



NanoDictionary*

This Nano-Dictionary, compiled by the Editorial Board, defines words frequently used in the context of nanoscience and nanotechnology. Words that retain their regular meanings have generally not been included. Where the meaning of a word prefixed by 'nano' is obvious, it is also not included. Multiple definitions in current use have been carefully considered and where only one meaning is given, we implicitly recommend that any others be abandoned. A few definitions must still be considered provisional. The list and definitions will be periodically reviewed and updated, and suggestions are constantly welcome.

acicular particle

Needle shaped particle.

aerodynamic diameter

Diameter of a spherical particle with a density of 1000 kg/m^3 , which has the same settling velocity in air as the particle under consideration.

aerosol

Metastable suspension of solid or liquid particles (generally within the range of about 1 nm to about $100 \mu\text{m}$ in diameter) in a gas.

aerosol diffusion charging

A method in which the Fuchs surface area of an aerosol is measured directly by passing electrically neutral particles through a unipolar ion cloud and measuring the resulting aerosol charge. When the charging rate is low, aerosol charge is proportional to the Fuchs surface area.

aerosol scavenging

The removal of particles from the air by other particles through inertial, gravitational or diffusive processes.

agglomerate

1. Group of particles held together by relatively weak (van der Waals and weak electrostatic) forces, requiring only physical means for separation.
2. Group of strongly associated particles that cannot easily be redispersed by mechanical means and may require chemical means as well.

aggregate

Assemblage of primary particles exhibiting an identifiable collective behaviour.

* All correspondence should be addressed to the Editorial Office.

aggregation, orthokinetic

Aggregation induced by hydrodynamic motion, such as stirring, sedimentation or convection.

aggregation, perikinetic

Aggregation induced by Brownian motion.

aspect ratio

The ratio of the longest Feret's diameter of a particle to the shortest perpendicular one.

assembler

Nanoscale device (hence also called a nano-assembler) for carrying out molecular manufacturing (q.v.) by assembling atoms and/or molecules. It may have the ability to replicate itself.

atomic force microscopy (AFM)

A technique for imaging surfaces by mechanically scanning their surface contours using a microfabricated probe; the deflexion of a sharp tip mounted on a soft cantilever is monitored as the tip is moved across the surface.

atomization

A technique for producing solid particles by dispersing molten material, a solution of the material or a suspension sprayed under conditions such that it breaks down and then solidifies or dries as a finely divided powder or aerosol. Typically used to make particles down to a size of 2 μm , i.e. larger than the nanoscale.

attrition

A form of comminution, where the reduction in size is caused by erosion resulting from the collision of particles with other particles or surfaces. Also referred to as ultrafine grinding or nanosizing.

Auger electron spectroscopy (AES)

A technique in which an electron spectrometer is used to measure the energy distribution of Auger electrons emitted from a surface. AES instruments can achieve lateral resolutions as low as 15 nm.

average agglomeration number (AAN)

An estimate of the degree of agglomeration in a suspension, i.e. the average number of primary particles per agglomerate.

BET analysis

A characterization technique based on a model developed by Brunauer, Emmet and Teller that involves admitting a gas (typically nitrogen or carbon dioxide but also gases such as krypton or argon) to an evacuated powdered sample and weighing the increase of mass due to gas adsorption, from which the surface area of the powder can be determined.

BET surface area

Surface area calculated from BET analysis.

bottom-up processing

An additive process to create nanostructures from atoms and molecules.

Brownian motion

The random motion of minute particles suspended in a fluid, first described in print by Robert Brown in 1828 (although priority of discovery probably belongs to Jan Ingenhousz), and now known to be due to the particles being bombarded by the molecules of the fluid. It provides a mechanism for diffusion. Brownian motion can be modelled as a random walk, and is the commonest example of a Wiener process.

buckminsterfullerene

A closed-cage structure having sixty carbon atoms consisting entirely of three-coordinate carbon atoms.

buckyball

See buckminsterfullerene.

bulk nanoparticles

Nanoparticles produced by industrial-scale processes (e.g. carbon black, titanium dioxide and fumed silica).

calcination

Producing or modifying a powder by heating to a high temperature in a dry environment.

carbon black

Elemental carbon in the form of near-spherical particles with major diameters less than 1 μm , and generally agglomerated.

carbon nanotube

Nanotube consisting of one or several graphene sheets rolled up into a seamless tube, forming single-walled (SWNT) or multi-walled (MWNT) tubes.

