# PH401:Nanomaterials Assignment

## End Sem Assignment

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By Rakshit Maheshwari(1701CE21)

## ANSWER 1

Transmission electron microscopy (TEM) is a microscopy technique in which a beam of electrons is transmitted through a specimen to form an image. The specimen is most often an ultrathin section less than 100 nm thick or a suspension on a grid. An image is formed from the interaction of the electrons with the sample as the beam is transmitted through the specimen. The image is then magnified and focused onto an imaging device, such as a fluorescent screen, a layer of photographic film, or a sensor such as a scintillator attached to a charge-coupled device.

Transmission electron microscopes are capable of imaging at a significantly higher resolution than light microscopes, owing to the smaller de Broglie wavelength of electrons. This enables the instrument to capture fine detail—even as small as a single column of atoms, which is thousands of times smaller than a resolvable object seen in a light microscope like various nanomaterials (soft & hard materials, biological samples, composites, ceramics, semiconductors and metals).

For designing purpose here we need to to take care of various parameters for the instrument and the characteristic of materials, like setting of voltage, beam current, magnetic lenses, sample stage and camera).



- **VOLTAGE:** The higher our voltage will be the better would be the resolution. The voltage could be setup as high as 20kV to 20,000kV. Basically the high potential is created for accelerating the electrons and that would be bombarded over the specimen. A very strong electric field ($109Vm^{-1}$) is applied to emit electrons from a metal filament. Temperature are lower than that needed for thermionic emission. This gives a much higher source brightness than in thermionic guns, but requires a very good vacuum. Voltage of the given TEM is 200kV.
- **BEAM CURRENT:** Here the beam current tells us about the rate of electrons being emitted from the electric guns. Assuming as the source of electron to be LaB6. And taking it as a physical quantity, we can attain a maximum beam current of 0.9340 mA.
- **MAGNETIC LENS:** A magnetic lens consisting of a tightly wound coil and a soft iron shroud surrounding the coil except for a small gap. The field is concentrated in that gap. Here, the given magnetic field generated through coil will act as a lens and would converge the electron on the sample. The Magnetic lenses used in TEMs are always constructed with an iron circuit to produce a high field strength across a short gap. The magnetic fields for TEM lenses are in the range of 10000-20000 gauss. Also, the focal length for the given magnetic lens could be calculated as:

$$\mathbf{f} = \frac{\mathbf{K}.\mathbf{V}_r}{(\mathbf{N}.\mathbf{I})^2}$$

K is the constant dependent over the dimensions and environment of the setup; $V_r$ is given to be 200KV and I is the current; N is number of turns in the coil. Thus, f can be is altered by changing I.

**SAMPLE STAGE:**

Material must be thin (< 100 nm). High resolution requires thickness ~20 nm

Preparation methods:

- Metals can be electro polished (Precision Ion polishing)

- Semiconductors, thin films and ceramics can be mechanically thinned by dimple grinder followed by ion thinning to achieve electron transparency.

**ULTRA-MICROTOMY:** A firmly mounted specimen is moved past a fixed knife of glass and diamond (for polymers and biological samples).

**STAINING:** Biological specimens are usually composed of elements that have relatively low atomic weights and in this way do not differ significantly from the embedding resins in which they are contained. To add contrast to the specimen, elements of high atomic weight are used to selectively stain the biological material and impart contrast when compared to the embedding resin. Atoms of high atomic weight are better able to stop or deflect the beam of electrons whereas elements of low weight allow them to pass relatively unimpeded.

There are a number of different types of buffers that are used as fixative vehicles. They each have certain properties which make them ideal for different purposes. Although they are typically used alone or in conjunction with electrolyte additives, some can be mixed for specific applications.

Cacodylate Buffer, Collidine Buffer, Phosphate Buffers, Tris Buffer, Veronal Acetate Buffer etc.

**Fixatives**: Aldehydes, Glutaraldehyde.

**CAMERA:**



Charge coupled device (CCD) cameras were first applied to transmission electron microscopy in the 1980s. For use in a TEM, in which electrons from the electron beam are converted to photons, which are then transferred to the sensor of the CCD via a fiber optic plate. The main reason for this is that direct exposure to the high energy electron beam risks damaging the sensor CCD. A typical CCD for a TEM will also incorporate a cooling device to reduce the temperature of the sensor to approximately -30 °C, which reduces dark current and improves signal to noise. Another widespread devices that were used was CMOS, STEM and direct electron detectors

For the given device, we also need to check its resolution for calculation the resolutions we would use our Next, the diffraction limit is defined as:

$$l = 0.612 * \lambda/NA$$

*l* is the diffraction limit; NA is the numerical aperture and λ is the wavelength of electron.

