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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 μ in the expression $\mu\Delta x$ for the fraction removed in passing through a thin layer Δx of a substance in the limit as Δx approaches zero, where Δx is measured in the direction of the beam.

[1] This terminology is under the jurisdiction of ASTM Committee E42 on Surface Analysis and is the direct responsibility of Subcommittee E42.02 on Terminology.

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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,

$$\epsilon(A_xB_y) = x\epsilon_A + y\epsilon_B \quad (1)$$

where:

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

A_xB_y and ϵ_A and ϵ_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