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# Standard Terminology Relating to Surface Analysis[1]

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## 1. Scope

1.1 This terminology is related to the various disciplines involved in surface analysis.

1.2 The definitions listed apply to (*a*) Auger electron spectroscopy (AES), (*b*) X-ray photoelectron spectroscopy (XPS), (*c*) ion-scattering spectroscopy (ISS), (*d*) secondary ion mass spectrometry (SIMS), and (*e*) energetic ion analysis (EIA).

## 2. Abbreviations

2.1 Abbreviations commonly used in surface analysis are as follows:

| | |
|---|---|
| AES | Auger electron spectroscopy |
| BS | backscattering spectroscopy |
| CHA | concentric hemispherical analyzer |
| CMA | cylindrical mirror analyzer |
| EIA | energetic ion analysis |
| eV | electron-volts |
| ESCA | electron spectroscopy for chemical analysis |
| FABMS | fast atom bombardment mass spectrometry |
| FWHM | full width at half maximum peak height |
| ISS | ion scattering spectroscopy |
| pp | peak-to-peak |
| RBS | Rutherford backscattering spectroscopy |
| RFA | retarding field analyzer |
| SAM | scanning Auger microprobe |
| SIMS | secondary ion mass spectrometry |
| SNMS | sputtered neutral mass spectrometry |
| XPS | X-ray photoelectron spectroscopy |

## 3. Terminology Definitions

**adventitious carbon referencing**— *XPS,* determining the charging potential of a particular specimen by comparing the experimentally determined binding energy of the *C* 1s binding energy from absorbed hydrocarbon on the specimen with a standard binding energy value.

NOTE 1—A nominal value of 285.0 is often used for the binding energy of the relevant C 1s peak, although some analysts prefer specific values in the range 284.6 eV to 285.2 eV depending on the nature of the substrate.

**analysis:**

*analysis area (specimen)*—two-dimensional region of a specimen surface measured in the plane of that surface from which the entire analytical signal or a specified percentage of that signal is detected.

*analysis volume (specimen)*—three-dimensional region of a specimen surface from which the entire analytical signal or a specified percentage of that signal is detected.

*analysis volume (spectrometer)*—three-dimensional region within a spectrometer from which the entire analytical signal or a specified percentage of that signal is detected.

*analyzer transmission*— see **spectrometer transmission.**

**angle:**

*collection—SIMS,* the angle between the normal to the original specimen surface and the axis of the secondary ion collection optics.

*of detector—EIA, SIMS,* the angle between the incident beam direction and the direction pointing from the beam spot to the center of the detector.

*of emission—AES, XPS,* the angle of emission or ejection of electrons from a solid measured relative to the normal to the surface.

*of incidence*— the angle between the incident beam and the normal to the surface.

*of scattering—EIA,* the angle between the incident beam direction and the direction in which a particle is traveling after it is scattered. If the particle is incident on the detector, this angle will be the same as **angle** *of detector.*

*solid, of detector—EIA,* the solid angle intercepted by the detector, with the radius originating at the beam spot.

*takeoff—AES, XPS* the angle at which particles leave a specimen measured relative to the plane of the specimen surface. (see **angle** *of emission*).

**angle lapping**—a method specimen preparation in which a specimen is mechanically polished at an angle to the original surface.

NOTE 2—This angle may often be less than 1° so that depth information with respect to the original surface is transformed lateral information.

**angle resolved AES**—the recording of Auger electron spectra as a function of angle emission.

*angular distribution of secondary ions*—see **secondary ions**.

**attenuation coefficient**—for a parallel beam of specified particles or radiation, the quantity $\mu$ in the expression $\mu\Delta x$ for the fraction removed in passing through a thin layer $\Delta x$ of a substance in the limit as $\Delta x$ approaches zero, where $\Delta x$ is measured in the direction of the beam.

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**Auger:**

*analysis volume*—see *volume* under **analysis**.

*chemical effects*—*AES,* see **chemical.**

*chemical shift*—*AES,* see **chemical.**

*current*—the electron current due to the emission of Auger electrons.

*electron*—an electron emitted as the result of an Auger process.

*electron yield*— the probability that an atom with a vacancy in a particular inner shell will relax by an Auger process.

*line scan*—a plot of Auger signal strength as a function of displacement along a designated line on the specimen surface. Normally, the abscissa is the line along which the signal is measured and the ordinate is directly proportional to signal strength.

*line shape*—the energy distribution in an Auger spectrum for a particular Auger transition.

*map*—two dimensional image of the specimen surface showing the location of emission of Auger electrons from a particular element. A map is normally produced by rastering the incident electron beam over the specimen surface and simultaneously recording the Auger signal strength for a particular transition as a function of position.

*matrix effects*—see **matrix effects,** *Auger*.

*parameter*—*XPS,* the kinetic energy of the sharpest Auger peak in the spectrum minus the kinetic energy of the most intense photoelectron peak from the same element; the energy of the ionizing photons must be specified.

*peak energy for dN(E)/dE, N(E)*—the designation of the energy of the Auger electron distribution. In *dN/dE* spectra, peak energies should be measured at the most negative excursions of the Auger features. In *N(E)* spectra, peak energies are measured at peak maxima. (Peak energies in *dN/dE* spectra are not the same as those in *N(E)* spectra.)

*process*—the relaxation, by electron emission, of an atom with a vacancy in an inner electron shell.

