report the kinetic energy of the ion beam as it impacts on the specimen surface. It is this energy that controls many ion/solid effects **(1)** rather than the energy of the ion beam as it leaves the gun. These two energies will differ if the specimen is electrically biased.

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[1] This guide is under the jurisdiction of ASTM Committee E-42 on Surface Analysis and is the direct responsibility of Subcommittee E42.08 on Ion Beam Sputtering.

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[2] The boldface numbers given in parentheses refer to a list of references at the end of this guide.

[3] *Annual Book of ASTM Standards*, Vol 03.06.

6.2.3 *Ion Current (A)*—Report the method used to measure the ion beam current. If a Faraday cup is used, note its aperture diameter relative to the ion beam diameter.

6.2.4 *Ion Current Density (A/m^2)*—The ion beam current density is the ion current passing through a unit cross-sectional area whose normal is parallel to the ion beam direction. It can be determined using a small aperture Faraday cup by measuring the total ion current collected by the Faraday cup divided by the area of the Faraday cup aperture and by the cosine of the angle between the ion beam and the normal to the Faraday cup aperture. In this case, the Faraday cup aperture must be small enough so that the current density may be assumed to be constant over the whole Faraday cup aperture.

6.2.4.1 Another method consists of measuring the ion beam current of a rastered ion beam and dividing by the area of the raster. In this case, the raster deflections should be much larger than the ion beam size.

6.2.4.2 Ion current density and ion beam size are further discussed in Practice E 684.

6.2.5 *Ion Beam Size Gaussian*—The two sigma width of a symmetrical Gaussian ion beam may be measured from the distance between 16 and 84 % intensity values as the ion beam is moved perpendicularly across a sharp edge. The full width at half maximum would be equivalent to 1.177 times this value. The axial symmetry may be checked by imaging details of a test sample.

6.2.5.1 If the ion beam is rastered, report the rastered beam dimensions on the specimen.

6.2.6 *Total Dose ($Ions/m^2$)*— Report the total dose, defined as the total charge per unit area that impinges on the specimen, so that ion beam damage can be assessed or number of atoms sputtered can be estimated.

6.2.7 *Angle of Incidence (Degrees)*—Report the angle of incidence, that is, the angle between the specimen surface normal and the incident ion beam direction.

6.2.8 *Specimen Rotation*—If specimen rotation is used, specify rotation rate and any effect on ion beam angle (that is, rotation axis not the sample normal **(3)**).

6.3 *Second Ion Gun*—If a second ion gun is used, for example, to reduce surface roughness, also report its parameters.

6.4 *Alignment of Ion Beam*—Report the procedure for the alignment of the ion beam with the probing beam, for example, an electron beam in Auger electron spectroscopy, so they are coincident on the specimen surface. Examples of this procedure are: use of a Faraday cup to alternately probe the position of each beam; and adjustment of the ion gun deflection voltages or mechanical position until a visible sputter crater is centered on the SEM image in a scanning Auger microprobe, or until the secondary electron images from both the scanning ion beam and electron beam are coincident.

6.5 *Ion Beam Sputtering Rate*—The ion beam sputtering rate can be reported relative to a reference material, such as a thermal silicon dioxide thin film on silicon **(4)**; the NiCr multilayer NIST standard reference material SRM 2135[4] **(5)**; the Cr/Cr oxide NIST standard reference material SRM 2136 **(5)**; or tantalum pentoxide thin film on tantalum[5], the NPL certified reference material **(6)**. The average ion beam sputtering rate on the specimen may be measured from the sputter crater depth divided by sputter etch time. The sputter crater depth is ascertained from a stylus profilometer measurement across the diameter of the sputter crater on the specimen.

7. Keywords

7.1 ion beam sputtering; surface analysis

[4] Available from Standard Reference Materials, National Institute of Standards and Technology, Bldg. 202/Rm. 204, Gaithersburg, MD 20899.

[5] Available from National Physical, Laboratory, Queens Rd., Teddington Middlesex Tw11-01WEngland.

REFERENCES

(**1**) Bevolo, A. J., "Ion-Solid Interactions in Surface Analysis," *Characterization of Semiconductor Materials, Principles, and Methods*, Vol I, G. Mcguire, Ed., Noyes Publ: New Jersey, 1989, pp. 147–232.

(**2**) For a discussion of appropriate Faraday cup dimensions (aperture and depth) and Faraday cup use, see Ingram, G. D. and Seah, M. P., "E: Scientific Instruments," *Journal of Physics*, Vol 22, 1989, pp. 242–249.

(**3**) Zalar, A., *Thin Solid Films 124*, 1989, p. 223.

(**4**) Degreve, B., and Ged, P., *Surface and Interface Analysis*, Vol 5, p. 83, 1983.

(**5**) Fine, J., Navinsek, B., Davarya, F., and Andreadis, T. D., *Journal of Vacuum Science Technology 20*, 449, 1982; Hoffman, S., and Zalar, A., *Surface and Interface Analysis 10*, 1987, p. 7.

(**6**) Hunt, C. P., and Seah, M. P., *Surface and Interface Analysis 5*, 1983, pp. 199–209; Seah, M. P., Holbourn, M. W., Davies, J. A., and Ortega, C., *Journal of Vacuum Science Technology, A5*, 1987, 1988–1993.