

Operations Of Scanning Electron Microscope

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A microscope is a combination of Greek words. *Mikros*, which means a small substance, and *scope*, which means to look. Scientists have always been interested in what the micro-world looks like. Biologists are involved in cell structures, colloidal particles, viruses, and bacteria, while material scientists are concerned with the homogeneity found in crystals, metals, and ceramics and further analyze the imperfections in these materials. The development of the microscope can be dated back to the Galilean invention of the telescope in the seventeenth century and Leeuwenhoek's hand lens. Since then, physicists, together with other machinists, have developed microscopes to work in different fields. The sizes and image resolutions have improved drastically in the recent past.

Most microscopes were initially dependent on light to give images inventions have been made to come up with lenses that use electron beams to generate images. Furthermore, the output is improved as images can now be produced in photographs and digital methods, which enables better analyses; hence, reliable results can be given. One crucial microscope today is the electron microscope. Though not clear who might have been the inventor, Max Knoll is credited due to a publication he made in 1935 giving a description that somehow appeared to be the microscope. There are varieties available in the market currently but the most common are the transmission and scanning electron microscope.

The Scanning Electron Microscope applies the use of electron beams compared to the conventional microscope that uses light beams to generate signals at solid specimen surface. The method of microscopy reveals the sample's external morphology, crystalline structure, chemical composition and the manner in which the materials are making the sample is oriented. SEM is also used in point analyses of a sample usually selected based on what the researcher wants to achieve, thus crucial in the qualitative determination of samples. Only a milligram of the sample is required to determine the shape, texture, and size of the specimen.

Principles

Operations of a Scanning Electron Microscope depends entirely on what you want to observe, how the specimen has been mounted and the information you wish to acquire. Flat-polished microstructure. The polishing itself will suffice (but it has to be an excellent polish). If etching, in general, you should etch more lightly than you would for optical microscopy. A specimen is mounted in Bakelite or epoxy; then, you'll need to connect the metal to your stage via conductive paint or tape. You'll also likely have charging problems from charge build-up in the mount.

When working with the fractured surface, you leave the cover alone, but make sure to electrically and mechanically ground the specimen to the stage. For corrosion or worn surfaces, one may need to

apply a coating to reduce charging on surface oxides or use low-vacuum mode if your Scanning Electron Microscope can do it. A researcher ought to find some way to ground the bulk metal. A standard “mirror polish” is not sufficient – the critical variable is surface deformation. Electro-polishing is best; if this isn’t possible, then a colloidal silica final polish with a very light load is necessary to remove surface deformation. A vibratory polisher is helpful for this specimen size: if you’re doing high-resolution imaging in an instrument with an electromagnetic immersion lens, then make the sample small. If the Scanning Electron Microscope has an electrostatic immersion lens, the size is only dependent on your stage dimensions and weight requirements. Thickness is not essential – you just sample the surface anyway.

Scanning electron microscope has accelerated electrons which have a high amount of kinetic energy. The energy dissipated into signals is usually produced as a result of electron-sample interaction when the sample stops incident electrons. The signs include backscattered electrons, secondary electrons that generate the image on a Scanning Electron Microscope, diffracted backscattered electrons for determining minerals` orientation and crystal structure, photons, heat and visible light.

Topography and morphology of the samples are usually dependent on the secondary electrons, while backscattered electrons are used in showing the illustrations of the contrast in the composition of multiphase samples. Photons produced are a result of incidental particles colliding with electrons in atoms` orbits in the sample. When an excited electron comes to a low energy state, the X-ray provided is of a fixed wavelength. The analysis is usually non-destructive as generated X-rays do not result in loss of volume in the sample hence material can repeatedly be analyzed.

Differences Between TEM And SEM

Scanning Electron Microscope.	Transmission Electron Microscope.
The beam is scanned and focused to a fine point lying over the sample surface.	The static beam was used.
The accelerating voltages are much lower.	Capable of operating at high accelerating voltage.
The specimen does not need to be prepared.	Specimen preparation is necessary.
Utilizes scattered electrons to generate results.	Operates on transmitted electrons.