*signal strengths*—*AES, XPS,* in *dN/dE* spectra, signal strengths are measured as the peak-to-peak heights of the Auger features. In *N(E)* spectra, signal strengths are measured as the heights of the Auger peaks above background. In *I(E),* signal strengths are measured as the areas under the electron energy distribution, *N(E).*

*spectrum, dN(E)/dE, N(E), I(E)*—*AES,* the display of Auger signal strength as a function of electron energy. Auger spectra from solids may be measured as the first derivative of the electron energy distribution and may be designated by *dN/dE.* The Auger electron energy distribution may be designated as *N(E).* With certain type analyzers (for example, the CMA) the displays are *dEN(E)*/dE and *EN(E).* The area under Auger peaks may be designated as *I(E)* with background subtraction method, and integration limits specified.

*transition*—transitions involved in electron emission by an Auger process are designated by indicating the electron shells. The first letter designates the shell containing the initial vacancy and the last two letters designate the shells containing electron vacancies created by Auger emission (for example, KLL, and LMN). When a bonding electron is involved the letter V is used (for example, LMV and KVV). When a particular subshell involved is known this can also be indicated (for example, $KL_1L_2$). Coupling terms may also be added where known ($L_3M_{4,5}M_{4,5};{}^1D$). More complicated Auger processes (such as, multiple initial ionizations and additional electronic excitations) can be designated by separating the initial and final states by a dash (for example, LL-VV and K-VVV). When an Auger process involves an electron from the same principal shell as the initial vacancy (for example, $L_1L_2M$) it is referred to as a Coster-Kronig transition. If both electrons are from the same principal shell as the initial vacancy (for example, $M_1M_2M_3$) it is called a super Coster-Kronig transition.

*transition rate*— the probability per unit time for two bound electrons to undergo energy state transitions such that one will fill an initial core hole vacancy and the other will go to a final state in the positive energy continuum.

**average emission function decay length**— the negative reciprocal slope of the logarithm of a specified exponential approximation to the emission depth distribution function over a specified range of depths, as determined by a straightline fit to the emission depth distribution function plotted on a logarithmic scale versus depth on a linear scale.

**background:**

*inelastic*—*ISS,* the response of the energy filtering and detection system to probe ions that have undergone inelastic scattering events at the specimen surface.

*instrumental*—*ISS,* the response of the energy filtering and detection system to events other than those induced by bombardment of the specimen surface by a beam of probe ions.

*secondary ion*—*ISS,* the response of the energy filtering and detection system to secondary ions produced by bombardment of the target material with probe ions.

*signal*— *for a specific measurement,* any signal present at a particular position due to processes or sources other than those of primary interest.

**backscattered electrons**— *AES,* electrons originating in the incident beam which are emitted after interaction with the target. By convention, electrons with energies greater than 50 eV are considered as backscattered electrons.

**backscattering:**

*energy*— *EIA,* energy of a particle from the analyzing beam after it has undergone a backscattering collision and escaped the specimen.

*factor*— *AES,* the fractional increase in the Auger current due to backscattered electrons.

*spectrum*—*EIA,* a plot of backscattering yield (ordinate) versus backscattering energy (abscissa).

*yield*— *EIA,* the number of particles detected (counts) per unit backscattering energy per incident ion.

**ball cratering**—a method of specimen preparation in which a specimen is polished by a sphere in order to expose compositional changes below the original surface of a specimen with the intent that the depth of these layers can be related to the position on the surface created by the ball.

**beam:**

*analyzing*—same as *incident.*

*current*—the total current incident on the specimen by the primary particle source.

*current density*— the current incident on the specimen per unit area.

*diameter—in surface analysis,* the full width of the incident beam at half maximum intensity measured in a plane normal to the beam direction. This plane must be specified and is often taken at the intersection of the beam center with the specimen.

*divergence, convergence*—angles spanned by the directions of all particles of the incident beam.

*energy*—the energy of the particles incident on the specimen surface, expressed in electron volts (eV).

*energy, primary*— the kinetic energy of the primary beam, usually expressed in kiloelectronvolts (keV).

*incident*—the energetic particles incident on the specimen.

*particle*—atomic or molecular species contained in the incident beam, regardless of state of ionization.

*primary*—a directed flux of particles (ions or neutrals) incident on the specimen.

*profile, primary ion*—the spatial distribution of the primary ion current in a plane perpendicular to the primary ion beam axis.

*size*—the full width at half-maximum of the beam at a given point in space that must be defined.

*spot*—the area on the specimen surface illuminated by the incident beam.

**binary elastic scattering event**— *ISS,* the collision between an incident probe ion and a single surface atom in which the total kinetic energy and momentum are conserved.

**binary elastic scattering peak**— *ISS,* an increase in the spectrometer detection system response above the background level which can be attributed to binary elastic scattering of the probe ion from a surface atom of a particular mass.

**binding energy**—the work that must be expended in removing an electron from a given electronic level to a reference level, such as the vacuum level or the Fermi level.

**blocking geometry**—*EIA,* experimental situation wherein the atom rows or planes of a single crystal target are aligned parallel to a vector from the specimen to the detector.

**Bragg's rule**—an empirical rule formulated by W. H. Bragg and R. Kleeman that states that the stopping cross section of a compound specimen is equal to the sum of the products of the elemental stopping cross sections for each constituent and its atomic fraction, that is,

$$\epsilon(A_xB_y) = x\epsilon_A + y\epsilon_B \tag{1}$$

where:

$\epsilon(A_xB_y)$ = the stopping cross section of the compound, and

$A_xB_y$ and $\epsilon_A$and $\epsilon_B$ = the stopping cross section of elements $A$ and $B$ respectively.

