INTERPRETATION OF TRANSMISSION ELECTRON MICROGRAPHS pdf

1: Scanning Electron Microscopy (SEM)

Edington J.W. () Interpretation of Transmission Electron Micrographs. In: Interpretation of Transmission Electron Micrographs. Philips Technical Library (Monographs in Practical Electron Microscopy in Materials Science).

Electrons are usually generated in an electron microscope by a process known as thermionic emission from a filament, usually tungsten, in the same manner as a light bulb , or alternatively by field electron emission. The transmitted beam contains information about electron density, phase and periodicity ; this beam is used to form an image. Layout of optical components in a basic TEM Hairpin style tungsten filament Single crystal LaB6 filament From the top down, the TEM consists of an emission source, which may be a tungsten filament or needle, or a lanthanum hexaboride LaB6 single crystal source. The electron source is typically mounted in a Wehnelt cylinder to provide preliminary focus of the emitted electrons into a beam. The upper lenses of the TEM then further focus the electron beam to the desired size and location. The interaction of electrons with a magnetic field will cause electrons to move according to the left hand rule , thus allowing for electromagnets to manipulate the electron beam. The use of magnetic fields allows for the formation of a magnetic lens of variable focusing power, the lens shape originating due to the distribution of magnetic flux. Additionally, electrostatic fields can cause the electrons to be deflected through a constant angle. Coupling of two deflections in opposing directions with a small intermediate gap allows for the formation of a shift in the beam path, allowing for beam shifting in TEM, which is important for STEM. From these two effects, as well as the use of an electron imaging system, sufficient control over the beam path is possible for TEM operation[citation needed]. The optical configuration of a TEM can be rapidly changed, unlike that for an optical microscope, as lenses in the beam path can be enabled, have their strength changed, or be disabled entirely simply via rapid electrical switching, the speed of which is limited by effects such as the magnetic hysteresis of the lenses. Optics[edit] The lenses of a TEM allow for beam convergence, with the angle of convergence as a variable parameter, giving the TEM the ability to change magnification simply by modifying the amount of current that flows through the coil, quadrupole or hexapole lenses. The quadrupole lens is an arrangement of electromagnetic coils at the vertices of the square, enabling the generation of a lensing magnetic fields, the hexapole configuration simply enhances the lens symmetry by using six, rather than four coils. Typically a TEM consists of three stages of lensing. The stages are the condenser lenses, the objective lenses, and the projector lenses. The condenser lenses are responsible for primary beam formation, while the objective lenses focus the beam that comes through the sample itself in STEM scanning mode, there are also objective lenses above the sample to make the incident electron beam convergent. The projector lenses are used to expand the beam onto the phosphor screen or other imaging device, such as film. It is noted that TEM optical configurations differ significantly with implementation, with manufacturers using custom lens configurations, such as in spherical aberration corrected instruments, [21] or TEMs using energy filtering to correct electron chromatic aberration. Components[edit] The electron source of the TEM is at the top, where the lensing system 4,7 and 8 focuses the beam on the specimen and then projects it onto the viewing screen The beam control is on the right 13 and 14 A TEM is composed of several components, which include a vacuum system in which the electrons travel, an electron emission source for generation of the electron stream, a series of electromagnetic lenses, as well as electrostatic plates. The latter two allow the operator to guide and manipulate the beam as required. Also required is a device to allow the insertion into, motion within, and removal of specimens from the beam path. Imaging devices are subsequently used to create an image from the electrons that exit the system. TEM components such as specimen holders and film cartridges must be routinely inserted or replaced requiring a system with the ability to re-evacuate on a regular basis. As such, TEMs are equipped with multiple pumping systems and airlocks and are not permanently vacuum sealed. The vacuum system for evacuating a TEM to an operating pressure level consists of several stages. Initially, a low or roughing vacuum is achieved with either a rotary vane pump or diaphragm pumps setting a sufficiently low pressure to allow the operation of a turbo-molecular or diffusion pump establishing high vacuum level necessary for operations. To allow for the low vacuum pump to not require continuous operation, while