The sample's composition and the surface is always the target.	The internal composition of a specimen is the center of attraction.
A large number of samples can be analyzed within a short time.	Only small samples can be analyzed at a time.
The resultant picture is displayed on a computer monitor.	Fluorescent screens are used for image display.

Instrumentation And Imaging

Components of most SEMs include an Electron Source where electrons get drawn from a field emission gun by placing the filament at a substantial electrical potential gradient. The electron gun produces electron beam usually focused as a small spot of diameter one nanometer. The beam is regularly scanned in a rectangle raster on the specimen, and the intensity is controlled remotely using a computer program that also stores the image generated. The values stored are mapped using the variations in brightness displayed by the model.

The SEM uses a magnetic lens. Current passing through the lens produces an electron beam. Changing the current, the strength of the lens changes. The feature is not found in an optical lens. Electron Lenses create a circular magnetic field that condenses electron beams as they pass through. Sample stage: the point where the solid sample is placed for analysis. Since experiments are conducted at high magnification, the stage is stable and with the capability of moving horizontally and vertically. The stage allowed for specimen tilting and was designed in a manner that did not allow a shift of the observation area. Motor-driven stages that use a computer are available.

Detectors for signals of interest to be generated during imaging detectors are used to attract the scattered electrons, which include secondary, X-rays and backscattered electrons. Most commonly used are solid state and scintillation detectors, which are capable of detecting backscattered and secondary electrons. In a scintillator, light is emitted once the particles hit a fluorescent screen. The view is amplified by which it is converted to electrical signal. The second detector amplifies the small signals from the incoming electrons in the semiconductor. Another sensor is also available, whose primary role is to monitor the net current the specimen absorbs. Display and data output devices. A computer fitted with a program from SEM manufacture.

Other Infrastructure Requirements are; Power Supply, vacuum system which prevents electrical discharge along the gun assembly, and allowing the electrons to move in the instrument undisturbed. A good vacuum is either produced by oil diffusion or turbo-molecular pumps. The latter is the most commonly used currently. The vacuum systems need to be automated to limit failures due to operation. When putting samples into the vacuum, they ought to be clean and compatible with the

void in use, a cooling system, a vibration-free floor, and a room free of electric and magnetic fields, as the electron path can bring about alteration if exposed to a magnetic field.

Operations

First, the gun generates electron beams onto the magnetic lenses, which are wrapped in solenoids. The coils are adjusted, focusing the incident beam on the sample; the adjustments are known to cause voltage fluctuations; hence operator is advised to readjust the speed the electrons interact with the surface of the specimen. These adjustments mostly come from computerized. SEM operator is also required to continually adjust the beam to enable magnification control and correctly determine the surface he/she desires for scanning. The shaft is focused on the stage where the solid sample is placed.

The acceleration of incident electrons is used to determine the interaction between the sample surface and incident electrons. Images produced are usually black and white and in three dimensions with magnification up to ten nanometers. In SEM, the resolution depends on the size of the region within the specimen in which signals come from and the position the electron beam is set. Judgment can be affected by different factors like signal type, spot size by the laser, sample composition, and beam energy.

Working Distance

In SEM, this is the distance a beam is focused. The distance from the lens pole piece to the sample on stage and an image is focused. The working length can be varied by shifting the stage up and down while you try to focus the specimen from the given height. The value is usually instrument and operator-dependent. Minimum magnification depends on the working distance. Best images get generated when operating with short working distances which is also varying depending on the detector efficiency of the SEM in use. Short working distance increases the minimum magnification that can be achieved. Short working distances, however, pose the challenge of small depth focus.

Increasing the working distance gives a more substantial depth of focus. The signal strength can, however, be compensated by increasing the spot size. The increased working distance also reduces shadowing and presents a grey appearance on topographic samples. Some resolution will be lost in the process. Long working distances and lower magnifications are reached. There is no standard working distance for SEM as this will depend solely on the hardware, and it will differ from system to system. For each SEM model and EDX detector, there will be a recommended working distance for analytical applications. The information obtained from the manufacturer of the detector, or whoever installed the sensor.

