Atom Probe Definitions: Batch 2 (Group 21B: Terms related to specimen preparation)

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21B.A: System-related terms

21B.A1
focused ion beam (FIB) system
instrument used for machining and fabrication of small material regions with sub-micrometre precision

[SOURCE: ISO 18115-1, modified.]

21B.A2
FIB milling
FIB etching
site-specific sputtering of the specimen using incident ion bombardment to thin or shape a particular region of interest

[SOURCE: ISO 20263, modified.]

21B.A3
ion implantation
process whereby ions in the focussed ion beam impinging onto a specimen are retained inside the specimen

[SOURCE: ISO 18115-1, modified.]

21B.A4
gas injection system
GIS
assembly of devices that together with the ion beam produces site-specific deposition of metals or insulators, or provides enhanced etching capabilities

[SOURCE: ISO 80004-8, modified.].

21B.A5
electron-beam-induced deposition//ion-beam-induced deposition
EBID//IBID
localized deposition of material induced by electron-beam or ion-beam irradiation of locally applied precursor gases

Note 1 to entry. The gas is typically delivered via a hollow-needle-based *gas injection system (GIS)* (21B.A4) in a FIB or FIB-SEM instrument.

Note 2 to entry: Commonly used precursor materials include organometallic compounds of Pt, W or C.

Note 3 to entry: EBID/IBID is typically used for structural reinforcement, to deposit a protective layer, or for fiducial marking during *FIB milling* (21B.A2).

21B.A6
cryoFIB preparation
specimen preparation using *FIB milling* (21B.A2) with the specimen held at cryogenic temperatures.

Note 1 to entry: Typically, this is performed to minimise diffusion or evaporation of specimen atoms.

21B.B: Beam-related terms

21B.B1
ion accelerating voltage
the measured-voltage (considered positive) between the specimen surface and the ion source of a *FIB system* (21A.A1)

Note 1 to entry: In APT contexts, this quantity is usually denoted by the symbol *V*.

21B.B2
incident ion energy
impact energy
the kinetic energy of individual (singly positively charged) accelerated ions in the FIB

[SOURCE ISO 17297:2024(E), modified.]

Note 1 to entry: This kinetic energy (*K*) is usually measured in keV and is given by the formula: $K=eV$, where *e* is the elementary (positive) charge.

Note 2 to entry: In some circumstances multiply charged ions might be present that have correspondingly greater kinetic energies.

21B.B3
ion beam current
ion probe current
value of the electric current in the ion beam that bombards the specimen

[SOURCE: ISO 15609-3, modified.]

21B.B4
angle of incidence
the angle between the incoming primary ion beam and the normal to the specimen surface

[SOURCE: ISO 18115-1, modified.]

21B.B5
beam diameter
the diameter of the ion beam, as assessed by the full-width-at-half-maximum (FWHM) of the radial ion-current density at the focus plane of the incident beam

[SOURCE: ISO 18115-1, modified.]

Note 1 to entry: In APT, the FWHM is the most used measure of beam diameter. Other measures (such as the "d4σ") exist and can be derived from the FWHM values for a gaussian beam. These alternative measures may be preferred in some circumstances or by some people.

Note 2 to entry: A specimen in the focus plane is commonly referred to as being at the working distance.

21B.B6
FIB impact spot
the area of the specimen surface onto which the ion beam impacts

Note 1 to entry: The area of the impact spot is measured normal to the ion-beam axis.

Note 2 to entry: Due to in-specimen processes induced by the ion beam, the area of damage may be larger than the FIB impact spot, and material-dependent.

21B.B7
dwell time
the time during which the incident ion beam is stationary at a specific pixel location, during imaging, milling or deposition processes

[SOURCE: ISO 17297:2024(E).]

21B.B8
sputtering
the phenomenon in which surface atoms are ejected from the specimen because of collisions between incoming energetic ions and specimen atoms

[SOURCE: ISO 17297:2024(E), modified.]