continually operating the turbo-molecular pumps, the vacuum side of a low-pressure pump may be connected to chambers which accommodate the exhaust gases from the turbo-molecular pump. For these very low pressures, either an ion pump or a getter material is used. Poor vacuum in a TEM can cause several problems ranging from the deposition of gas inside the TEM onto the specimen while viewed in a process known as electron beam induced deposition to more severe cathode damages caused by electrical discharge. The specimen holders hold a standard size of sample grid or self-supporting specimen. Standard TEM grid sizes are 3. The sample is placed onto the meshed area having a diameter of approximately 2. Usual grid materials are copper, molybdenum, gold or platinum. This grid is placed into the sample holder, which is paired with the specimen stage. A wide variety of designs of stages and holders exist, depending upon the type of experiment being performed. In addition to 3. These grids were particularly used in the mineral sciences where a large degree of tilt can be required and where specimen material may be extremely rare. Once inserted into a TEM, the sample has to be manipulated to locate the region of interest to the beam, such as in single grain diffraction, in a specific orientation. To accommodate this, the TEM stage allows movement of the sample in the XY plane, Z height adjustment, and commonly a single tilt direction parallel to the axis of side entry bolders. Sample rotation may be available on specialized diffraction holders and stages. Some modern TEMs provide the ability for two orthogonal tilt angles of movement with specialized holder designs called double-tilt sample holders. Some stage designs, such as top-entry or vertical insertion stages once common for high resolution TEM studies, may simply only have X-Y translation available. The design criteria of TEM stages are complex, owing to the simultaneous requirements of mechanical and electron-optical constraints and specialized models are available for different methods. A TEM stage is required to have the ability to hold a specimen and be manipulated to bring the region of interest into the path of the electron beam. Modern devices may use electrical stage designs, using screw gearing in concert with stepper motors , providing the operator with a computer-based stage input, such as a joystick or trackball. Two main designs for stages in a TEM exist, the side-entry and top entry version. A diagram of a single axis tilt sample holder for insertion into a TEM goniometer. Titling of the holder is achieved by rotation of the entire goniometer The most common is the side entry holder, where the specimen is placed near the tip of a long metal brass or stainless steel rod, with the specimen placed flat in a small bore. Along the rod are several polymer vacuum rings to allow for the formation of a vacuum seal of sufficient quality, when inserted into the stage. The stage is thus designed to accommodate the rod, placing the sample either in between or near the objective lens, dependent upon the objective design. When inserted into the stage, the side entry holder has its tip contained within the TEM vacuum, and the base is presented to atmosphere, the airlock formed by the vacuum rings. Insertion procedures for side-entry TEM holders typically involve the rotation of the sample to trigger micro switches that initiate evacuation of the airlock before the sample is inserted into the TEM column. The second design is the top-entry holder consists of a cartridge that is several cm long with a bore drilled down the cartridge axis. The specimen is loaded into the bore, possibly using a small screw ring to hold the sample in place. This cartridge is inserted into an airlock with the bore perpendicular to the TEM optic axis. When sealed, the airlock is manipulated to push the cartridge such that the cartridge falls into place, where the bore hole becomes aligned with the beam axis, such that the beam travels down the cartridge bore and into the specimen. Such designs are typically unable to be tilted without blocking the beam path or interfering with the objective lens.

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2: Transmission electron microscopy - Wikipedia

Transmission electron microscopy (TEM, also sometimes conventional transmission electron microscopy or CTEM) is a microscopy technique in which a beam of electrons is transmitted through a specimen to form an image.