The reason for this is that it will depend on the take-off angle of the detector and the design of the final pole piece in the SEM. The working distance needs to be set such that it is focused at the point

where the incident beam strikes the specimen. Too high or too low and the take-off angle will be incorrect, and the counts will plummet. Some software can correct for a slight variation in working distance and calculate the resultant take-off angle, but even in these cases, the numbers will be low. The effect of incorrect

Applications

SEMs have broad applications ranging from science to industrial fields. The SEM is mainly used in generating images of high-resolution samples and further outlining variations in the chemical compositions. These may include acquiring spot chemical analysis and creating compositional maps. Especially between rare earth elements and transition metals, measurement of small objects like 50nm, examination of the crystallographic and micro fabric orientation in different materials, and phase analysis based on the crystalline and chemical structure of the samples. The use of SEM can also detect surface fractures and contaminations. Also, the instrument finds practical application in the production of computer microchips.

Life sciences. In research laboratories, Electron microscopes are used in the exploration of disease mechanisms, visualizing the three-dimensional structures of cells and tissues. Observation of macromolecular complexes of viruses and bacteria to help in disease diagnosis. In cellular biology, especially cell membrane imaging, to assist in studying sub-cellular morphology. Electronics components: production of semiconductors, electric systems, solar panels and circuit components. The scanning electron microscope comes hand in detecting defects that would have typically not been identified using the naked eye. Failure analysis can also be determined by the process and allow the engineers to crack to cause of the defect.

Mining companies apply the use of electron microscopes in the analysis of mineral structures. The experiments help the companies in maximizing the recovery of metals and on point to explore depending on the composition of the mineral in question. Gas and oil explorers also apply similar techniques to check the porosity of the reservoir and the source rocks. Such exploration minimizes risks in extraction and further reduces unwanted expenditures incurred as a result of trial-and-error procedures. In the field of research, microscopes are used in discoveries and understanding of primary next-generation tools and systems like solar technologies, better fuels, and materials that are light and robust but pose no security threat to human health. The field of Nano-characterization is also currently booming, and it highly depends on the use of electron microscopy.

Advantages

There is no material with the ability to study solid samples compared to SEM. It is effortless to operate. All that is required is proper training. Most processes are computerized and run on software, making operations user-friendly. The instrument is fast, with the capacity of completing EDS, BSE and

SEI analyses within five minutes. The device produces three-dimensional images that are well-detailed. More important is the data is digitally generated; hence, analysis and retrieval become easy.

Other microscopic techniques involve multiple preparations of a sample, which is not the case for SEM, as the samples require minimal preparation procedures before being mounted inside the vacuum chamber. SEM is handy for microstructure analysis, either nature surface or fracture surface. Sometimes, people use it to observe domains in ferroelectrics after chemical etching. There are several modes for SEM machines, such as secondary electron imaging, backscattered electron imaging, and EDX. The latter two are helpful if there is a second phase of your samples.

Limitations

A Scanning Electron Microscope is expensive, and further cost of maintenance and operation is very high. The instrument alone is enormous and would require more significant space and an additional problem if relocation is necessary. SEMs require a steady voltage, cold water circulation, and current to their electromagnetic coils at all times. To use SEM for analysis, samples need to be stable and with the capability to fit in the microscope chamber. The samples need to be firm in a vacuum environment, creating a problem for those that outgas in low pressure, like organic materials and hydrocarbons, which are not suitable for examination in conventional SEMs.

The detectors cannot detect light elements like hydrogen, helium, and lithium. Mostly, SEMs apply solid-state X-ray detectors, which are very fast and have easy utility; the problem is they possess poor energy resolution. Only specialized trained personnel can operate the instrument further adding training cost or hiring cost to an organization wishing to employ the use of SEM in their research. There are minimal risks of exposure to radiation due to electrons scattering below the sample surface. Though the instrument is designed to eliminate such emissions, operators are advised to be cautious. SEM analyzes the outer surface of the specimen. Thus limits the amount of information you can get from the specimen. It can only show the morphology of the specimen.