**bremsstrahlung**—*XPS,* photon radiation, continuously distributed in energy up to the energy of the incident electrons, emitted from an anode due to deceleration of incident electrons within the anode. The bremsstrahlung from a conventional X-ray source contributes to the background and the Auger signal strengths in an XPS spectrum.

**cascade mixing**—the rearrangement of the constituents of a solid, within the penetration depth of an incident particle, caused by collisions between the incident particles and the atoms of the solid.

**channel**—*EIA,* an interval of the measured energy of backscattered particles defined by adjacent energy thresholds in the analog-to-digital converter used for spectrum production.

**channeling**—motion of energetic particles along certain axial or planar directions of a crystalline solid as the particles penetrate the specimen. The potentials of the individual atoms of the solid combine to reduce scattering with those atoms.

**channeling**—*SIMS,* the process by which particles preferentially penetrate crystalline specimens in certain crystallographic directions because of the relatively open arrangement of atoms presented to the impinging particle beam.

**characteristic electron loss phenomena**—*AES,* the inelastic scattering of electrons in solids that produces a discrete energy loss determined by the characteristics of the material. The most probable form is due to excitation of valence electrons. For some solids (for example, nontransition metals), inelastic scattering is dominated by plasmon excitations (a collective excitation of valence electrons). For other solids, the inelastic scattering may be due to a combination of plasmon excitation and single valence electron excitations. Inelastic scattering can also occur through the excitation of core level electrons when this is energetically possible.

**characteristic X-rays**—photons emitted by ionized atoms and having a particular distribution in energy and intensity characteristic of the atomic number and chemical environment of the atom; in XPS, the term is ordinarily used in reference to the X-ray source of the spectrometer.

**charge:**

*charge modification*—any method used to alter the amount or the distribution of charge on a specimen surface.

*charge neutralization—ISS, SIMS,* a technique in which a surface under ion bombardment is maintained at a known potential by compensating for the accumulated charge.

*charge referencing*—any method used to adjust the energy scale calibration of a spectrometer to accommodate the effects of steady-state charging of a specimen surface.

**charging potential**—*in surface analysis*, the electrical potential of the surface of an insulating specimen caused by irradiation. If the specimen is heterogeneous, there may be different charging potentials on different areas of the surface.

**chemical:**

*effects—AES,* any change in the shape of an Auger spectrum or in the Auger peak energy for an element which is due to chemical bonding.

*shift— AES, XPS,* a change in peak energy because of a change in the chemical environment of the atom.

*collection angle*—See **angle.**

**collision cascade**—a sequential energy transfer between atoms in a solid as a result of bombardment by an energetic species.

**compositional depth profile**—the chemical composition and the atomic concentration measured as a function of distance from the surface.

**constant energy resolution**— *AES, XPS,* a mode of operation in which the instrumental resolution is constant over the spectrum. See **fixed analyzer transmission.**

**Coster-Kronig transition**— *AES, XPS* Auger process involving an electron from the same principal shell as the initial vacancy (for example, $L_1 L_2M$).

**counts**—*EIA,* events recorded by the detector and registered in a channel of a backscattering spectrum. Counts constitute the ordinate of a BS spectrum.

*integrated*—sum of all counts registered in a given set of channels or their corresponding energy ranges.

*per channel*—number of counts in a single channel; unit of the ordinate of a backscattering spectrum.

**crater edge effect**—*SIMS,* a signal caused by secondary ions that originate from depths shallower than the maximum depth of the crater formed by primary bombardment.

**cross section:**

*enhanced elastic—EIA,* cross section for elastic scattering that is larger than that predicted by *Rutherford* due to partial penetration of a nucleus in the specimen by the incident particle.

*nuclear reaction—EIA,* the probability of a particular nuclear reaction as a function of energy and the emission direction of the detected product. Usually expressed as an area in units of barns = $10^{-28}$ m$^2$.

*Rutherford—EIA,* nuclear reaction cross section for the particular case of elastic scattering as calculated from classical mechanics. First evaluated by *Rutherford.*

*stopping—EIA,* the energy loss of a particle incident on the specimen per unit area density of specimen atoms. Usually expressed in units of eV·cm$^2$/atom.

**cross-sectioning**—a method in which a specimen is mechanically cleaved, cut, or polished in a plane perpendicular to the interface under study, so that associated compositional differences or gradients in the plane of the polished surface may be observed.

**current integration**—the measurement of total electric charge deposited into a specimen by the incident beam.

**curve resolving**—the construction of the individual peaks of a spectrum that consists of overlapping peaks, also called curve fitting or peak fitting.

**deconvolution**—*AES, XPS,* a mathematical procedure to (*1*) remove the contribution to a peak of one of the factors contributing to its line width, for example, X-ray linewidth, analyzer broadening; or (*2*) remove the energy loss background by deconvoluting the spectrum with an electron energy loss spectrum.

**deep emission function decay length**—the asymptotic emission function decay length for increasing depths from the surface.

**depth profiling**—*AES, XPS, SIMS,* monitoring the signal strength as a function of some variable (for example, sputtering time) that can be related to distance from the surface.

**depth resolution**—*AES, XPS, SIMS,* the depth range over which a signal increases (or decreases) by a specified amount when profiling an ideally sharp interface between two media. By convention, the depth resolution corresponds to the distance over which a 16 % to 84 % (or 84 % to 16 %) change in signal is measured.

**depth scale**—*EIA,* a relationship between energy loss and target depth that allows a direct correlation between multichannel analyzer channel number and depth in the specimen.