Scanning electron microscope Image of bacillus subtilis taken with a s electron microscope The SEM produces images by probing the specimen with a focused electron beam that is scanned across a rectangular area of the specimen raster scanning. When the electron beam interacts with the specimen, it loses energy by a variety of mechanisms. The lost energy is converted into alternative forms such as heat, emission of low-energy secondary electrons and high-energy backscattered electrons, light emission cathodoluminescence or X-ray emission, all of which provide signals carrying information about the properties of the specimen surface, such as its topography and composition. The image displayed by an SEM maps the varying intensity of any of these signals into the image in a position corresponding to the position of the beam on the specimen when the signal was generated. In the SEM image of an ant shown below and to the right, the image was constructed from signals produced by a secondary electron detector, the normal or conventional imaging mode in most SEMs. However, because the SEM images the surface of a sample rather than its interior, the electrons do not have to travel through the sample. This reduces the need for extensive sample preparation to thin the specimen to electron transparency. The SEM is able to image bulk samples that can fit on its stage and still be maneuvered, including a height less than the working distance being used, often 4 millimeters for high-resolution images. The SEM also has a great depth of field, and so can produce images that are good representations of the three-dimensional surface shape of the sample. Another advantage of SEMs comes with environmental scanning electron microscopes ESEM that can produce images of good quality and resolution with hydrated samples or in low, rather than high, vacuum or under chamber gases. This facilitates imaging unfixed biological samples that are unstable in the high vacuum of conventional electron microscopes. An image of an ant in a scanning electron microscope Color In their most common configurations, electron microscopes produce images with a single brightness value per pixel, with the results usually rendered in grayscale. This may be done to clarify structure or for aesthetic effect and generally does not add new information about the specimen. Examples are the Energy-dispersive X-ray spectroscopy EDS detectors used in elemental analysis and Cathodoluminescence microscope CL systems that analyse the intensity and spectrum of electron-induced luminescence in for example geological specimens. In SEM systems using these detectors, it is common to color code the signals and superimpose them in a single color image, so that differences in the distribution of the various components of the specimen can be seen clearly and compared. Such images can be made while maintaining the full integrity of the original signal, which is not modified in any way. Scanning transmission electron microscopy The STEM rasters a focused incident probe across a specimen that as with the TEM has been thinned to facilitate detection of electrons scattered through the specimen. The STEMs use of SEM-like beam rastering simplifies annular dark-field imaging , and other analytical techniques, but also means that image data is acquired in serial rather than in parallel fashion. Sample preparation An insect coated in gold for viewing with a scanning electron microscope Materials to be viewed under an electron microscope may require processing to produce a suitable sample. The technique required varies depending on the specimen and the analysis required: Negative stain â€” suspensions containing nanoparticles or fine biological material such as viruses and bacteria are briefly mixed with a dilute solution of an electron-opaque solution such as ammonium molybdate, uranyl acetate or formate , or phosphotungstic acid. This mixture is applied to a suitably coated EM grid, blotted, then allowed to dry. Viewing of this preparation in the TEM should be carried out without delay for best results. The method is important in microbiology for fast but crude morphological identification, but can also be used as the basis for high-resolution 3D reconstruction using EM tomography methodology when carbon films are used for support. Negative staining is also used for observation of nanoparticles. Cryofixation â€” freezing a specimen so rapidly, in liquid ethane , and maintained at liquid nitrogen or even liquid helium temperatures, so that the water forms vitreous non-crystalline ice. This preserves the specimen in a snapshot of its solution state. An