chemical vapour deposition

A top-down production method where vapour is formed in a reaction chamber and condensed onto a solid substrate to form a thin film.

coagulation

The formation of aggregates by the addition of an electrolyte to a suspension of particles.

coalescence

The formation of homogeneous particles through the collision and subsequent merging or mixing of the material of the particles.

comminution

The reduction of particle size by fracture.

deflocculation

Breaking down a floc.

dendrimer

Macromolecule built up from a monomer, with new branches added to each existing branch.

differential mobility analysis (DMA)

A method for establishing the size distribution of aerosols, based on the distribution of mobilities of electrostatically charged particles in an electric field.

dynamic light scattering (DLS)

The measurement of the time-dependent fluctuations in the scattered intensity of coherent monochromatic light. These fluctuations arise because the particles are small enough to undergo random thermal (Brownian, q.v.) motion, and the distance between them is therefore constantly varying. The measurement yields the diffusion coefficient of the particles from which, via the Stokes-Einstein equations, and knowing the viscosity of the medium, the hydrodynamic radius (or diameter) can be calculated.

electrical double layer (EDL)

Two oppositely charged layers of ions existing at an electrified solid/liquid interface due to the attraction of counterions towards the interface by the interfacial charge.

electro-explosion

A process for the production of nanoparticles whereby a wire is fed into a reactor and subjected to a high-current, high-voltage microsecond pulse to cause it to explode.

electrohydrodynamic atomization

A process for the production of monodisperse droplets in the micrometre range. Liquid is supplied to a nozzle, and an electric field is generated between the nozzle and a counterelectrode; when the electrical stress overcomes the surface tension of the liquid, a cone is formed, from which a thin jet emerges and breaks up into monodisperse droplets.

electrokinetic phenomena

Electrophoresis and electro-osmosis: effect when an applied electric field causes the relative motion between a charged surface or particle and a continuous phase containing ions; for phenomena including streaming and sedimentation (Dorn) potential: effect where an electrical potential is generated when a liquid containing ions is caused to flow past a charged surface or particle.

electron energy loss spectroscopy (EELS)

A technique in which inelastic interactions of an electron beam with atoms in a sample results in an electron energy distribution spectrum, from which compositional and chemical bonding

information can be extracted.

electron probe microanalysis (EPMA)

Spatially-resolved elemental analysis based upon electron-excited X-ray spectrometry with a focused electron probe and an electron interaction volume with micrometre to submicrometre dimensions.

electrospinning

A fabrication process using an electric field to control the deposition of polymer nanofibres onto a target substrate.

engineered nanoparticles

Nanoparticles manufactured to have definite properties or a definite composition.

epiphaniometer

Instrument for measuring the Fuchs surface area of aerosols directly. The aerosol is passed through a charging chamber where Pb isotopes emerging from a decaying actinium source are attached to the particle surfaces. The particles are transported through a capillary to a collecting filter; the amount of radioactivity measured is proportional to the particle surface area.

equivalent diameter

Diameter of a sphere that behaves like the actual particle with respect to or deduced from a chosen property (e.g. aerodynamic, diffusive or hydrodynamic (q.v.) mobility, perimeter, surface or volume).

eutactic

Characterized by more or less precise molecular order, like that of a perfect crystal, or the interior of a protein molecule; contrasted to the disorder of bulk materials, solution environments, or biological structures on a cellular scale. Just as a crystal with sparse defects is best described as a crystal (rather than as amorphous), so a eutactic structure with sparse defects is best described as (imperfectly) eutactic, rather than as disordered.

exploding wire aerosol generation

See electro-explosion.

Feret's diameter

The distance between two parallel tangents on opposite sides of the image of a particle.

field flow fractionation (FFF)

A method of separating particles in a fluid flowing in a channel by applying a field perpendicular to the flow, e.g. a transverse flow or thermal field.

flame pyrolysis

A gas phase synthesis method where flame heat is used to vaporize feedstock material and initiate chemical reactions to produce nanoparticles.

floc

An assembly of particles suspended in a liquid, which, having been initially dispersed, have become weakly attracted to each other.

flocculation

The process of forming a floc.

fluidized bed processing

Fabricating or coating objects with another material while in a reactor that uses a suspension of particles in an upward flow of fluid (or a downward flow if the particles are less dense than the fluid) to support the objects.