**detection limit**—the smallest concentration of an element or compound that can be measured for specific analysis conditions and data collection periods.

DISCUSSION—By convention, the detection limit is often taken to occur when the total signal minus the background signal is two or three times the standard deviation of the background signal above the background signal. This convention may not be applicable to all measurements.

**detector:**

*angle— EIA,* see **angle** *of detector:*

*efficiency—EIA,* fraction of particles incident on the detector that actually generate a detectable signal.

*foil— EIA,* a thin sheet, usually metal or plastic, placed over a detector to absorb low energy or high mass products, or both, from nuclear reactions, while transmitting other reaction products.

*solid angle*—see **angle,** *solid, of detector.*

**dose**—number of beam particles per unit area that impinge on the specimen. Alternatively, the dose may be defined as the charge per unit area that impinges on the specimen.

*rate*—number of beam particles per unit area per second that impinge on the specimen. Alternatively, the dose rate may be defined as the current per unit area that impinges on the specimen.

**effective attenuation length**—the average emission function decay length when the emission depth distribution function is sufficiently close to exponential for a given application.

**electron:**

*flooding—in surface analysis,* irradiation of a specimen with low-energy electrons in order to change (generally to reduce) or stabilize the charging potential.

*inelastic mean free path*—the average of distances, measured along the trajectories, that particles with a given energy travel between inelastic collisions in a substance.

*retardation—AES, XPS,* a method of measuring the kinetic energy distribution by retarding the emitted electrons before or within the analyzer.

*spectrometer*—see **electron energy analyzer**.

**electron energy analyzer**— *AES, XPS,* a device for measuring the number of electrons as a function of kinetic energy. (See also **spectrometer**)

*pass energy—XPS, AES,* the mean kinetic energy of electrons in the energy dispersive portion of an electron energy analyzer that will allow them to traverse the analyzer and be counted.

*fixed analyzer transmission—AES, XPS,* a mode of analyzer operation that varies the electron retardation but keeps the pass energy constant in the final analyzer stage.

*fixed retarding ratio—AES, XPS,* a mode of operation in which the electron kinetic energy is analyzed by varying the retarding potential on lens elements preceding the analyzer and the analyzer pass energy so that the analyzer pass energy is a constant fraction of the kinetic energy.

**electron energy loss spectrum**— *XPS*, the energy spectrum of electrons from a monoenergetic electron source after interaction with the specimen, exhibiting peaks due to inelastic loss processes. The spectrum obtained using an incident electron beam of about the same energy as an XPS peak approximates the loss spectrum associated with that XPS peak. Also see **characteristic electron loss phenomena.**

*electron flooding*— see **electron.**

*electron retardation*— see **electron.**

*electron spectrometer*— see **electron energy analyzer.**

**emission depth distribution function (for a measured signal)**—for particles or radiation emitted from a surface in a given direction, the probability that the particle or radiation leaving the surface in a specified state originated from a specified depth measured normally from the surface into the material.

**emission function decay length**—the negative reciprocal slope of the logarithm of the emission depth distribution function at a specified depth.

**energy:**

*per channel*—*EIA*, energy differences between two successive channels.

*edge*— *EIA*, values of the backscattering energy in a BS spectrum for an element (or isotope) that is located at the surface of the specimen.

*loss*— *EIA*, energy dissipated by the particles of the incident beam as they penetrate through the specimen.

*of incident beam*— average energy of analyzing particle in the incident beam at the moment of impact.

*pass*—(See *pass energy* under **electron energy analyzer**.)

*surface approximation*—*EIA*, see **surface energy approximation.**

**equilibrium surface composition**—see **sputtering.**

**ESCA**—acronym for "electron spectroscopy for chemical analysis," a term historically used to describe a technique whereby one generates electron spectra by irradiating a specimen with narrow band characteristic X-rays.

**excitation depth distribution function**— the probability that specified excitations are created at specified depths measured normally from a surface into the material by a beam of specified particles or radiation incident on the surface in a given direction.

*extra-atomic relaxation energy*—*XPS*, see **screening energy.**

**Fermi energy (level)**— *for metals*, the energy of the top-most filled electron level at zero Kelvin. *For insulators and semiconductors*, the Fermi level is usually between the valence and conduction bands.

**Fermi level referencing**— *XPS*, a method of establishing the binding energy scale for a particular specimen by assigning the kinetic energy corresponding to the Fermi level, as determined by analysis of the specimen's XPS or UPS spectrum, as the point of zero binding energy. See also **Fermi energy (level)**.

*fixed analyzer transmission*—see **electron energy analyzer.**

*fixed retarding ratio*— see **electron energy analyzer.**

**fluence**—the number of beam particles per unit area, where that area is defined perpendicular to the direction of the beam.

**flux**—the number of beam particles per unit area per second, where the area is defined to be perpendicular to the direction of the beam.

**fractional ion yield**— *SIMS*, the ratio of the number of secondary ions of a particular species to the total number of secondary ions emitted by a specimen.

**glancing exit**—*AES*, *EIA*, *XPS*, geometrical arrangement in which the scattered (or emitted) particles are near 90° from the normal to the specimen surface. This results in improved depth resolution.

**glancing incidence**—*AES*, *EIA*, geometrical arrangement in which the incident particles are near 90° from the normal to the specimen surface. This results in improved depth resolution.

**gold decoration**—*XPS*, a method whereby a very thin coat of evaporated gold on an insulator is used as a charge reference; the gold should be deposited as unconnected islands covering the area analyzed.