entire field called cryo-electron microscopy has branched from this technique. With the development of cryo-electron microscopy of vitreous sections CEMOVIS , it is now possible to observe samples from virtually any biological specimen close to its native state. Embedding, biological specimens â€" after dehydration, tissue for observation in the transmission electron microscope is embedded so it can be sectioned ready for viewing. After the resin has been polymerized hardened the sample is thin sectioned ultrathin sections and stained â€" it is then ready for viewing. Embedding, materials â€" after embedding in resin, the specimen is usually ground and polished to a mirror-like finish using ultra-fine abrasives. The polishing process must be performed carefully to minimize scratches and other polishing artifacts that reduce image quality. Metal shadowing â€" Metal e. Replication â€" A surface shadowed with metal e. This is followed by removal of the specimen material e. Sectioning â€" produces thin slices of the specimen, semitransparent to electrons. Disposable glass knives are also used because they can be made in the lab and are much cheaper. Staining â€" uses heavy metals such as lead , uranium or tungsten to scatter imaging electrons and thus give contrast between different structures, since many especially biological materials are nearly "transparent" to electrons weak phase objects. In biology, specimens can be stained "en bloc" before embedding and also later after sectioning. Typically thin sections are stained for several minutes with an aqueous or alcoholic solution of uranyl acetate followed by aqueous lead citrate. The second coat of carbon, evaporated perpendicular to the average surface plane is often performed to improve the stability of the replica coating. The specimen is returned to room temperature and pressure, then the extremely fragile "pre-shadowed" metal replica of the fracture surface is released from the underlying biological material by careful chemical digestion with acids, hypochlorite solution or SDS detergent. The still-floating replica is thoroughly washed free from residual chemicals, carefully fished up on fine grids, dried then viewed in the TEM. Freeze-fracture replica immunogold labeling FRIL â€" the freeze-fracture method has been modified to allow the identification of the components of the fracture face by immunogold labeling. Instead of removing all the underlying tissue of the thawed replica as the final step before viewing in the microscope the tissue thickness is minimized during or after the fracture process. The thin layer of tissue remains bound to the metal replica so it can be immunogold labeled with antibodies to the structures of choice. The thin layer of the original specimen on the replica with gold attached allows the identification of structures in the fracture plane. A subclass of this is focused ion beam milling, where gallium ions are used to produce an electron transparent membrane in a specific region of the sample, for example through a device within a microprocessor. Ion beam milling may also be used for cross-section polishing prior to SEM analysis of materials that are difficult to prepare using mechanical polishing. Conductive coating â€" an ultrathin coating of electrically conducting material, deposited either by high vacuum evaporation or by low vacuum sputter coating of the sample. This is done to prevent the accumulation of static electric fields at the specimen due to the electron irradiation required during imaging. Earthing â€" to avoid electrical charge accumulation on a conductively coated sample, it is usually electrically connected to the metal sample holder. Often an electrically conductive adhesive is used for this purpose. Disadvantages Electron microscopes are expensive to build and maintain, on the order of other complex machines such as airplanes. Microscopes designed to achieve high resolutions must be housed in stable buildings sometimes underground with special services such as magnetic field canceling systems. Operating the electron microscope requires specialized training and continuing practice and education. The samples largely have to be viewed in vacuum , as the molecules that make up air would scatter the electrons. Various techniques for in situ electron microscopy of gaseous samples have been developed as well. The low-voltage mode of modern microscopes makes possible the observation of non-conductive specimens without coating. Non-conductive materials can be imaged also by a variable pressure or environmental scanning electron microscope. Small, stable specimens such as carbon nanotubes , diatom frustules and small mineral crystals asbestos fibres, for example require no special treatment before being examined in the electron microscope. Samples of hydrated materials, including almost all biological specimens have to be prepared in various ways to stabilize them, reduce their thickness ultrathin sectioning and increase their electron optical contrast staining. These processes may result in artifacts , but these can usually be identified by comparing the results obtained by using radically different specimen preparation methods. Since the s, analysis of cryofixed ,

vitrified specimens has also become increasingly used by scientists, further confirming the validity of this technique.

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3: Transmission Electron Microscope (TEM) - AS Biology

