Glossary of Technical terms used in Materials Science

Addition polymerisation	A mechanism by which monomers with a double carbon (alkene) bond join end-to-end to form a much longer molecule or polymer.
Alloy	A metallic mixture of two or more elements. These may form a random solution of one metal in another or separate components or phases of different composition. Alloys may be interstitial (in which smaller alloy atoms occupy interstices) or substitutional, in which one alloy element replaces an atom of a similar sized element in a crystal structure.
Anions	Negatively charged ions, usually of non-metals.
Anisotropy	A feature of some materials that they do not exhibit the same physical properties in all directions, e.g. long chain polymers which have their polymer chains aligned, and the paper used by most newspapers, which tears neatly in one direction, but raggedly in another.
Anode	The electrode to which anions are attracted and at which an oxidation reaction takes place.
Austenite	A solid solution of carbon in iron achieved at high temperature, about 900°C. This structure is only thermodynamically stable at high temperature, but does exist at low temperatures due to the slow movement/diffusion of atoms that prevents restructuring into a more stable crystal form. The crystal structure of austenite is fcc.
Bio-materials	A growing branch of Materials Science dedicated to materials used in medical applications. The specific environment of a living body, being acceptable to the immune system, compatibility with organic tissue, biochemistry of cells... and much more make this an exciting field of current research.
Body-centred cubic crystal structure or bcc	A crystal structure in which the basic repeat unit is a cube with an atom at each corner AND an additional atom at the centre of the cube, i.e. 9 atoms per unit cube.
Brittle	A fracture with little of no plastic deformation. The opposite of ductile.
Brownian Motion	The agitation of small particles suspended in a fluid. Noted by Robert Brown, 18th century. Not explained until Albert Einstein used it to give evidence of the existence of atoms, early 20th century. (It was this explanation in a paper that made Einstein's reputation in the scientific community.)
Cast iron	The name given to the iron based material which contains between 1.7 and 6.67% carbon. See also, Pure irons and Steels
Cathode	The electrode to which cations are attracted and at which a reduction reaction takes place.

Cations	Positively charged ions, usually of metals.	
Cementite	Iron carbide, Fe_3C, an intermetallic material is formed when the composition of carbon in a steel reaches 6.67%. The carbon is interstitial and gives rise to 3 x Fe atoms for each C atom. (The formula is not implying a molecular structure nor a type of bonding.) Grain boundaries or specific planes within the crystal with wider atomic spacing, offer relatively low energy sites for carbon to diffuse to: as it does, the local composition increases eventually reaching the 6.67% composition needed for cementite formation. At the same time, this depletes the carbon concentration within the grains, allowing the formation of the ferrite phase. Cementite therefore appears at grain boundaries and in higher concentrations, along certain crystal planes, forming parallel bands or lamellae. Because cementite is very hard compared to the ferrite, the result is a strengthening of the steel. Increasing carbon / cementite increases hardness but reduces toughness and vice versa.	
Ceramic	A giant covalent compound typically formed between a metal or metalloid and oxygen.	
Colloid	A two phase material, usually of very small solid particles suspended in a liquid medium. Electrostatic forces keep the particles separated.	
Composite Materials	Materials made from more than one component in such a way as to maximise the combined properties of the material. Examples include (natural) wood, bone, (synthetic) fibre glass, alloys.	
Compression	Loaded such that opposite ends are being squeezed together.	
Compressive Stress	Stress which is squeezing a material, i.e. the material is in compression.	
Condensation polymerisation	A mechanism by which monomers, typically containing carbonyl groups, join together and in which a small molecule such as water is also formed during the reaction.	
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Contraction cavity	In a large casting, the surface solidifies and contracts faster than the centre. The effect of contraction is for the bulk material to move to the outer surface. In a 3D casting this tends to leave a gap or a number of gaps near to the centre.	