Laboratory Preparation Of Cement And Soil Specimen For Observation

Geotechnical engineering has immensely advanced in recent years, though failures in construction are, nevertheless, a challenge. Soft soils are highly deformable. The fabric morphology and cementation levels are significant contributors to the microstructure for distinguishing soft and sensitive ground conditions. Water is the most likely agent causing softness in soils. Soft soil possesses low, unconfined compressive strength with very high compressibility. The experiment attributed to the fact that it has high water content with fragile microstructure.

Techniques have been developed to stabilize cement used in the construction of unique structures.

Researchers are focusing on studying the properties of cement preserved by soil. Features such as permeability and soil strength can be investigated using a scanning electron microscope; thus, the microstructure changes are observed. The following is a typical laboratory procedure used in the investigation of soil and cement microstructure employing the use of a scanning electron microscope. Several studies have been conducted to study the reactivity and microstructure of cement. Experiments in SEM characterize the chemical reactivity.

Materials And Methods

Materials needed include beakers, an oxidizing catalyst like Benzoyl peroxide, a vacuum desiccator, a grinder, a diamond cutter, a thermostat, and Ordinary Portland cement, the most widely used stabilizer. It is used alone or mixed with several additives. Loess soil samples are categorized into distinctive types depending on aggregation and grain structure. Soft and wrapped clay in cling film to maintain the moisture content. Scanning Electron Microscope is preferred as it uses electrons, unlike an optical microscope that operates on light.

Test specimens are usually analyzed within seven curing days. A small cement-rubber chip is placed on the specimen holder, which is followed by a thin coating of gold about fifteen nanometers thick. The layer provides surface conductivity. A sputter coater is usually preferred. The specimen sample is required to be flat enough to enhance micrograph capturing. The pieces coated are then placed in the scanning electron microscope and the operating kilovolts set. The microstructural changes observed in the matrix of the specimen made it stable. Visual examination is used to find products obtained after hydration.

Excellent particles like the cement and sand specimens have a small surface ratio. Hence, do not require coating. Assessment of soil fabric is sometimes difficult due to the necessity to secure a smooth scanning surface. To obtain undisturbed plane samples are usually molded and dried naturally in the laboratory. The dried samples are then broken utilizing the hand. A small cutter piece of about 1cm² is cut from the vertical profile of the section. The process will present the undisturbed zone aiding in viewing when placed under SEM.

Procedure

Soil samples are cut in a tabular shape after drying in air. Pour polyline into a beaker and add benzoyl peroxide paste, stirring thoroughly. Soil and cement samples are then placed separately in the activated polyline. The samples are then placed in a vacuum desiccator and, using a sucker, evacuated until no more air rises. Once the bubbling stops, soaked samples are kept in a thermostat overnight at fifty degrees centigrade. Samples are evacuated again to remove any possible bubbles left, heated at seventy degrees centigrade and placed into the thermostat once more. The curing process is now over. Quickly remove the cured sample and cut it into tabular using the diamond

cutter. Using course carborundum, grind one side of the sliced sample. Make into medium, excellent and very fine samples, mounting the polished end with thermoplastic cement.

Observation Of The Microstructure Of Cement And Soil Specimen Under SEM

The scanning electron microscope is currently not utilized in biology and medical science alone. The instrument finds an array of uses in the field of metallurgy, the development of semiconductors, and ceramics. The new techniques introduced every day make the use of SEM easier. One can now capture micrographs only after a short training. When observing specimens like soil, a researcher is usually interested in the following: crystal shape, cementation mechanism, and agglomeration of the cement. Such an experiment takes a longer time to get the result because a series of tests are conducted to ascertain the phenomena investigated. A series of compression tests are performed on the samples, in addition to SEM and X-ray diffraction analysis. The experiments are also used to determine how cement gets stabilized for use in the construction industry.

The small electron probe diameter on the specimen gives high magnification. Image smoothness is dependent on the current probe; thus, it is necessary to choose a probe current appropriate for the observation conditions. Another phenomenon worth checking for valid observation is the accelerating voltage. Smaller electron probes are achieved when high accelerating images are applied to the specimen. The accelerating model should, however, not be increased beyond the average threshold as there might be specimen damages and charge-up possibilities. The operating principles of SEM are to have lower accelerating images to produce more excellent photos.