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Ardenne applied the scanning principle not only to achieve magnification but also to purposefully eliminate the chromatic aberration otherwise inherent in the electron microscope. He further discussed the various detection modes, possibilities and theory of SEM, [6] together with the construction of the first high magnification SEM. Principles and capacities[edit] The signals used by a scanning electron microscope to produce an image result from interactions of the electron beam with atoms at various depths within the sample. Various types of signals are produced including secondary electrons SE , reflected or back-scattered electrons BSE , characteristic X-rays and light cathodoluminescence CL , absorbed current specimen current and transmitted electrons. Secondary electron detectors are standard equipment in all SEMs, but it is rare for a single machine to have detectors for all other possible signals. In secondary electron imaging SEI , the secondary electrons are emitted from very close to the specimen surface. Consequently, SEI can produce very high-resolution images of a sample surface, revealing details less than 1 nm in size. Back-scattered electrons BSE are beam electrons that are reflected from the sample by elastic scattering. They emerge from deeper locations within the specimen and, consequently, the resolution of BSE images is less than SE images. However, BSE are often used in analytical SEM, along with the spectra made from the characteristic X-rays, because the intensity of the BSE signal is strongly related to the atomic number Z of the specimen. BSE images can provide information about the distribution, but not the identity, of different elements in the sample. The energy or wavelength of these characteristic X-rays can be measured by Energy-dispersive X-ray spectroscopy or Wavelength-dispersive X-ray spectroscopy and used to identify and measure the abundance of elements in the sample and map their distribution. Due to the very narrow electron beam, SEM micrographs have a large depth of field yielding a characteristic three-dimensional appearance useful for understanding the surface structure of a sample. A wide range of magnifications is possible, from about 10 times about equivalent to that of a powerful hand-lens to more than , times, about times the magnification limit of the best light microscopes. No conductive coating was applied: SEM samples are prepared to withstand the vacuum conditions and the high energy beam of electrons, and have to be small enough to fit on the specimen stage. Samples are generally mounted rigidly to a specimen holder or stub using a conductive adhesive. Nonconductive specimens collect charge when scanned by the electron beam, and especially in secondary electron imaging mode, this causes scanning faults and other image artifacts. For conventional imaging in the SEM, specimens must be electrically conductive , at least at the surface, and electrically grounded to prevent the accumulation of electrostatic charge. Metal objects require little special preparation for SEM except for cleaning and conductively mounting to a specimen stub. Non-conducting materials are usually coated with an ultrathin coating of electrically conducting material, deposited on the sample either by low-vacuum sputter coating or by high-vacuum evaporation. The improvement arises because secondary electron emission for high-Z materials is enhanced. An alternative to coating for some biological samples is to increase the bulk conductivity of the material by impregnation with osmium using variants of the OTO staining method O-osmium tetroxide , T- thiocarbohydrazide , O-osmium. The high-pressure region around the sample in the ESEM neutralizes charge and provides an amplification of the secondary electron signal. To prevent charging of non-conductive specimens, operating conditions must be adjusted such that the incoming beam current is equal to sum of outcoming secondary and backscattered electrons currents a condition that is more often met at accelerating voltages of 0. This technique is achieved in two steps: The main preparation techniques are not required in the environmental SEM outlined below, but some biological specimens can benefit from fixation. Biological samples[edit] For SEM, a specimen is normally required to be completely dry, since the specimen chamber is at high vacuum. Hard, dry materials such as wood, bone, feathers, dried insects, or shells including egg shells [19] can be examined with little further treatment, but living cells and tissues and whole, soft-bodied organisms require chemical fixation to preserve and stabilize their structure. Fixation is usually