Corrosion	The electrochemical process by which a metal reacts with its environment.
Creep	The movement of atoms or molecules past each other under the effect of a low stress. This is essentially a temperature-dependent, self-diffusion process resulting in deformation. Some plastics and lead are examples of materials that creep at room temperature.
Crevice Corrosion	In small, confined spaces, diffusion of oxygen to steel surfaces in inhibited. The difference in oxygen concentration between that over a small area in a crevice and a large area outside the crevice is sufficient to set up a corrosion cell (essentially differential aeration) in which the small are of the crevice is subjected to a high corrosion current. Thus corrosion is localised to a small area – potentially with catastrophic results.
Cross Link	A chemical bridge between two separate molecules joining them together.
Dendrite	A many branched crystal, such as a snowflake, in which branches have branches and so on. Dendritic literally means "like a dendrite".
Dislocation	A discontinuity in a crystal due to an extra plane of atoms squeezed between two normal planes. The edge of the extra plane distorts the crystal lattice causing local stress.
Ductile	A property due to the plastic deformation of materials which allows the material to be drawn out into a wire or beaten into shape.
Elastic	The ability of a material to stretch under the influence of an external stress / force, but to return to the original shape and size once the stress / force is removed.
Elastomer	Polymers with a large elastic range, that is are elastic for very large strains
Electomotive force, emf	The electrical potential between two electrodes of an electrochemical cell when no current flows
Electrical Potential	"The work done when a unit positive electrical charge moves from an infinite distance to that point." The absolute value can not be determined, so values are compared to reference or standard values, typically the hydrogen electrode or the more practical calomel electrode. The difference in potential (potential difference) between an electrode and a reference electrode is referred to as the "electrode potential". The SI unit used is the volt, V
Electrochemical Cell	An arrangement by which an electrical current can be produced from a redox reaction in which the reduction and oxidation half reactions take place at separate electrodes.

Electrode	The interface between an electrolyte and an external circuit at which electrochemical reactions occur. There are two types of electrode, namely anode and cathode.
Electrolyte	A medium containing ions which are free to move (solution, fused or molten state and even solid in some circumstances). Like a conductor, the electrolyte allows charged particles to flow, hence it conducts electricity. Unlike a conductor, it can be changed, at the electrodes, by the passage of that current.
Extrude	The forcing of a ductile solid through a hole so as to produce a bar or wire with the external shape of the hole. Squeezing tooth paste illustrates the process. Metals can also be squeezed through a hole (or die) at very high pressures and elevated temperatures. The technique is very versatile and can be used to make, for example, copper wire or sections of railway carriages (aluminium).
Face-centred cubic crystal structure or fcc	A crystal structure in which the basic repeat unit is a cube with an atom at each corner AND an additional atom at the centre of each face, i.e. 14 atoms per unit cube.
Ferrite	A stable form of crystalline iron at room temperature which contains little or no carbon. The crystal structure of ferrite is bcc.
Ferrofluid	A magnetic liquid. A sol of magnetic nanoparticles in a liquid (aqueous or hydrocarbon) phase. The particles exhibit ferromagnetic behaviour individually, and the liquid as a whole responds in a ferromagnetic way to magnetic fields. However, the liquid does not retain any magnetism as a solid ferromagnet would do.
Ferromagnetic	Behaving like a magnetised piece of iron (ferrum, Fe).
Fracture Stress	Stress at fracture, taking into account any necking occurring.
Galvanise	A process of protecting iron by giving the surface a sacrificial coating of zinc. Zinc is more reactive than iron, therefore it is anodic with respect to iron and corrodes preferentially. Coatings can be applied by “hot dipping”, electrolysis or painting.
Grain	The name given to the crystals in a metallic structure.
Hardness	A measure of a material’s resistance to deformation. Tested by measuring the extent of plastic deformation by a standard indentation test.
Heat treatment	Refers to the modifying of mechanical properties by holding a metal at a specific set temperature for a period of time and the rate at which it is allowed to cool.
Hyper-eutectoid steel	A ferrous material which contains more than 6.67% carbon. See also Cast irons, Pure irons, Steel.