21B.B9
sputtering rate
name of a group of alternative parameters that define how rapidly a surface is sputtered because of the impingement of an energetic ion beam

[SOURCE: ISO 181115-1, modified.]

Note 1 to entry: Sputtering rate can be quantified in various ways, e.g. mass per unit time, volume per unit time, but in APT the most used quantity is the "depth sputtering rate", usually measured in nm/s.

Name of a group of alternative parameters that define how rapidly a surface is sputtered because of the impingement of an energetic ion beam.

Note1 to entry: Sputtering rate can be quantified in various ways, e.g. mass per unit time, volume per unit time, but in APT the most used quantity is the "depth sputtering rate", usually measured in nm/s.

Note 2 to entry: Use of the term "erosion rate" in the context of *APT specimen preparation* (21B.C4) is discouraged.

21B.B10
relative sputtering rate
the ratio of the sputtering rate (however quantitively defined) of the specimen of interest to the similarly defined sputtering rate of a reference specimen sputtered under the same conditions

[SOURCE: ISO 18115-1, modified.]

21B.B11
preferential sputtering
sputtering-induced change in the equilibrium surface composition or morphology of the specimen: this can occur when sputtering a multi-component specimen

[SOURCE: ISO 181115-1, modified.]

21B.B12
penetration depth
typical depth to which an energetic incident ion travels into the specimen when implanted

[SOURCE: ISO 22493 modified.]

Note 1 to entry: This parameter depends strongly on the material properties of the specimen and on the kinetic energy of the incident ion.

Note 2 to entry: Initial implantation is in the direction of the ion beam. However, due to lateral scattering within the specimen, the final ion position may be laterally displaced from the beam.

21B.B13
ion-beam-induced damage
damage to the specimen that is caused by the ion beam

[SOURCE: ISO 18115-1, modified.]

Note 1 to entry. This may include: *amorphisation* (21B.B14) and/or *redeposition* (21B.B16), surface roughness or non-uniformities in the thickness of the damaged-layer, induced defects, *ion implantation* (21B.A3), atomic mixing, and any other beam-induced specimen alterations.

21B.B14
amorphization
development of an amorphous layer at the surface or sidewalls of a crystalline specimen, by displacement of atoms from their original equilibrium positions

[SOURCE: ISO 17297:2024(E), modified.]

Note 1 to entry: Typically, this is caused when a collision cascade is generated within the specimen by the impingement of energetic ions.

21B.B15
amorphous layer thickness
the thickness of the amorphization damage

Note 1 to entry: Typically, this thickness is almost proportional to the penetration depth of the ion implantation.

21B.B16
redeposition
deposition of sputtered specimen material back onto the specimen surface

[SOURCE ISO 18115-1:2023(E).]

21B.B17
specimen charging
process by which electric charge, brought in by an ion or electron beam, accumulates at or near the specimen surface and gives rise to related electrostatic potential distributions

21B.C: Specimen-related terms

21B.C1
specimen
<APT> general term for a chosen piece of the material under investigation, at any stage of its development from a *bulk/initial specimen* (21B.C2) into an *APT specimen* (21B.C3)

21B.C2
bulk/initial specimen
<APT> the material of interest that is to be processed to become an *APT specimen* (21B.C3).

Note 1 to entry: Bulk/initial specimens may have many forms e.g., wafers, wires, minerals, biological material, etc.

21B.C3
APT specimen
<APT> general name for a fully prepared needle-shaped piece of the original bulk/initial specimen, mounted on a suitable specimen carrier and ready for atom probe analysis

21B.C4
APT specimen preparation
<APT> a process whereby an *APT specimen* (21B.C3) is prepared from a *bulk/initial specimen* (21B.C3)

Note 1 to entry: Preparation usually involves: either a wire that is *electrochemically polished* (21B.C15); or a *lift-out volume* (21B.C10) that is processed by *FIB milling* (21B.A2); or deposition onto a pre-formed needle-shaped substrate.