*grazing exit (incidence)*—*EIA*, same as **glancing exit (incidence).**

**image depth profile**— *AES*, *XPS*, *SIMS*, a three-dimensional representation of the spatial distribution of a particular elemental or molecular species (as indicated by emitted secondary ions or electrons) as a function of depth or material removed by sputtering.

**incident particle energy**—the effective energy of the primary particles incident on the specimen surface, usually expressed in kiloelectronvolts (keV) per atomic particle.

**inelastic:**

*inelastic mean free path*— see **electron.**

*scattering correction to background*—*XPS*, a method of correcting background for contributions of inelastic scattering processes, most often approximated by simulating the background through a peak by assuming that the rise in background is proportional to the peak area at higher kinetic energy. A more accurate correction is done by deconvolving the energy loss spectrum itself.

*scattering cross-section*—*AES*, *XPS*, a measure of the probability that an electron traversing a material will undergo an inelastic scattering process, expressed as an area per unit event.

*scattering event*—*ISS*, a collision process in which a fraction of the kinetic energy imparted by the probe ion contributes to an increase in the internal energy of the target material, and is not recovered as kinetic energy of the scattered probe ion or target atom recoil.

**information depth**—maximum depth, normal to the specimen surface, from which useful signal information is obtained.

DISCUSSION—The information depth can be identified with the specimen thickness from which a specified percentage (for example, 95 % or 99 %) of the detected signal originates. The information depth can be determined from a measured, calculated, or estimated depth distribution function for the signal of interest.

**instrumental detection efficiency**—*SIMS*, the ratio of ions for a particular species detected to ions produced.

**interatomic Auger process**— *AES, XPS,* an Auger transition in which final electron vacancies are in valence levels or molecular orbitals, some of which may be predominantly orbitals of a neighboring bonded atom.

**interface**—a boundary between two phases with different chemical or physical properties.

**interface width, observed**— *AES, XPS, SIMS,* the distance over which a 16 % to 84 % (or 84 % to 16 %) change in signal is measured at the junction of two dissimilar matrices.

**interfacial region**—that volume adjacent to an interface having physical or chemical properties different from either bulk phase as a result of its proximity to the interface.

**interference signal**— *SIMS,* signal measured at the mass position of interest due to another, undesired species.

**internal carbon referencing**— *XPS,* a method of determining the charging potential of a specimen by comparing the experimentally determined binding energy of the C1s peak maximum from a specific carbon group within the specimen to a standard binding energy value for that carbon group. A hydrocarbon group within the specimen is often used for this purpose.

**interphase**—the region between two distinct phases over which there is a variation of a property.

**intrinsic linewidth, of specimen**—*AES, XPS,* the linewidth contribution arising from the specimen. The measured linewidth is a convolution of this function and broadening contributions of the instrument (for example, X-ray source radiation linewidth, spectrometer energy resolution).

**ion beam**—a directed flux of charged atoms or molecules.

*current*—the measured rate of flow of charged atoms or molecules incident upon the specimen per unit time, usually expressed in amperes (A).

*current density*— the ion beam current incident on the specimen per unit cross-sectional area, usually expressed in amperes per square centimetre (A/cm$^2$).

*energy*—in surface analysis, the mean kinetic energy of the ions in the beam (see **beam**, *energy*).

**ion image**—*SIMS,* a two-dimensional representation of the spatial distribution of a particular secondary ion emitted from a specific area of the specimen.

**ion implantation**—the injection of ions into a specimen.

**ionization cross-section**—the probability that an incident particle traversing a gas or solid will produce an ionizing collision. The total ionization cross-section includes all electron vacancies produced by a primary collision and subsequent Coster-Kronig or Auger decay process. The partial ionization cross-section results from one particular process such as a primary collision to produce an initial innershell vacancy in a particular shell, a Coster-Kronig process, or an Auger ejection process to produce particular distributions of electron vacancies.

**ion lifetime**—the average time that an ion exists in a particular electronic configuration, for example, a vacancy in a particular shell in an atom.

**ion neutralization**—*ISS, SIMS,* the charge exchange processes in which a probe is neutralized by the material surface or gas phase species with which it interacts.

**ion-scattering:**

*spectrometer—ISS,* an instrument capable of generating a beam of principally monoenergetic, singly charged, low-energy ions and determining the energy distribution of the probe ions that have been scattered from the solid surface through a known angle.

*spectrometry—ISS,* a technique to elucidate composition and structure of the outermost atomic layers of a solid material, in which principally monoenergetic, singly charged, low-energy (less than 10 keV) probe ions are scattered from the surface and are subsequently detected and recorded as a function of the energy or scattering angle, or both.

*spectrum—ISS,* a representation in which the scattered ion intensity is presented as a function of the ratio of the scattered ion energy to the incident ion energy.

**ion species**—type and charge of ion such as $Ar^+$, $O^-$, and $H_2^+$. If an isotope is used, it should be specified.

**knock-on**—the movement of a constituent of the specimen deeper into the specimen matrix as a result of collisions with the primary particle.

**Koopmans energy**—a calculated energy of an electron in an orbital, on the assumption that its removal to infinity is unaccompanied by electronic relaxation.

**K-value**—*EIA,* a kinematic factor (between 0 and 1) that relates the backscattered energy to the incident energy.

**mass:**

*analyzer*—a device for dispersing ions as a function of their mass-to-charge ratio.

*resolution*—the ratio $M/\Delta M$ where $\Delta M$ is the full width at half-maximum peak height for the ion peak of mass $M$.

*resolving power*— the peak-to-valley ratio between adjacent, equal-sized peaks, separated by one mass unit.