Ingot	A bar of metal formed by pouring liquid metal into a rectangular mould and allowing it to solidify/freeze.
Inhibitor	A chemical which slows down, or stops a chemical reaction, by increasing the activation energy of the rate determining step, that is an inhibitor is the opposite of a catalyst. The term is frequently applied to chemicals which prevent corrosion in this way.
Interstices	The gaps between spherical atoms into which smaller atoms can collect, such as happens when carbon atoms collect between the physically much larger iron atoms. Alloys which contain an alloying element in these interstices is said to be Interstitial.
Martensite	A microstructure producing very hard steel when austenite is quenched rapidly from about 900°C to below 300°C. Martensite is also obtained in other alloys, such as shape memory alloys, for example "Nitinol".
Materials Science	The applied science that studies the useful and economic substances on which manufacturing and engineering industries depend. Branches include bio-materials, ceramics, composites, corrosion, metallurgy, nano-materials, plastics, processing. Materials Science is cross-disciplinary in nature and provides much stimulation in the application of diverse disciplines to solve real, practical problems.
Metallurgy	The branch of Materials Science that specialises in metal.
Micron	Unit of distance = 10^{-6}m
Monomer	A small molecule which can react with other molecules to form larger chains or polymers.
Mould	A container for a liquid which holds the liquid in a specific shape until the liquid solidifies and adopts the shape of the inside of the container.
Nano-material	A general term applied to anything to do with properties of nanoparticles.
Nanometre	Unit of distance = 10^{-9}m (Approximately the diameter of 10 H atoms.)
Nanoparticle	A particle that has dimensions of the order of magnitude in nanometres. These particles generally contain up to a few hundred thousand atoms and are so small that quantum effects are still significant and they do not scatter light.
Necking	Thinning due to plastic deformation in a ductile specimen under tensile stress.
Oxidation	Can be considered as that half of a chemical reaction in which… • Oxygen is added, or • Hydrogen is removed, or • Electrons are lost, or • Oxidation number is increased.

Passivation	Under certain oxidising conditions, a thin protective iron oxide layer can be formed which behaves somewhat like that on aluminium, but more fragile. The formation of this protective oxide layer is called passivation.
Pearlite	A microscopic feature of iron carbide lamellae within grains of carbon steel. The lamellae (or platelets) develop along a crystal plane appearing as parallel lines. These lines can interfere with light to give a "mother of pearl" effect when viewed.
Phase	A separate component in a heterogeneous chemical system. E.g. a water and ice mix is two phases of the same substance whereas a salt solution is a single phase made of two substances. There can be many phases in metal systems either due to different crystal structures or different chemical composition.
Plastic	The ability of a material to flow under sufficient stress allowing changes in shape without breaking. Plastic deformation results in permanent shape changes when atoms or molecules slide past one another. Ideal plastic properties are illustrated by ***Plastic***ine.
Plastics	A type of polymer which have a stable shape under normal conditions, but which exhibit plastic deformation at some stage in their manufacture or use. There are two classes, thermoplastics and thermosetting plastics.
Polymer	A molecule (natural or synthetic) made up from repeat units of a monomer molecule.
Potential Difference	The work done when a unit positive electrical charge moves from one point to another. The SI unit used is the volt, V
Processing	Reference to industrial scale manufacturing of materials or objects. Steel making is an industrial process for producing a material and the manufacture of plastic bottles is a process of producing a finished product from a processed material.
Pure Irons	The name given to iron with less than 0.03% carbon and has a purely ferrite composition at 723ºC. See also Steel and Cast iron.
Quench	A rapid cooling of a material. In steel it usually refers to cooling from over 860°C to below 300°C by immersing in water or oil. The rapid cooling prevents diffusion of carbon atoms resulting in meta-stable phase transformations. A range of microstructures can be produced depending on composition, start and finish temperatures and rate of cooling, One structure resulting from quenching which gives rise to very hard steel, or shape memory properties in some nickel / Titanium / Aluminium / Copper alloys is described as Martensite.

Redox	A full chemical reaction which can be separated into reduction and oxidation processes which occur at the same time. OIL RIG = **O**xidation **I**s **L**OSS, **R**eduction **I**s **G**AIN of electrons
Reduction	Can be considered as that half of a chemical reaction in which… • Hydrogen is added, or • Oxygen is removed, or • Electrons are gained, or • Oxidation number is decreased.
Rusting	The aqueous corrosion of iron to form rust – iron oxide, Fe_3O_4.
Sacrificial Protection	A technique to protect a structural metal from a corrosive environment by connecting it to a more reactive metal. The more reactive metal reacts anodically and is corroded, and the structural metal is protected cathodically. Thus the reactive metal is sacrificed to protect the structural metal. Examples include galvanising, cadmium plating and bolting bars of zinc or magnesium to the (iron) hulls of ships.
Samurai Sword	The swords are made (only) for Samurai warriors by a method which is a martial art in itself, the craftsman being a "Master" in the art. The process was originally learned from the Chinese, but perfected by the Japanese. Samurai swords are known to have been made as early as the 7th century and are still made today. Perhaps the peak of the art was in the 17th/18th century. The process of changing the iron ore to finished sword can take several months, including the construction of the furnace to extract the steel from ore. Repeated layering and forge welding can produced up to 30,000 layers in a single blade. Polishing and sharpening the sword can take as long as the forge welding process! More than one sword will be made at any one time, with different swords at different stages of preparation.
Steel	An alloy of iron containing between 0.03 and 1.7% carbon and has an austenite structure at 1130ºC because all of the carbon dissolves in the steel at this temperature. Other alloying elements may be added to modify mechanical and chemical properties of the alloy. See also, Pure irons and Cast iron.
Strain	The ratio of extension t original length of an object under stress. $\varepsilon = \frac{x}{l}$ Where ε = strain, a dimensionless quantity. X = extension, m. l = original length, m.
Strength	The compressive or tensile load that can be withstood.

