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Chapter 1 : NPTEL :: Metallurgy and Material Science - Introduction to Materials Science and Engineering

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Metals are shaped by processes such as: Casting â€” molten metal is poured into a shaped mold. Forging â€” a red-hot billet is hammered into shape. Rolling â€” a billet is passed through successively narrower rollers to create a sheet. Laser cladding â€” metallic powder is blown through a movable laser beam e. The resulting melted metal reaches a substrate to form a melt pool. By moving the laser head, it is possible to stack the tracks and build up a three-dimensional piece. Extrusion â€” a hot and malleable metal is forced under pressure through a die , which shapes it before it cools. Sintering â€” a powdered metal is heated in a non-oxidizing environment after being compressed into a die. Machining â€” lathes , milling machines , and drills cut the cold metal to shape. Fabrication â€” sheets of metal are cut with guillotines or gas cutters and bent and welded into structural shape. Work hardening creates microscopic defects in the metal, which resist further changes of shape. Various forms of casting exist in industry and academia. These include sand casting , investment casting also called the lost wax process , die casting , and continuous castings. Each of these forms has advantages for certain metals and applications considering factors like magnetism and corrosion. Common heat treatment processes include annealing , precipitation strengthening , quenching , and tempering. There is a balance between hardness and toughness in any steel; the harder the steel, the less tough or impact-resistant it is, and the more impact-resistant it is, the less hard it is. Tempering relieves stresses in the metal that were caused by the hardening process; tempering makes the metal less hard while making it better able to sustain impacts without breaking. Often, mechanical and thermal treatments are combined in what are known as thermo-mechanical treatments for better properties and more efficient processing of materials. These processes are common to high-alloy special steels, superalloys and titanium alloys. Plating Electroplating is a chemical surface-treatment technique. It involves bonding a thin layer of another metal such as gold , silver , chromium or zinc to the surface of the product. This is done by selecting the coating material electrolyte solution which is the material that is going to coat the work piece gold, silver, There needs to be two electrodes of different materials one the same material as the coating material and one that is receiving the coating material. It is also used to make inexpensive metals look like the more expensive ones gold, silver. Shot peening Shot peening is a cold working process used to finish metal parts. In the process of shot peening, small round shot is blasted against the surface of the part to be finished. This process is used to prolong the product life of the part, prevent stress corrosion failures, and also prevent fatigue. The shot leaves small dimples on the surface like a peen hammer does, which cause compression stress under the dimple. As the shot media strikes the material over and over, it forms many overlapping dimples throughout the piece being treated. The compression stress in the surface of the material strengthens the part and makes it more resistant to fatigue failure, stress failures, corrosion failure, and cracking. Thermal spraying Thermal spraying techniques are another popular finishing option, and often have better high temperature properties than electroplated coatings. Thermal spraying, also known as a spray welding process, [21] is an industrial coating process that consists of a heat source flame or other and a coating material that can be in a powder or wire form which is melted then sprayed on the surface of the material being treated at a high velocity. The spray treating process is known by many different names such as hvof, plasma spray, flame spray, arc spray, and metalizing. Microstructure[edit] Metallography allows the metallurgist to study the microstructure of metals. Metallurgists study the microscopic and macroscopic properties using metallography , a technique invented by Henry Clifton Sorby. In metallography, an alloy of interest is ground flat and polished to a mirror finish. The sample can then be etched to reveal the microstructure and macrostructure of the metal. The sample is then examined in an optical or electron microscope , and the image contrast provides details on the composition, mechanical properties, and processing history. Crystallography , often using diffraction of x-rays or electrons , is another valuable tool available to the modern metallurgist. Crystallography allows identification of unknown materials and reveals the crystal structure of the sample. Quantitative crystallography can be used to calculate the amount of phases present as well as the degree of strain to which a sample has been subjected.

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The material of choice of a given era is often a defining point. Phrases such as Stone Age, Bronze Age, Iron Age, and Steel Age are historic, if arbitrary examples.. Originally deriving from the manufacture of ceramics and its putative derivative metallurgy, materials science is one of the oldest forms of engineering and applied.