*spectrum*—a plot of the measured ion signal as a function of mass-to-charge ratio.

**matrix effects:**

*Auger*—any change of an Auger spectrum (for example, shape or signal strength) due to the physical environment (for example, amorphous/crystalline, thin layer/thick layer, or rough/smooth surface) of the emitting element and not due to chemical bonding or changes in concentration.

*SIMS*—any change in the secondary ion yields which are caused by changes in the chemical composition or structure of a particular specimen.

*AES*—see **Auger**.

**mean escape depth**—the average depth normal to the surface from which the specified particles or radiations escape as defined by:

$$\int_0^\infty z\phi(z,\theta)dz \,/ \int_0^\infty \phi(z,\theta)dz \qquad (2)$$

where $\phi(z,\theta)$ = the emission depth distribution function for depth $z$ from the surface into the material and for direction of emission $\theta$ with respect to the surface normal.

**mean free path—**See **electron**, *inelastic mean free path.*

**modified Auger parameter**—the Auger parameter plus the photon energy, which equals the kinetic energy of the sharpest Auger peak plus the binding energy of the most intense photoelectron peak.

**modulation**—*AES,* the periodic waveform added to the spectrometer pass energy to obtain the desired Auger spectrum display. The modulation should be given as eV peak-to-peak, thereby including the geometrical factor of the spectrometer, rather than volts peak-to-peak. The frequency and waveform should also be given.

**molecular SIMS**—the SIMS technique when applied to molecular or polyatomic secondary ions.

**multiple scattering event**— *ISS,* a collision process that may be described as a sequence of binary scattering events which may or may not be elastic.

**multiplet or exchange splitting**— *XPS,* splitting of a photoelectron line caused by the interaction of the unpaired electron created by photoemission with other unpaired electrons in the atom.

**natural linewidth—**See **intrinsic linewidth.**

**noise**—*in surface analysis,* the random fluctuation of the measured intensity at a particular location in a spectrum, usually expressed as an RMS (root-mean-square), standard deviation, or a peak-to-peak value.

**orbital energy**—*XPS,* Koopmans energy corrected for intra-atomic relaxation.

**organic (inorganic) SIMS**—the SIMS technique when applied to organic (inorganic) specimens or organic (inorganic) molecules placed on a solid.

**peak width, FWHM**—full width at half-maximum peak height above background.

**photoelectric cross-section**—the probability that an incident photon traversing a material will produce a photoelectron from a given subshell, expressed as an area unit per event.

**photoelectric effect**—a dipole interaction involving the interaction of photons with bound electrons in atoms, molecules, and solids, resulting in production of photoelectrons and excited ions.

*photoelectron satellite peaks***—**See **photoelectron X-ray satellite peaks,** and **shakeup lines or shakeup satellites.**

**photoelectron X-ray satellite peaks**—photoelectron peaks in a spectrum resulting from photoemission induced by characteristic minor X-ray lines associated with the X-ray spectrum of the anode material.

**photoelectron X-ray satellite subtraction**— the removal of photoelectron X-ray satellite peaks from a spectrum.

**photoemission**—the emission of electrons from atoms or molecules caused by photoelectric effects.

**pileup**—*EIA,* counts in a backscattering spectrum arising from two separate events that occur so closely in time that the signals are not resolved by the detection system and cause counts to be recorded in erroneous channels.

**plasmon loss lines**—peaks in an electron spectrum that are due to certain characteristic energy losses of electrons emitted from the specimen. These losses occur as a result of the excitation of collective oscillations among the valence band electrons.

*polarization energy***—** see **screening energy.**

**polyatomic ion**—a charged multi-atom species.

**positive (negative) ion yield**—the total number of positive (negative) secondary ions sputtered from the specimen per incident primary particle.

*preferential sputtering***—** See **sputtering.**

**probe ion**—an ionic species intentionally produced by an ion source and directed onto the specimen surface at a known incident angle with a known energy.

**quantitative analysis**—the determination of the concentration and distribution of elements within the Auger analysis volume.

DISCUSSION—For elements uniformly distributed over the analyzed volume, the concentrations should be reported as weight or atomic percentages. For uniform distributions in a plane, but nonuniform distributions normal to this plane, concentrations should be reported as weight or atoms per unit area. For nonuniform distributions in a plane, but uniform distributions normal to the plane (over the detected depth), the concentration should be reported in percent area covered.

**radial sectioning**—a method of specimen preparation in which a specimen is polished by a cylinder in order to expose compositional changes below the original surface of a specimen with the intent that the depth of these layers can be related to the position on the surface created by the cylinder.

**radiation induced (or enhanced) diffusion**— atom movement in the solid, well beyond the typical penetration depth of an incident particle, due to particle beam damage or bombardment induced defects.

**raster**—*SIMS,* the two-dimensional pattern swept out by the deflection of a primary ion beam.

**recoil implantation or knock-on**—the injection, due to collisions caused by incident particles, of surface or near surface atoms into the bulk along the path of the incident beam.

**relaxation energy**—*XPS,* the energy associated with intra-atomic or extra-atomic electronic readjustment to the removal of an atomic electron, so as to minimize the energy of the final state of the system.

**resolution:**

*depth*— *EIA,* energy resolution translated into an equivalent resolution of depth in the specimen.

*energy*— *EIA,* the full width at half-maximum (FWHM) of the measured energy distribution when the energy distribution of the backscattered particles is monoenergetic.

*lateral*—*EIA,* the distance measured on the surface of a specimen over which changes in composition can be established with confidence by BS. This resolution is generally determined by the size of the beam spot.