Stress	Stress is a scalar quantity analogous to pressure and is defined as force per unit area… $\sigma = \frac{F}{A}$ where σ = stress, Nm^{-2}. F = force, N A = Cross sectional area, m^2. See also, Fracture Stress, Yield Stress
Sword of Damascus	A style of sword popularly, but erroneously, credited with being made in Damascus where highly polished steel swords were, in fact made and inlaid with gold. Damascus swords were actually made in Persia (now Iran) but could be bought in Damascus. It seems likely that the Damascus sword smiths may have "finished off" some actual Damascus swords by polishing and adding gold inlay. An expedition organized by Robert Boyle – yes, the Boyle's Law Boyle) was sent to investigate and report on Damascus swords. The so-called Damascus swords were patterned, due to the method used in forging the steel. They were produced by the thermo- mechanical (heating and hammering) processing of a hypereutectoid steel (crucible steel or wootz). The confusion arises because the swords were thought to have a pattern similar to that found on Damascus silk. Thus the different, Western European, pattern-welding process that produced similar patterns was called "damascening". This was intended to reproduce the structures seen on these swords and is still used to this day to produce high quality shotgun barrels. A display of this metalwork for guns is in the Pitt-Rivers Museum in Oxford.
Temper colour	Providing the steel surface is clean, when tempered in air, oxides form on the surface. The thickness of these oxides is determined by the temperature (NOT time) of tempering. The crystal structure of the oxide layer then behaves as a grating causing interference of the incident light and resulting in different colours being seen. The thickness of the oxide and hence tempering temperature can be estimated, therefore, by the colour of the tempered surface… Yellow = 225°C Brown = 250°C Blue = 300°C Dark Blue = 315°C *Note – Values are subjective to estimating shades of colours.*

Tempering	One method of heat treating a steel by raising the temperature of a quenched piece of carbon steel from room temperature to the region of 200 to 300°C and holding it for a time, depending on its size. This allows diffusion and changes in crystal structure to take place within the steel. The result is to improve toughness and ductility of the final steel without losing too much strength.
Tensile Stress	Stress which is stretching a material, i.e. the material is in tension.
Tension	Loaded such that opposite ends are being pulled apart.
Thermoplastic	A class of polymer which softens and become ductile on heating. These may be addition polymers (polythene, polystyrene, pvc…) or condensation polymers (nylon, perspex…).
Thermosetting	A class of polymer which hardens permanently due to cross linking when heated (or cured). These are usually condensation polymers (bakelite, epoxy resin, SBR after vulcanisation…).
Thixotropic	Property of becoming liquid when shaken or stirred then returning to a gel state afterwards. Having high static shear strength and low dynamic shear strength simultaneously
Toughness	The ability of a material to absorb energy from an impact. To illustrate, elastomers are soft and stretch easily. By stretching they absorb energy from an impact and are, therefore very tough. By contrast, ceramics are very hard, but are also brittle, absorbing little energy of an impact – these materials are NOT tough.
Yield Stress	Carbon steels have the onset of plastic deformation delayed by the pinning of dislocations by interstitial carbon atoms. However, eventually, the steel "Yields" and dislocations begin to move, leaving carbon atoms behind. The dislocations are no longer pinned and subsequent dislocation movement occurs at a lower stress, that is, it becomes easier to bend the steel a second time. If the steel is tempered, carbon atoms can again, in time, diffuse to the new sites of dislocations and pin them once more.
Young's Modulus	Elastic modulus represented by the ratio of stress to strain… $E = \frac{\sigma}{\varepsilon}$ Where E = Young's Modulus, σ = stress, Nm^{-2}, ε = strain, dimensionless

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