Fuchs surface area

Surface area (of an aerosol particle) that interacts with its carrier gas.

fullerene

Any closed-cage structure having more than 20 carbon atoms consisting entirely of three-coordinate carbon atoms.

fume

Cloud of airborne particles, including nanoparticles of low volatility, arising from the condensation of vapours emanating from either chemical or physical reactions.

fumed powder

Powder recovered from a fume.

functionalization

The attachment of chemical functional groups to a surface.

furnace flow processing

A method of gas phase synthesis that produces particles from a saturated vapour, used for substances having a high vapour pressure at intermediate temperatures.

granulation

Comminution producing large particles.

graphene

Individual layers of carbon atoms arranged in a honeycomb-like lattice, as in graphite.

Hamaker constant

A material constant that measures the strength of the attractive van der Waals force between two surfaces.

heterocoagulation

The aggregation of dissimilar particles by the addition of an electrolyte to a suspension of them.

heterodisperse system

Bulk powder or suspension containing particles of different sizes.

high energy milling

Comminution that relies on kinetic energy to fragment material into progressively finer sizes.

hydrodynamic diameter

Diameter of a sphere diffusing in a liquid, with the same diffusion coefficient as the actual particle.

hydrosol

Sol in which water forms the dispersion medium.

incidental nanoparticles

Nanoparticles formed as a by-product of natural or artificial processes, e.g. welding, rubbing, milling, grinding or combustion.

inorganic nanotube

Nanotube composed of non-carbon atoms.

isoelectric point (IEP)

pH at which a suspended particle has a zeta potential of zero.

isoionic point

pH of a solution in which a suspended particle or molecule contains as many negative charges as positive ones.

isometric particle

Particle with the same length in the three Euclidean dimensions.

laser plasma deposition (LPD)

A production method in which vapour is formed and then ionized to form a plasma in a reaction chamber as a result of laser irradiation of a solid state target, and then deposits onto solid substrates placed in the chamber.

mechanosynthesis

The formation of covalent bonds by placing (in a controlled fashion) one atom (or molecule) next to another. A key process of molecular manufacturing (q.v.). Could be accomplished, but not necessarily, by (nano)assemblers (q.v.).

mesoscopic

Referring to a scale above that of atoms, covering typically the range 1 to 100 nm, i.e. overlapping the nanoscale.

milled powder

Powder produced by comminution in a mill.

molecular manufacturing (MM)

A radical nanotechnology concept pioneered by K.E. Drexler involving computer-controlled engineering and construction of nanoscale machines (including nanogears, nanosorters,

nanomotors, nanofactories, and (nano)assemblers) to make macroscopic objects. Could be described as the principles of mechanical engineering applied to chemistry.

monodisperse system

Powder or particle suspension containing primary particles with a narrow size distribution.

nanosarray

Array of nanoscale objects.

nanobalance

Any device for determining the mass of a nanoparticle.

nanobelt

See nanoribbon.

nanobiotechnology

1. Nanotechnology applied to 'bio', e.g. nanodevices for probing living organisms and nanomaterials for implants.
2. 'Bio' applied to 'nano', i.e. biomolecules used to make nanodevices, e.g. protein-based optically-switched optical switches and massively parallel fabrication via biological growth.
3. Bio-inspired nanotechnology: the use of biological construction principles for the design and fabrication of devices and materials.

nanoblock

Many-atom component used for building products, usually considered to have been assembled with atomic precision. A nanoblock may be simply a structural component, or it can have functionality built in (e.g. actuation, power or data signal conduction, or computation).

nanobot

Autonomous or semi-autonomous robot with an overall size less than 100 nm. Envisaged especially for use in healthcare: nanobots would circulate in the blood etc. carrying out monitoring and repair.

nanochip

Integrated electronic circuit or photonic device whose features are on the nanoscale.

nanochondrion

Hypothetical nanomachine (a synthetic mitochondrion) living inside a cell, and participating in its metabolism.

nanocluster

Small nanoparticle, i.e. group of atoms or molecules whose largest overall dimension is only a few nanometres.

nanocomposite

Composite material in which at least one of the phases has at least one dimension on the nanoscale.

nanocomputer

Information processor whose overall dimensions are less than 100 nm.

nanocrystal

Crystalline nanoparticle.

nanoelectromechanical system (NEMS)

Generic term to describe nanoscale microelectromechanical systems (MEMS).