*system*— *EIA,* the energy or depth resolution measured in a BS spectrum for a monoenergetic incident beam.

**resonance reaction**—*EIA,* a nuclear reaction that has a narrow peak in the nuclear reaction cross section, which is so much larger than the nuclear reaction cross sections at adjacent energies both above and below the peak that essentially all the particles detected from the reaction are due to the peak.

**satellite peaks—**See **photoelectron X-ray satellite peaks** and **shake-up lines or shake-up satellites.**

**scattered ion:**

*energy*— *ISS, for a binary elastic collision*, the kinetic energy of the probe ion following a binary elastic collision, $E_s$, is given by:

$$E_s = E_0[M_0/(M_0 + M_1)]^2(\cos\theta + [(M_1/M_0)^2 - \sin^2\theta]^{1/2})^2 \qquad (3)$$

where:

$E_s$ = kinetic energy for the scattered probe ion,

$E_0$ = energy of the incident probe ion prior to collision, determined from the product of ionic charge and accelerating potential,

$M_0$ = mass of the probe ion,

$M_1$ = mass of the target atom, and

θ = angle between the initial and final velocity vectors for the probe ion, as determined from a common origin in the laboratory coordinate system, expressed as a value between 0 and 180°.

*energy ratio—ISS,* the value $E_s/E_0$ which may be used as the abscissa of an ion-scattering spectrum. For definition of $E_s$ and $E_0$, see **scattered ion** *energy.*

*intensity, experimental—ISS,* the measured response of the energy filtering and detection system as a consequence of bombarding the specimen material with a beam of probe ions, usually presented as the ordinate of an ion-scattering spectrum.

*intensity, theoretical—ISS,* defined by an equation of the form:

$$I_i(\theta) = I_0 N_i P_i \alpha_i (d\sigma_i/d\Omega)\theta \Delta\Omega T \qquad (4)$$

where:

$I_i(\theta)$ = scattered ion intensity from atoms of species, $i$, at a given scattering angle, θ, ions $s^{-1}$,

$I_0$ = intensity of incident probe ions, ions $s^{-1}$,

$N_i$ = number of scattering centers of species $i$ per unit area of surface, or per unit volume accessible to the incident beam, atoms $metre^{-2}$,

$P_i$ = probability that the probe ion remains ionized after interacting with an atom of species $i$,

$\alpha_i$ = geometric or shadowing factor for species $i$ in the given environment and geometry,

$(d\sigma_i/d\Omega)\theta$ = differential scattering cross section per unit solid angle, for species $i$, taken at the angle for which scattering is measured; that is, the angular distribution of scattered ion intensity per unit flux of incident ions, per atom of species $i$, $metre^2$ $atom^{-1}$ $steradian^{-1}$,

$\Delta\Omega$ = solid angle of acceptance determined by the entrance aperture of the filtering and detection system, steradians, and

$T$ = fractional transmission of the analyzing and detection system.

**screening energy**—the diminished energy of an ion due to coulombic attraction of electrons in the immediate environment.

**secondary electrons**— *AES,* electrons leaving a surface, produced through various mechanisms of energy transfer from the incident beam. By convention, electrons with energies ≤50 eV are considered as secondary electrons.

**secondary ion**—ions ejected from a specimen surface as a result of energy transfer from a primary beam.

*angular distribution—SIMS,* the secondary ion yield as a function of emission angle.

*energy distribution*—the number of secondary ions as a function of the energy at a specified collection angle.

*signal gating*— the process of accepting secondary ion signal from only a portion of the sputtered area of the specimen to minimize crater edge effects.

*yield*—the total number of ions sputtered from the specimen per incident ion of given mass, energy, charge, and angle of incidence.

**selected area aperture**— *SIMS,* the mechanical equivalent of electronic signal gating, commonly used in stigmatic mass spectrometers.

**sensitivity factor:**

*elemental—XPS,* intensities of peaks relative to those of a standard, for example, F1s, for atoms in typical homogeneous environments. Division of peak height or peak area intensities by the appropriate sensitivity factors gives the relative number of atoms detected, on the assumption of sample homogeneity.

*relative Auger elemental—AES,* the ratio of the Auger signal strength of a specified Auger transition from a single element to that from a selected standard element (for example, silver), as measured under identical conditions.

*SIMS*—the factor used to convert the net counts per unit time, for a particular species, matrix and experimental conditions, to concentration.

**shakeoff process**—*XPS,* a multi-electron photoelectric process in which two or more electrons are emitted, partitioning between them the excess kinetic energy.

**shakeup lines or shakeup satellites**—*XPS,* photoelectrons originating from photoelectric processes in which the final ion is left in an excited state, so that the photoelectron has a characteristic energy slightly less than that of the normal photoelectron.

**signal height**—*EIA,* the number of counts in the channels of a backscattering spectrum due to a specific element in the target.

**signal-to-background ratio**— *AES,* the ratio of signal (above background) to that of the nearby background on the high kinetic energy side of the elastically scattered Auger electrons.

**signal to background ratio**— *SIMS, XPS, for a spectral peak,* the ratio of the maximum counts in the peak above the background to the magnitude of the background.

**signal-to-noise ratio**—the ratio of the signal intensity (above background) to that of noise in determining that signal.

DISCUSSION—The method of noise measurement must be specified, such as, rms (root mean square), or peak-to-peak.