Note 2 to entry: Preparation includes mounting the specimen onto an appropriate *specimen carrier* (21B.C12).

21B.C5
apex region
top region of-a needle-shaped APT specimen, closest to the extraction electrode.

Note 1 to entry: Use of the term "apex" to mean "apex region" is discouraged.

21B.C6
apex
the topmost point of a needle-shaped APT specimen (term mainly used in modelling)

21B.C7
region of interest
ROI
a specific volume of the *bulk/initial specimen* (21B.C2) that is targeted for analysis by APT

Note 1 to entry: Examples include defects, interfaces, material layers, precipitates, etc.)

21B.C8
end pointing
the action of ensuring that the *region of interest* (21B.C7) is retained in the *apex region* (21B.C5) of the *APT specimen* (21B.C3)

21B.C9
protective layer
protection layer
a layer of material (different from the specimen material) deposited onto the specimen to minimise ion-beam-induced damage

[SOURCE: ISO 17297:2024(E), modified.]

Note 1 to entry: Use of the term "cap" to mean "protective layer" is discouraged.

21B.C10
lift-out volume
<APT> a chosen micrometre-scale volume created from the bulk/initial specimen using FIB milling

Note 1 to entry: This chosen volume contains the *region of interest* (21B.C7) and is an intermediate specimen-form in *APT specimen preparation* (21B.C4).

Note 2 to entry: Typical dimensions of FIB-lift-out volumes are approximately 20 µm in length, 1 µm–2 µm in height and about 1 µm–2 µm in cross-section.

21B.C11
lift-out
removal, from the bulk/initial specimen, of a lift-out volume containing the *region of interest* (21B.C7)

[SOURCE: ISO 17297:2024(E), modified.]

Note 1 to entry: This is typically performed by using a manipulator or similar picking tool. After *lift-out* (21B.C11) the volume is mounted onto some form of *specimen carrier* (21B.C12).

21B.C12
specimen carrier
a physical carrier, onto which a specimen is mounted during its preparation, that can be directly loaded/inserted into an atom probe

Note 1 to entry: Examples include a flat-top micro-post array, pre-sharpened micro-post array, a wire, a TEM half-grid, etc.

21B.C13
annular milling
annular sharpening
<APT> FIB milling of a mounted *lift-out volume* (21B.C10), to form a sharp needle-shaped specimen

Note 1 to entry: This is typically performed by using (in the milling) progressively smaller concentric ring patterns.

21B.C14
cleaning
polishing
reduction or elimination of ion-beam-induced damage at the specimen surface

[SOURCE: ISO 17297:2024(E), modified.]

Note 1 to entry: Methods used include lowering the incident ion energy/current, wet etching, chemical etching, or broad argon ion milling.

21B.C15
electrochemical polishing
<APT> process whereby an *APT specimen* (21B.C3) is prepared by an electrochemical polishing process (using a suitable liquid chemical environment) to form a needle-shaped specimen from the *bulk/initial specimen* (21B.C2) of interest

21B.C16
chemical loading
process of adding atoms or molecules of a different chemical species to a specimen, by in-diffusion from its surface

Note 1 to entry: This process is sometimes simply called "'loading".

Note 2 to entry: The term "loading" is preferred over the alternative term "charging".

Note 3 to entry: This term is not to be confused with loading, or inserting, a specimen into an instrument.

Note 4 to entry: Typical species used for loading include hydrogen and deuterium.

Note 5 to entry: Use of the term "doping" to mean "chemical loading" is discouraged, because "doping" has a specific meaning in the context of semiconductor physics.

21B.C17
gas-phase chemical loading
chemical loading (21B.C16) that takes place when the specimen is immersed in a gas of the atoms or molecules of interest

21B.C18
solution-based chemical loading
chemical loading (21B.C16) that takes place when the specimen is immersed in a solution containing the atoms or molecules of interest

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