nanoelectronics

Portmanteau term encompassing molecular electronics and nanoscale or single electron devices.

nanofabrication

Fabrication of materials and devices with control at the scale of a few nm.

nanofacture

Manufacture using nanotechnology, typically implying the use of molecular manufacturing.

nanofibre

Nanostructure with a fibre diameter of 1 to 100 nm and a length to diameter ratio of greater than 3:1.

nanofilter

Membrane or mesh with orifices in the range 1 to 100 nm.

nanofluidics

The technology of controlling fluids in structures whose features are in the 1–100 nm range.

nanohorn

Hollow nanoscale cone with a curved axis, typically based on SWNT (single walled carbon nanotubes).

nanoinprinting

Letterpress at the nanoscale, typically using an elastomer (most commonly PDME) as the stamp.

nanoindentation

Measurement procedure in which the force required to press a sharp diamond indenter into a material is measured as a function of indentation depth, resolved on the scale of nanometres. Young's modulus, hardness and yield strength can be determined. Creep, plastic flow and fracture of materials can also be investigated.

nanolithography

Photolithography on the nanoscale.

nanomachine

Artificial molecular machine made by molecular manufacturing.

nanomanipulator

Device for controlling the position of a workpiece with nanometre precision.

nanomaterial

A generic term for nanocomposites, nanoparticles, nanofilms, nanowires, etc.

nanomesh

Nanoscale mesh (nanoscale interstices and/or their bounds).

nanoöptics

The interaction of light and matter on the nanoscale. A key element of nanoscale optics is imaging/spectroscopy in the near-field (see near-field scanning optical microscopy). This technique enables measurements far below the classical diffraction limit and thus provides single molecule/nanoparticle detection and characterization capabilities.

nanoparticle

Particle 1 to 100 nm in diameter.

nanopen

1. Atomic force microscope (AFM) tip, adapted and used for drawing lines.
2. Small corral made by top-down or bottom-up processes, for confining nanoparticles in two or three dimensions.

nanopharmaceutical (noun)

Apothecaries' preparation making use of nanotechnology (e.g. nanoscale particles for drug delivery applications).

nanophase

Discrete phase within a material, whose properties (reflexion, absorption, conduction etc.) are a function of the characteristic spatial extension of the phase.

nanophotonics

A synonym for integrated optics or fibre optics.

nanopipette

Nanoscale tube used for delivering minute quantities of a fluid.

nanopore

Hole in a membrane, of diameter 1 to 100 nm.

nanopowder

Collection of nanoparticles.

nanoprobe

1. Tip for a scanning probe microscope.
2. Nanoscale machine used for one or more of imaging, reporting on, diagnosing and treating disease within the (human) body.

nanoreplicator

Nanomachine capable of self-replication.

nanoribbon

Nanofibre with an approximately rectangular cross-section; the ratio of the longer to the shorter dimensions of the cross-section is typically greater than 2:1.

nanorod

Straight solid nanofibre.

nanorope

Twisted nanofibres.

nanoscale

Having one or more Euclidean spatial dimensions typically in the range of 100 nm or less, i.e. from the (macro) molecular down to the atomic scale, but excluding the subatomic scale.

nanoscience

Study of phenomena at atomic (but not subatomic), molecular and macromolecular scales, especially where properties differ significantly from those at a larger scale, in order to achieve understanding of those phenomena.

nanosensor

Nanoscale sensor.

nanoshell

Hollow nanoparticle.

nanosome

Hypothetical nanodevice existing symbiotically inside a biological cell, performing mechano-synthesis and disassembly and replicating within the cell. Similar to nanochondrion (q.v.).

nanospin electronics

Spin polarized transport of electrons in nanostructures.

nanostuctured

Having identifiable structure at the nanoscale.

nanosurgery

Surgery at the nanoscale, e.g. molecular repair surgery on individual living cells.

nanotechnology

1. The design, characterization, production and application of materials, devices and systems by controlling shape and size at the nanoscale.
2. The deliberate and controlled manipulation, precision placement, measurement, modelling and production of matter at the nanoscale in order to create materials, devices, and systems with fundamentally new properties and functions.

nanotoxicology

The study of the toxic effects of nanomaterials, especially nanoparticles, on living systems, particularly human beings.

nanotube

Hollow nanofibre.

nanowire

Conducting or semiconducting nanofibre, used as a building block in nanoscale devices. Striped or 'superlatticed' nanowires can function as transistors, LEDs (light-emitting diodes) and other optoelectronic devices, biochemical sensors, heat-pumping thermoelectric devices, or all of the above, along the same length of wire.

near-field scanning optical microscopy (NSOM)

A technique for imaging surfaces in transmission or reflexion by mechanically scanning a light source, typically an optical fibre, of a diameter much smaller than the wavelength of light over the surface whilst monitoring the transmitted or reflected light.

organosol

Sol in which an organic liquid forms the dispersion medium.