**smoothing**—*XPS,* a mathematical treatment of the data to reduce the noise.

**specimen charging**—the accumulation of electrical charge on the specimen caused by particle bombardment.

**spectrometer:electron energy analyzer**

*dispersion—AES,* the change in electron image position at the exit of a spectrometer per unit change in electron energy.

*energy resolution—AES, XPS,* the ratio of the full width at half-maximum intensity of the response curve for monoenergetic electrons at a given energy to the energy of the electrons.

*transmission—AES, XPS,* the ratio of the number of electrons at a given energy transmitted through the spectrometer to the number entering the entrance aperture of the spectrometer at that energy.

**spectrum:**

*aligned incidence—EIA,* a backscattering spectrum recorded with the analyzing beam aligned with crystallographic axes or planes of the specimen that produce channeling.

*random (incidence)—EIA,* a backscattering spectrum recorded with the analyzing beam incident on the specimen in a direction such as to produce no channeling.

**spin orbit splitting**—the splitting of p-, d-, or f-levels arising from coupling of the spin and orbital angular momentum.

**sputter depth profile**— *AES,* the compositional depth profile obtained when material is removed by sputtering as a result of ion bombardment.

**sputter depth profile**— *SIMS,* the compositional depth profile obtained when material is removed by sputtering as a result of primary bombardment.

**sputtered neutral mass spectrometry**—*SNMS* a method in which a mass spectrometer is used to measure the mass-to-charge quotient and abundance of secondary ionised neutral species emitted from a sample as a result of particle bombardment

NOTE 3—The neutral species may be detected by using plasma, electron, or photon ionization methods.

**sputtering**—the phenomenon which occurs when atoms and ions are ejected from the specimen as a result of particle bombardment.

*equilibrium surface composition*—the steady-state surface composition produced by sputter-etching a homogeneous specimen under nonvarying conditions for the ambient vacuum and the primary beam.

*fractional yield—SIMS,* the ratio of the number of atoms and ions of a particular element to the total number of atoms and ions ejected from the specimen.

*preferential*— the phenomenon which may occur when the sputtering of multicomponent specimens causes a change in the equilibrium surface composition of the specimen.

*rate*—the amount of specimen material removed per unit time as a result of particle bombardment.

*yield*—the number of atoms and ions ejected from the specimen per incident ion.

**statistical noise**—*XPS,* the noise in the spectrum due solely to the statistics of randomly detected single events; the root mean square of the deviations in neighboring channels is equal to the square root of the average counts per channel.

**stopping:**

*cross section—EIA,* see **cross section,** *stopping.*

*cross section factor—EIA,* the stopping factor expressed per unit volume density of the constituent molecular entity of the specimen at the appropriate depth.

*factor— EIA,* the ratio between a (differential) energy interval in a backscattering spectrum and the corresponding (differential) depth interval in the specimen.

*power— EIA,* same as **stopping,** *cross section.*

**surface**—an interface between a condensed phase and a non-condensed phase (or free space).

**surface energy approximation**— *EIA,* a simplification of calculations involving the energy of an ion passing through a solid specimen. The energy of the ion at the surface is used in place of a properly averaged energy. This approximation is used to determine the energy at which scattering or stopping cross sections, or both, are evaluated.

**surface roughness**—*AES,* the deviation of the topography of an actual surface from an ideal atomically smooth and planar surface. The rms deviation from the center line average is a measure of surface roughness.

**surface segregation**—a diffusion controlled process (as opposed to evaporation, preferential sputtering, or other processes) that causes the surface composition of a homogeneous solid to differ from the bulk composition.

**synchrotron radiation**— *XPS,* a continuous radiation created by the acceleration of high energy electrons, as in a synchrotron or storage ring. Monochromatized, it is a practical variable energy source of photons for photoelectron spectroscopy.

**target**—specimen under investigation.

*thick— EIA,* specimen whose thickness produces backscattered particles whose energies, for each constitutive element, vary greatly with respect to the system resolution.

*thin— EIA,* specimen whose thickness is sufficiently small that the variations in energies of particles backscattered from atoms of each constitutive element is small with respect to the system resolution.

*tilt, of target*—same as **angle** *of incidence.*

**thin film**—a layer of material, typically less than 100 nm in thickness deposited or grown on a substrate.

**time constant**—*AES,* the time required for a signal to change by $1 - (1/e)$ (63.2 %) of its final value in response to a step function input.

**useful ion yield**—*SIMS,* the ratio of the number of ions of a particular isotope detected to the total number of atoms and ions of the same element sputtered.

**vacuum level**—the potential of the vacuum space at a sufficiently large distance outside the specimen such that electric fields caused by different work functions of different parts of the surface are zero or extremely small.

**vacuum level referencing**— *XPS,* a method of establishing the binding energy scale for a particular specimen by assigning the kinetic energy corresponding to the vacuum level as the point of zero binding energy. See also **vacuum level**.

**valence band spectrum**— *XPS,* photoelectron energy distribution arising from the less tightly bound electrons involved in the chemical bonds of the specimen material.

**work function**—the potential barrier that must be overcome to remove an electron from the Fermi level of a specimen to the vacuum level.

**X-ray ghost line**—*XPS,* lines in a spectrum due to presence of contaminating X-ray photons from an impurity in the X-ray anode, from the X-ray window, or from certain elements present in the specimen.

**X-ray linewidth**—the energy width of the principal characteristic X-ray; in XPS it usually refers to that of the X-ray source. The X-ray linewidth contributes to the photoelectron peak widths.

**X-ray monochromator**—a device used to eliminate photons of energies other than those in a narrow band.

**zone of mixing**—the layer of the specimen surface within which the primary beam causes atomic mixing.