performed by incubation in a solution of a buffered chemical fixative, such as glutaraldehyde , sometimes in combination with formaldehyde [20] [21] [22] and other fixatives, [23] and optionally followed by postfixation with osmium tetroxide. Because air-drying causes collapse and shrinkage, this is commonly achieved by replacement of water in the cells with organic solvents such as ethanol or acetone , and replacement of these solvents in turn with a transitional fluid such as liquid carbon dioxide by critical point drying. If the SEM is equipped with a cold stage for cryo microscopy, cryofixation may be used and low-temperature scanning electron microscopy performed on the cryogenically fixed specimens. The preparation method reveals the proteins embedded in the lipid bilayer. This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. February Learn how and when to remove this template message Back-scattered electron imaging, quantitative X-ray analysis, and X-ray mapping of specimens often requires grinding and polishing the surfaces to an ultra smooth surface. In general, metals are not coated prior to imaging in the SEM because they are conductive and provide their own pathway to ground. Fractography is the study of fractured surfaces that can be done on a light microscope or, commonly, on an SEM. The fractured surface is cut to a suitable size, cleaned of any organic residues, and mounted on a specimen holder for viewing in the SEM. Integrated circuits may be cut with a focused ion beam FIB or other ion beam milling instrument for viewing in the SEM. Special high-resolution coating techniques are required for high-magnification imaging of inorganic thin films. Scanning process and image formation[edit] Schematic of an SEM In a typical SEM, an electron beam is thermionically emitted from an electron gun fitted with a tungsten filament cathode. Tungsten is normally used in thermionic electron guns because it has the highest melting point and lowest vapor pressure of all metals, thereby allowing it to be electrically heated for electron emission, and because of its low cost. Other types of electron emitters include lanthanum hexaboride LaB 6 cathodes, which can be used in a standard tungsten filament SEM if the vacuum system is upgraded or field emission guns FEG , which may be of the cold-cathode type using tungsten single crystal emitters or the thermally assisted Schottky type, that use emitters of zirconium oxide. The electron beam, which typically has an energy ranging from 0. The beam passes through pairs of scanning coils or pairs of deflector plates in the electron column, typically in the final lens, which deflect the beam in the x and y axes so that it scans in a raster fashion over a rectangular area of the sample surface. The energy exchange between the electron beam and the sample results in the reflection of high-energy electrons by elastic scattering, emission of secondary electrons by inelastic scattering and the emission of electromagnetic radiation , each of which can be detected by specialized detectors. The beam current absorbed by the specimen can also be detected and used to create images of the distribution of specimen current. Electronic amplifiers of various types are used to amplify the signals, which are displayed as variations in brightness on a computer monitor or, for vintage models, on a cathode ray tube. Each pixel of computer video memory is synchronized with the position of the beam on the specimen in the microscope, and the resulting image is, therefore, a distribution map of the intensity of the signal being emitted from the scanned area of the specimen. Older microscopes captured images on film, but most modern instrument collect digital images. Low-temperature SEM magnification series for a snow crystal. The crystals are captured, stored, and sputter-coated with platinum at cryogenic temperatures for imaging. Magnification[edit] Magnification in an SEM can be controlled over a range of about 6 orders of magnitude from about 10 to , times. Unlike optical and transmission electron microscopes, image magnification in an SEM is not a function of the power of the objective lens. SEMs may have condenser and objective lenses, but their function is to focus the beam to a spot, and not to image the specimen. Provided the electron gun can generate a beam with sufficiently small diameter, an SEM could in principle work entirely without condenser or objective lenses, although it might not be very versatile or achieve very high resolution. In an SEM, as in scanning probe microscopy , magnification results from the ratio of the dimensions of the raster on the specimen and the raster on the display device. Assuming that the display screen has a fixed size, higher magnification results from reducing the size of the raster on the specimen, and vice versa. Magnification is therefore controlled by the current supplied to the x, y scanning coils, or the voltage supplied to the x, y deflector plates, and not by objective lens power. Due to their low energy, these electrons originate within a few nanometers from the