Ostwald ripening

A redistribution process taking place in an initially polydisperse particle suspension, in which larger crystals grow at the expense of smaller ones, which dissolve away.

photoelectron spectroscopy

A physico-chemical analysis technique in which UV, vacuum ultraviolet (VUV) or X-radiation is used to excite electrons out from bound states in a solid and subsequently detected using an electron energy analyser. The technique can also be extended to measure the angular distribution of the electrons, providing information on the band structure or, via photoelectron diffraction, on the geometric structure of the surface region of a crystalline solid.

photoemission electron microscopy (PEEM)

A physico-chemical analysis technique in which linearly or circularly polarized X- or UV radiation is focused onto the sample surface, allowing the distribution of electrons emitted from the surface to be imaged. Typical resolution, 8 nm.

photoemission spectroscopy

See photoelectron spectroscopy.

photon correlation spectroscopy (PCS)

See dynamic light scattering (DLS).

point of zero charge (PZC)

pH at which the negative and positive charges of a suspended particle are balanced, so that it has no net charge.

primary particle

Particle which, in the context of whatever phenomenon is being discussed, has no substructure and cannot be subdivided.

quantum dot

Nanoscale particle that exhibits size-dependent electronic and optical properties due to quantum confinement.

quasi-elastic light scattering (QELS)

See dynamic light scattering (DLS).

scanning mobility particle sizing (SMPS)

A technique for detecting and counting nanoparticles, which gives both size and number information, and is capable of measuring aerosol size distribution typically from 3 to 800 nm; operates by charging particles and separating them based on their mobility when passing between electrodes.

scanning near-field optical microscopy (SNOM)

See near-field scanning optical microscopy (NSOM).

scanning probe microscopy (SPM)

Denotes a family of techniques, including (q.v.) AFM, STM and SNOM, for imaging surfaces using the interaction of a physical probe with the surface.

scanning tunnelling microscopy (STM)

A technique for revealing the apparent electron density-related atomic structure of surfaces, using a needle-like probe near the object under observation; a tunnelling current, which is measured, is generated by altering the potential at the tip of the probe; a three dimensional representation of the sample surface is generated by rastering the surface of the object and constructing isocurrents.

self-assembly

A process that produces structures by spontaneous agglomeration or aggregation of smaller entities into larger stable structures, driven by minimization of Gibbs free energy, but whose actual path is determined by the principle of least action.

self-organization

1. A self-connecting process (see self-assembly).
- 2a. An organizing process occurring within a subspace of a larger system, the rest of which system becomes more disorganized.
- 2b. The ability of far-from-equilibrium systems to develop patterns or spatially correlated (nano)structure in the absence of external control. Self-organization occurs in a wide variety of nanostructured systems including colloidal nanoparticle arrays and dewetting polymer films. Self-organization contrasts with (molecular) self-assembly by virtue of the effects occurring far from equilibrium.

slipping plane

Layer that separates the stationary and mobile phases in tangential flow of liquid with respect to a solid surface.

soft lithography

See nanoimprinting.

sol

Liquid dispersion containing particles of colloidal dimensions.

sol-gel processing

The conversion of a sol to a gel to produce a thin film (which may be comminuted to produce particles).

solution phase templating

A method for producing well-defined structures in solution using molecular self-assembly in conjunction with a template.

sonication

High-frequency sound waves typically used to aid the dispersion of nanoparticles in a liquid.

specific surface area

The ratio of the surface area to the mass of a (nano)powder.

supersphere

Roughly spherical agglomerate formed from roughly spherical primary particles.

thermal spraying and coating

A process for creating nanoparticles and nanostructured coatings where powder or wire is partially melted using a gas or plasma flame and then deposited onto a surface to give a thin layer.

top-down processing

A subtractive process for producing nanostructures from bulk materials.

ultrafine particle

Nanoparticle.

zeta potential

Electrostatic potential at the slipping plane relative to the potential in the bulk solution.