During observation, there are image disturbances that are likely to be experienced. The images may lack contrast and sharpness, probably due to the wrong capture of the micrographs; hence, specialized handling is always necessary. Poor quality images that are jagged at the edges. Distorted and noisy photos. The disturbances are usually a result of defects with the instruments, specimens not appropriately prepared, unqualified operators and general disruption in the installation room like magnetic radiations.

More sophisticated detectors are invented; hence, the quality of results increases. Field-emission gun e-beam is a classic example that produces high brightness using low beam energies. Such devices have made it easier to perform experiments on elements with atomic numbers between twenty-five to eighty-three. Thus, there is the possibility of applying voltages below ten kilovolts to improve the analysis of small-sized components. In quantitative analysis shape and size of the particle are always uncontrollable and cannot be measured accurately. Correctional procedures have been developed to reduce particle effects.

X-ray spectra are always used when performing qualitative analysis. The elements present in the sand particle are irradiated using the beam. Analysis may be point, line and mapping. Line analysis is used

in displaying one-dimensional distribution. Mapping analysis displays 2D images of elements. X-ray mapping is normally used for identifying different element distributions, though with a limited analysis area.

Charging Effect In SEM

When conducting experiments, it has been discovered that errors occur due to charging effects, especially when inferring the size and shape of the specimen from the image. The result gets utilized in the facilitation of imaging in the SEM. The conventional SEM contrast only exhibits the characteristics on the surface. The charging variation can reveal information about the underlying structure minus any signal to excite the sample. The effect considers the prospects of developing newer test methods utilizing advanced integrated circuits. Signs disseminating information from the specimen are likely to be stimulated when an accelerated e-beam illuminates the sample. The signal electrons may be backscattered, secondary, transmission, X-ray and auger. Since Knoll invented the first electron microscope, many modifications have been made.

The insulating specimen is charging to arise as a result of the interaction of electrons and the specimen. Accelerated primary electrons hit the sample, and secondary electrons get emitted. The secondary electrons transmit energy with a range of zero to the power of inner electrons. This force is usually intrinsic as the exact secondary electron possesses energy below fifty electoral volts. Backscattered are known to possess more complex energy. The difference between currents of primary particles and the secondary electron is used to regulate the specimen charging state. Usually evaluated through SE yield. A positively charged specimen has a secondary electron than one, on the contrary, will have a negative charge. Some specimens' SE yield may be dependent on the incident angle of PE relative to the surface of the specimen.

As the incident angle increases, PE scattering happens near the face of the sample, contributing to the production of more electrons, which are ionized, thus escaping to become SEs. The variation in secondary electron yield brings topographic contrast to samples with irregular surfaces. Charging the insulators results in very strongly negative charges, which lead to high acceleration voltage and eventually cause charging artifacts images using the scanning electron microscope. An equilibrium can be reached in the charging process. The procedure goes hand-in-hand with capacitance charging. High surface potential leads to weak secondary electron imaging signals. High surface potential brings a dark image effect in the SEM.

Charging insulating specimens is a complicated process. The interactions electrons in the electron beam involve complex operations like diffusion, trapping, and collision, therefore, charging method is time-dependent. Secondly, the internal properties of the specimen also affect the process of charging. Finally, the surface potential and charging process are restricted. Adjacent irradiation influences the scanning of an electron beam inside the SEM.

Utilizing Specimen Surface Charging In SEM

Researchers are interested in the usefulness of charging effects. Experiments have been conducted to observe how the outcome can be used for different research purposes. The first utilization of charging impact is in the e-beam-induced current. The EBIC exists in semiconductor devices. Chung et al. (1980) detected a conductor-insulator composite while applying a charging micrograph. It was able to indicate a direct difference in the electric conductivity of the two materials. Chung considers that free conductive charge gain brings about a very high negative potential; in this way, the effect enhances SE emission, and image contrast appears. Most recently, Nagase et al., while observing silicon nanostructure, which was oxide embedded in the one-electron transistor, attributes contrast formation to secondary electron yield difference, which is a result of the surface charging.

The difference in voltage can also result from the accumulation of charges in the process of charging specimens. Aton, a scientist, developed a technique that he used in the testing of isolation and IC microstructure continuity. The method utilizes voltage contrast, which the charge deposit produces when connected to the nodes of microstructure as a result of electron beam irradiation.