sample surface. The accelerated secondary electrons are now sufficiently energetic to cause the scintillator to emit flashes of light cathodoluminescence , which are conducted to a photomultiplier outside the SEM column via a light pipe and a window in the wall of the specimen chamber. The amplified electrical signal output by the photomultiplier is displayed as a two-dimensional intensity distribution that can be viewed and photographed on an analogue video display, or subjected to analog-to-digital conversion and displayed and saved as a digital image. This process relies on a raster-scanned primary beam. The brightness of the signal depends on the number of secondary electrons reaching the detector. If the beam enters the sample perpendicular to the surface, then the activated region is uniform about the axis of the beam and a certain number of electrons "escape" from within the sample. As the angle of incidence increases, the interaction volume increases and the "escape" distance of one side of the beam decreases, resulting in more secondary electrons being emitted from the sample. Thus steep surfaces and edges tend to be brighter than flat surfaces, which results in images with a well-defined, three-dimensional appearance. Using the signal of secondary electrons image resolution less than 0. Detection of backscattered electrons[edit] Comparison of SEM techniques: Since heavy elements high atomic number backscatter electrons more strongly than light elements low atomic number , and thus appear brighter in the image, BSEs are used to detect contrast between areas with different chemical compositions. Dedicated backscattered electron detectors are positioned above the sample in a "doughnut" type arrangement, concentric with the electron beam, maximizing the solid angle of collection. BSE detectors are usually either of scintillator or of semiconductor types. When all parts of the detector are used to collect electrons symmetrically about the beam, atomic number contrast is produced. However, strong topographic contrast is produced by collecting back-scattered electrons from one side above the specimen using an asymmetrical, directional BSE detector; the resulting contrast appears as illumination of the topography from that side. Semiconductor detectors can be made in radial segments that can be switched in or out to control the type of contrast produced and its directionality. Backscattered electrons can also be used to form an electron backscatter diffraction EBSD image that can be used to determine the crystallographic structure of the specimen. The high-energy electrons from the SEM beam will inject charge carriers into the semiconductor. Thus, beam electrons lose energy by promoting electrons from the valence band into the conduction band , leaving behind holes. In a direct bandgap material, recombination of these electron-hole pairs will result in cathodoluminescence; if the sample contains an internal electric field, such as is present at a p-n junction , the SEM beam injection of carriers will cause electron beam induced current EBIC to flow. Cathodoluminescence and EBIC are referred to as "beam-injection" techniques, and are very powerful probes of the optoelectronic behavior of semiconductors, in particular for studying nanoscale features and defects. The blue and green channels represent real colors, the red channel corresponds to UV emission. Cathodoluminescence , the emission of light when atoms excited by high-energy electrons return to their ground state, is analogous to UV -induced fluorescence , and some materials such as zinc sulfide and some fluorescent dyes, exhibit both phenomena. Over the last decades, cathodoluminescence was most commonly experienced as the light emission from the inner surface of the cathode ray tube in television sets and computer CRT monitors. In the SEM, CL detectors either collect all light emitted by the specimen or can analyse the wavelengths emitted by the specimen and display an emission spectrum or an image of the distribution of cathodoluminescence emitted by the specimen in real color. X-ray microanalysis[edit] Characteristic X-rays that are produced by the interaction of electrons with the sample may also be detected in an SEM equipped for energy-dispersive X-ray spectroscopy or wavelength dispersive X-ray spectroscopy. Analysis of the x-ray signals may be used to map the distribution and estimate the abundance of elements in the sample. Resolution of the SEM[edit] Play media A video illustrating a typical practical magnification range of a scanning electron microscope designed for biological specimens. Unlike in an optical system, the resolution is not limited by the diffraction limit , fineness of lenses or mirrors or detector array resolution. The focusing optics can be large and coarse, and the SE detector is fist-sized and simply detects current. Instead, the spatial resolution of the SEM depends on the size of the electron spot, which in turn depends on both the wavelength of the electrons and the electron-optical system that produces the scanning beam. The resolution is also limited by the size of the interaction volume, the volume of specimen material that interacts with the

electron beam. The spot size and the interaction volume are both large compared to the distances between atoms, so the resolution of the SEM is not high enough to image individual atoms, as is possible with transmission electron microscope TEM. The SEM has compensating advantages, though, including the ability to image a comparatively large area of the specimen; the ability to image bulk materials not just thin films or foils ; and the variety of analytical modes available for measuring the composition and properties of the specimen. Environmental scanning electron microscope Conventional SEM requires samples to be imaged under vacuum , because a gas atmosphere rapidly spreads and attenuates electron beams. As a consequence, samples that produce a significant amount of vapour , e. Processes involving phase transitions , such as the drying of adhesives or melting of alloys , liquid transport, chemical reactions, and solid-air-gas systems, in general cannot be observed. Some observations of living insects have been possible however.

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4: Scanning electron microscope - Wikipedia

contents 3. interpretation of transmission electron micrographs image contrast i. diffraction contrast summary of theory the perfect crystal.