Nanomaterials research takes a materials science-based approach to nanotechnology , leveraging advances in materials metrology and synthesis which have been developed in support of microfabrication research. Materials with structure at the nanoscale often have unique optical, electronic, or mechanical properties. The field of nanomaterials is loosely organized, like the traditional field of chemistry, into organic carbon-based nanomaterials such as fullerenes, and inorganic nanomaterials based on other elements, such as silicon. Examples of nanomaterials include fullerenes , carbon nanotubes , nanocrystals , etc. Biomaterial The iridescent nacre inside a nautilus shell. A biomaterial is any matter, surface, or construct that interacts with biological systems. The study of biomaterials is called bio materials science. It has experienced steady and strong growth over its history, with many companies investing large amounts of money into developing new products. Biomaterials science encompasses elements of medicine , biology , chemistry , tissue engineering , and materials science. Biomaterials can be derived either from nature or synthesized in a laboratory using a variety of chemical approaches using metallic components, polymers , bioceramics , or composite materials. Such functions may be benign, like being used for a heart valve , or may be bioactive with a more interactive functionality such as hydroxylapatite coated hip implants. Biomaterials are also used every day in dental applications, surgery, and drug delivery. For example, a construct with impregnated pharmaceutical products can be placed into the body, which permits the prolonged release of a drug over an extended period of time. A biomaterial may also be an autograft , allograft or xenograft used as an organ transplant material. Electronic, optical, and magnetic[edit] Negative index metamaterial. These materials form the basis of our modern computing world, and hence research into these materials is of vital importance. Semiconductors are a traditional example of these types of materials. They are materials that have properties that are intermediate between conductors and insulators. Their electrical conductivities are very sensitive to impurity concentrations, and this allows for the use of doping to achieve desirable electronic properties. Hence, semiconductors form the basis of the traditional computer. This field also includes new areas of research such as superconducting materials, spintronics , metamaterials , etc. The study of these materials involves knowledge of materials science and solid-state physics or condensed matter physics. Computational science and theory[edit] With the increase in computing power, simulating the behavior of materials has become possible. This enables materials scientists to discover properties of materials formerly unknown, as well as to design new materials. Up until now, new materials were found by time-consuming trial and error processes. But, now it is hoped that computational methods could drastically reduce that time, and allow tailoring materials properties. This involves simulating materials at all length scales, using methods such as density functional theory , molecular dynamics , etc. In industry[edit] Radical materials advances can drive the creation of new products or even new industries, but stable industries also employ materials scientists to make incremental improvements and troubleshoot issues with currently used materials. Industrial applications of materials science include materials design, cost-benefit tradeoffs in industrial production of materials, processing methods casting , rolling , welding , ion implantation , crystal growth , thin-film deposition , sintering , glassblowing , etc. Besides material characterization, the material scientist or engineer also deals with extracting materials and converting them into useful forms. Thus ingot casting, foundry methods, blast furnace extraction, and electrolytic extraction are all part of the required knowledge of a materials engineer. Often the presence, absence, or variation of minute quantities of secondary elements and compounds in a bulk material will greatly affect the final properties of the materials produced. Thus, the extracting and purifying methods used to extract iron in a blast furnace can affect the quality of steel that is produced. Ceramics and glasses[edit] Main article: Ceramic Si_3N_4 ceramic bearing parts Another application of material science is the structures of ceramics and glass typically associated with the most brittle materials. Bonding in ceramics and glasses uses covalent and ionic-covalent types with SiO_2 silica or sand as a fundamental building block. Ceramics are as soft as clay or as hard as stone and concrete. Usually, they are crystalline in form. Most glasses contain a metal oxide fused with silica. At high temperatures used to prepare glass, the material is a viscous liquid. The structure of glass forms into an amorphous state upon cooling. Windowpanes and eyeglasses are important examples. Fibers of glass are also available. Scratch resistant Corning Gorilla Glass is a well-known example of the application of materials science to drastically improve the properties of common components. Diamond and carbon in its graphite form are considered to be ceramics. Engineering ceramics are known for their stiffness and stability under high temperatures, compression and electrical stress. Alumina, silicon carbide , and tungsten carbide are made from a fine powder of their constituents in a process of sintering with a binder. Hot pressing provides higher density material. Chemical vapor deposition can place a film of a ceramic on another material. Cermets are ceramic particles containing some metals. The wear resistance of tools is derived from cemented carbides with the metal phase of cobalt and nickel typically added to modify properties. Filaments are commonly used for reinforcement in composite materials. Another application of materials science in industry is making composite materials. These are structured materials composed of two or more macroscopic phases. RCC is a laminated composite material made from graphite rayon cloth and impregnated with a phenolic resin. After curing at high temperature in an autoclave, the laminate is pyrolized to convert the resin to carbon, impregnated with furfural alcohol in a vacuum chamber, and cured-pyrolized to convert the furfural alcohol to carbon. To provide oxidation resistance for reuse ability, the outer layers of the RCC are converted to silicon carbide. Other examples can be seen in the "plastic" casings of television sets, cell-phones and so on. These plastic casings are usually a composite material made up of a thermoplastic matrix such as acrylonitrile butadiene styrene ABS in which calcium carbonate chalk, talc , glass fibers or carbon fibers have been added for added strength, bulk, or electrostatic dispersion. These additions may be termed reinforcing fibers, or dispersants, depending on their purpose.

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Chapter 8 : Material Science and Metallurgy â€“ Mechanical Engineering

Metallurgy is a domain of materials science and of materials engineering that studies the physical and chemical behavior of metallic elements and their mixtures, which are called alloys.

Chapter 9 : Materials Science and Metallurgy Engineering

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