Modern IC fabricators are improved to give more precise measurements and observations. Promptly specimen structural information can be observed when covered in insulating film making it able to reveal even the broadest structures. Charging the specimen produces surface potential. Voltage contrast is found when the possibility is immobilized. Therefore, considering this fact, charging variation can also be defined as image contrast revealed as a result of electric surface potential brought about by the charging effect of the insulated specimen.

Mechanism Of Charging Contrast

To control the contrast mechanism, analysis of the secondary electron is necessary. Calculating the SE signal is complicated, and accurate measurements may be difficult to gain. To achieve reliable results, first insulating surface's SE yield should be constant as alterations of the surface potential are very minimal, and the landing energy of PE, if varied, will alter the SE yield. The e-beam is normal incidence; the SE yield, therefore, is dependent on the accelerating voltage only.

In SEM contrast, yields of SE are large compared to light components. Complex elements have more electrons than smaller elements. Heavy elements like tungsten have SEM contrast, which is brighter than lighter materials like aluminum. Incident e-beam is usually deflected due to the accumulation of charges on its surface, reducing secondary electrons produced by the specimen. The contrast in SEM images is as a result of atomic number difference of samples used. Penetration depth is dependent on the atomic number. At insufficient coating, the variation depends on the charging effect and the conditions of the metallic surfaces.

Despite all these improvements, quantitative analysis is still a challenge for some SEM contrasts, like

the charging contrasts. Methods like Monte Carlo are the few practical tools that can be applied in the interpretation of SEM contrasts. Charging effect observed can be enhanced in the formation of new image contrasts, however at high accelerations negative charging gets prevented from inhibiting production of image artifacts. The specimen charging alters surface potential, facilitating voltage contrast. A loaded specimen has charges accumulated near its surface and within; this leads to the formation of a stronger electric field when shone with the e-beam irradiation.

Reducing Charging Effect

The point at which a sample gets hit by an electron beam in a scanning electron microscope is equivalent to the junctions found in electric circuits. The intersection is the point where charging takes place. The charging load is the most common problem associated with SEM. During scanning electron microscope analysis, the irradiation of the specimen with the electron beam causes the accumulation of static charges on the surface of the sample. The effect is the image information deteriorates through the influence of the electron signals by the charges. The image distortion created is unpleasant and may lead to misinterpretation of results. The three most common charging effects are negative and positive charging, spontaneous emission and beam interaction artifacts. Research has been done to reduce the charging effect and enhance image information.

Coating With A Conductive Film

The method was applied to non-conducting samples. This film needs to be very thin. When a sample is coated, the charges developed pass to the ground through the conducting layer. In this way, the negative electrons do not accumulate on the surface of the specimen. The method is not appropriate for semiconductor samples as it is destructive to them, and once coated, the samples cannot be used further for micro-probing electrically.

Using Less Accelerating Energy

By reducing the beam energy, the charging effect gets decreased. Applying biasing voltage lessens the impact drastically. Using less power becomes more effective with coated specimen surfaces. Reduced landing energy a cross-over point is reached where the net charge reaches zero consequently more electrons leaves the specimen compared to those from the primary beam. The technique, however, yields dim images unless the electron gun is tuned to give higher brightness, which increases running costs.

Conventional electron probe operates with an accelerating voltage between fifteen and twenty-five kilovolts. Thus is capable of providing a thermionic source that is used to excite the elements. When using lower energies electron beam interaction in the particle is reduced. Therefore, X-ray generated by the particle is usually similar as if produced from the more significant material. The choice of

acceleration voltage depends on the problems you have to resolve, the type of SEM you have, the kind of material, and the preparation technique employed. For example, if you had conventional high-vacuum SEM with tungsten and equipped with an EDS system, an acceleration voltage between 15-20 kV is suitable for EDS analysis, while for high-resolution imaging of materials in secondary electrons, the acceleration voltage of 25-30 kV is more appropriate. One needs to consider what information is desired as well as the nature of the sample and set kV accordingly.