Vibration-free floor Room free of ambient magnetic and electric fields SEMs always have at least one detector usually a secondary electron detector , and most have additional detectors. The specific capabilities of a particular instrument are critically dependent on which detectors it accommodates. Applications The SEM is routinely used to generate high-resolution images of shapes of objects SEI and to show spatial variations in chemical compositions: Precise measurement of very small features and objects down to 50 nm in size is also accomplished using the SEM. Backescattered electron images BSE can be used for rapid discrimination of phases in multiphase samples. SEMs equipped with diffracted backscattered electron detectors EBSD can be used to examine microfabric and crystallographic orientation in many materials. Strengths There is arguably no other instrument with the breadth of applications in the study of solid materials that compares with the SEM. The SEM is critical in all fields that require characterization of solid materials. While this contribution is most concerned with geological applications, it is important to note that these applications are a very small subset of the scientific and industrial applications that exist for this instrumentation. Many applications require minimal sample preparation. Modern SEMs generate data in digital formats, which are highly portable. Limitations Samples must be solid and they must fit into the microscope chamber. Maximum size in horizontal dimensions is usually on the order of 10 cm, vertical dimensions are generally much more limited and rarely exceed 40 mm. For most instruments samples must be stable in a vacuum on the order of - torr. However, "low vacuum" and "environmental" SEMs also exist, and many of these types of samples can be successfully examined in these specialized instruments. Most SEMs use a solid state x-ray detector EDS , and while these detectors are very fast and easy to utilize, they have relatively poor energy resolution and sensitivity to elements present in low abundances when compared to wavelength dispersive x-ray detectors WDS on most electron probe microanalyzers EPMA. Minimal preparation includes acquisition of a sample that will fit into the SEM chamber and some accommodation to prevent charge build-up on electrically insulating samples. Most electrically insulating samples are coated with a thin layer of conducting material, commonly carbon, gold, or some other metal or alloy. The choice of material for conductive coatings depends on the data to be acquired: Alternatively, an electrically insulating sample can be examined without a conductive coating in an instrument capable of "low vacuum" operation.

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5: Electron microscope - Wikipedia

The short (5 minute) presentation below includes transmission electron microscope pictures and some micrographs formed by transmission electron microscopes. It also describes some of the basic physical principles that explain how and why transmission electron microscopes work.

Transmission electron microscopy is explained in some school biology courses e. AS Biology in the UK. What is a transmission electron microscope? A large piece of scientific equipment see the video below that forms detailed images micrographs of extremely small objects or areas of objects by passing a beam of electrons through a very thin slice of the object or area of interest. What is transmission electron microscopy? What is a transmission electron micrograph? An image generated by a transmission electron microscope. It is useful for biologists to know about TEMs because they may need to look at micrographs, including transmission electron micrographs, to study biological structures. In order to interpret images accurately it helps, and is sometimes necessary, to understand how the image was formed. Advantages of Transmission Electron Microscope The advantages of a TEM over a light microscope are the advantages of electron microscopes in general over light microscopes - just brief key points appear below, see compare light vs electron microscopes for further details. Electron microscopes can resolve very much greater detail than light microscopes because the electron beam has a much shorter wavelength than the comparably longer wavelength of visible light that forms the image in a light microscope. The high magnification power is possible due to high voltage applied to the electromagnetic objective. Limitations of Transmission Electron Microscopes TEM s It is not possible to observe living specimens because the whole system must be in a vacuum in order for the image to be formed. Considerable preparation of specimens is involved. This includes staining specimens using specially selected chemicals. The specimens must also be very thin. Artefacts may appear in micrographs so accurate interpretation of TEMs may require considerable expertise and experience in addition to knowledge of the process used to prepare specimens and then form specific images. Artefacts are features in micrographs that are present due to the preparation processes rather than due to the specimen itself. Video about Transmission Electron Microscopy The short 5 minute presentation below includes transmission electron microscope pictures and some micrographs formed by transmission electron microscopes. It also describes some of the basic physical principles that explain how and why transmission electron microscopes work. Taking a few minutes to watch this TEM video clip may help you remember the key points about TEMs and appreciate their physical size and complexity - which shows why light microscopes are used in schools and colleges while electron microscopes are generally used in research environments. Some of this information in the video exceeds the requirements of AS Biology. It is probably intended for physicists e.

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