In the case of low atomic number samples, like life science samples or polymers, usually, it is usually good to start at 5kV. In fact, now with beam deceleration available on many new instruments, it is not unusual to have landing energies much below 5kV to get both right structures and minimize charge accumulation in the sample. In the case of high atomic number samples such as metals, you may go to 7-10kV for imaging, but it is rare indeed that you need to go higher for good secondary electron imaging. The loss of secondary electron signals more than outweighs the theoretical prediction that higher kV always results in better resolution.

Low Vacuum Imaging

The method is used when the sample conductivity is not enough to prevent charging. Provide reduction through compensation of the charges. A sample is intrinsically prepared to avoid charging. The positively charged ions produced when an electron beam passes through the chamber are known to neutralize the surface charge. The technique is compatible with an array of negatron energies, making it suitable for all non-conducting specimens. For higher magnifications, however, the resolutions will be reduced due to the scattering of primary and secondary electrons caused by the gas molecules.

Charge Neutralization Using Ion Gun

In this method, an ion gun is used to generate ions instead of using the electron beam. Positive ions are created inside the directed ion gun to the surface of the sample. The method is ideal because it does not reduce the image signal-to-noise ratio. Additionally, samples were mounted using a conductive bridge. The bridge connects the sample holder to the top of the specimen surface. A conductive carbon tape is typically used in this case.

Methods Of Applying Coating To Specimen

The modern SEM possesses the capacity to yield images even at low voltages and lower vacuum modes, enabling the handling of some non-ideal specimens minus many sample preparations. In electron microscopy, sample coating is a necessary procedure that aids in the improvement of specimen imaging. Coating inhibits thermal damage and reduces charging to such a degree that it improves secondary electron signals during the examination. Materials are coated to make them

conductive. The most conventional materials used in the coating are platinum, carbon, gold, and vapors of ruthenium. The coating needs to be thin, between five and fifty nanometers.

The layer should not cover surface morphology but only present a conductive covering for charging. The coat should also not create heat buildup and be capable of minimizing the beam damage. Studies have shown heavy coatings provide high secondary electron yield. The phenomena improve the signal to noise. It presents the disadvantage of lower energy negatrons and the production of X-rays. Such have a negative impact on the sensitivity of backscattered electrons involving imaging. The coating technique used is highly dependent on the application and the resolution.

When selecting a coating technique, one needs to ensure a method that is in line with the observation magnification chosen. Thick coatings bring out visible particles with the complicated structure of interest. Both techniques have the disadvantage that the image resolutions are reduced. VP has the advantage that you don't have to coat them, but you don't see the original surface anymore, primarily if you use a transparent splash coating. EDS will automatically get C or any other element in your spectra, which might be disturbed if your samples contain this element and you don't know it. The coating has the advantage that you can image practically any sample surface, charging or not. When using heavy elements, the sample also impresses with strong image contrasts, etc.

Platinum Sputtered Coatings

Platinum has the highest electron emission known, plus its resistivity to corrosion makes it appropriate for coating on SEM specimens. Polymer materials are damaged by ion irradiation more easily; hence, coating is necessary before observation under the electron microscope. Compared to commonly used gold, platinum is most suitable as only a thin layer is required, half of what is used for gold. Using platinum presents less distortion to the specimen and has with superior background-to-peak ratio when applying X-ray analysis. Condensed atoms of Pt give coats with very fine microstructure. The method prevents charging on the sample, which occurs because of static electric accumulation. Other advantages include a reduction in the damage to the microscope beam, increased conduction, and an increase in the thermal conduction of the specimen; samples that are beam sensitive get protected, SE emission is improved and improved edge resolutions.

Carbon

Carbon evaporation provides conduction to nonconductive samples, especially those imaged at extraordinary voltages. The method is very appropriate for analytical characterization. Since carbon is transparent to the electron beam, it is preferred when conducting X-ray microanalysis. Carbon, in the form of a rod or thread, gets mounted into the vacuum system. This is usually between the high-current terminals. The carbon gets heated to evaporation which then deposits onto the specimen. The coating indicates the first layers, allowing electrons to get focused on the target material. The method

is also appropriate as it limits particles get embedded in the polished specimen.

Current Trends And Prospects

The future paradigm of electron microscopes is going fully digital. The shift will allow diagnosis and analysis where researchers will interact with images on screen while manipulating the specimen. A world of virtual microscopy with the capacity of whole slide imaging. Data storage and image dissemination are conducted at breakneck speeds. Digital imaging comes with high resolutions. The advances also support complex workflow as a result of specimens that need to be worked on a daily basis. The more advanced electron microscopes present easy specimen preparation and the same sample being used over and over for subsequent experiments, thus saving on cost.

Advances in SEM optics, detectors and electron sources have reduced technical defects that arise during experiments. The introduction of more sensitive sensors will be useful, especially when working with small electron probes. The electron microscope usage in the detection of defects has saved modern engineers from making reliable instruments. The failure analysis done at the industrial level helps in anomaly detection. It will not be possible for nanotechnology and nanoscience fields to progress without improved methods in microscopy.

Conclusion

Technological advancements have led to the manufacturing of better varieties of scanning electron microscopes that come with better image quality with minimum operations. The SEM has a wide range of opportunities, but mainly, it is characterized by a vast focus depth, which is very beneficial at low magnification in comparison to light microscopy. Nowadays, this can be compensated by multiple imaging at different focus lengths using different laser scanning or new generations of light microscopes. A reconstruction generates a sharp image considering all focused parts of the previously collected images. The other significant advantage of an SEM – and this was undoubtedly the main driving force for their development – is that you can go to higher magnifications than by light microscopy. In this case, it is more beneficial to use smaller samples since the weight of a sample may affect the stability of the stage, especially if you need to tilt it. This is no “must” but reduces merely possible errors.

However, you need to consider why you want to see what and that sample preparation will always affect your original surface conditions. The main question is, of course, HOW MUCH it will influence it, and this is from material to material difference. During grinding and polishing you will introduce surface-near deformations, etching is often phased or crystal defect specific and can resolve entire phases. Electro-polishing only works for conductive materials and only in exceptional cases for bimetals or multiple-metal samples since they react differently.

Mechanically polished samples, which reflect ideally like a mirror, often show in SEM still tiny

scratches or residual deformation zones of no more existing scratches. Using BSE images (orientation contrast) or especially EBSD you will often see them very clearly. So far, you need to be critical of the interpretation of SEM images, especially at high magnifications. Today, there is a [scanning transmission electron microscope](#) that has both the principles of SEM and TEM.

Works Cited

CRAWFORD, C. K. (1980). Ion charge neutralization effects in scanning electron microscopes. *Scanning Electron Microscopy*, 4, 12-25.

Gillot, A. J. (1969). Study of the fabric of fine grained sediments with the scanning electron. *Journal of Sedimentary Petrology*, 91-103.

Goldstein JI, Newbury DE, Echlin P, Joy DC, Romig AD, Lyman CE, Fiori C, Lifshin E. (1992). *Scanning Electron Microscopy and X-ray Microanalysis* (2 ed.). New York: Plenum Press.

Goldstein, J., Newbury, D., Joy, D., Lyman, C., Echlin, P., Lifshin, E., Sawyer, L. & Michael, J. (2003). *Scanning Electron Microscopy and X-Ray Microanalysis*. New York: Springer.

GRUBB, D. T. (1974). Review: Radiation damage and electron microscopy of organic polymers. *Journal of Materials Science*, 9, 1717-1756.

JOY, D. C. (2002). SMART - a program to measure SEM resolution and imaging performance. *Journal of Microscopy*, 208, 24-25.

L, R. (1975). *Review of the radiation damage problem of organic specimens*. In: Siegel BM, Beaman DR (eds) *Electron microscopy*. New York: Wiley.

Misell D, L. (1977). *Developments in electron microscopy and analysis*. Bristol: Academia.

PAWLEY, J. B. (1972). Charging artifacts in the scanning electron microscope. *Scanning Electron Microscopy*, 1, 152-160.

SHAFFNER, T. J. & VAN VELD, R. D. (1971). Charging' effects in the scanning electron microscope. *Journal of Physics E: Scientific Instruments*, 4, 634-637.