*l* is the length below which we cannot distinguish two objects next to each other. The relationship is called the Abbé equation. In it, NA = n* sin θ is the numerical aperture of the imaging lens, n is the refractive index of the medium, and θ is the half-angle of the impinging rays from normal incidence. Here assuming (Sin θ ~ θ ~ 0.01) and n to be 1.

**THEORETICAL RESOLUTION**

Calculating the λ, from the formula:

$$\lambda = \frac{h}{\sqrt{2m_0eV\left(1 + eV/2m_0c^2\right)}}$$

It could be approximated to be $1.225/(V)^{0.5}$ in (nm);

Putting, this value in the given formula we get our wavelength of electron to be 2.739 x 10-3 nm.

Further putting this value in (i) we get I (diffraction limit) to be **0.167 nm**.

Now, being particle we will always notice that the resolution will always be larger than the theoretical value. Thus our Practical resolution will be larger than 0.167. The deviation could be because of aberrations, contrast, distortions.

**ABERRATIONS:** This is a property of optical systems such as lenses that causes light to be spread out over some region of space rather than focused to a point, after transmission. Aberrations cause the image formed by a lens to be blurred or distorted, with the nature of the distortion depending on the type of aberration. Aberrations occur because the simple paraxial theory is not a completely accurate model of the effect of an optical system on light, rather than due to flaws in the optical elements.

**DISTORTIONS:** Although distortion can be irregular or doesn't follow any pattern, the most commonly encountered distortions are radially symmetric, or approximately so, arising from the symmetry of a photographic lens. These radial distortions can usually be classified as either barrel distortions or pincushion distortions.



**CONTRAST:** It is the difference in luminance or colour that makes an object (or its representation in an image or display) distinguishable. In visual perception of the real world, contrast is determined by the difference in the colour and brightness of the object and other objects within the same field of view. The maximum contrast of an image is the contrast ratio or dynamic range.

**BRIGHT-FIELD TEM:** The aperture is used to select the non-scattered (transmitted) electrons, whilst the scattered electrons are blocked. Therefore, images produced by bright-field TEM areas with crystalline or high mass density appear dark, allowing for the precise structure being studied to stand out.

**Advantages:** Bright-field images are the most common images produced by transmission electron microscopy. They enhance the contrast of image and are suitable for most structures.

**Disadvantages:** Problems related to contrast occur. Also, they are not suitable for crystalline structures that are too small.

**DARK-FIELD TEM:** Here the scattered electrons are selected, while the non-scattered electrons are excluded by the aperture. Thus, the area around the sample being examined will appear light, rather than dark. Although dark field TEM is not as commonly used as bright field, it has its own distinctive advantages.

**Advantages:** Smaller crystalline structures which cannot be imaged with bright field TEM can be viewed easily with dark field TEM because of selection of electrons scattered by the aperture. The features such as crystal lattice, crystal defects, dislocations, stacking faults and particle size can also be studied of the aforementioned structures. Dark field images provide more detail in cases where bright field images are not clear. Due to low noise, it is favourable for certain areas of research.

**Disadvantages**: Sample should be strongly illuminated, which can cause damage to sample. Besides sample, dust particles also scatter light and are imaged.

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**ANSWER 2 :**

2(i) Grazing incidence X-ray and neutron diffraction (GID, GIXD, GIND), typically from a crystalline structure uses small incident angles for the incoming X-ray or neutron beam, so that diffraction can be made surface sensitive. It is used to study surfaces and layers because wave penetration is limited.

2(iii) **Sample Preparation Starters**



Some samples need to be coated to make them conductive. Metals require no preparation due to their inherent ability to conduct electricity. However, non-metals need to be coated with a conductive material. Most often, a thin layer of gold works. This requires the use of a sputter-coater.

Important parameters in preparing a sample for SEM imaging are as follows:

**Sample Cleaning**

A clean sample is essential for image clarity. For biological samples, use appropriate buffers or distilled water for cleaning the samples. Use a surfactant if the sample requires more vigorous cleaning. If the biological property of the sample is known, then you might be able to use proteolytic enzyme cleaning. To remove oils on the sample surface, wash with appropriate solvents. Additionally, you can use ultrasonic baths for cleaning the sample. However, ultrasonic baths require caution in order to avoid damaging the sample.

**Sample Fixation and Dehydration**

Use a fixative like glutaldehyde or osmium vapor to maintain the structural details of the sample. Note that if a fixative uses a phosphate based buffer for its preparation, salt deposits may interfere with the sample's image quality. For dehydration, use a graded series of alcohol and finish off the final dehydration step with 100% alcohol or acetone.

## Drying

Prior to placing the sample in a high vacuum environment, it must be totally dry. Otherwise, water vaporization will obstruct the electron beam and interfere with image clarity. When using biological samples, be careful when doing critical point drying (or CPD), so as to not compromise the structural integrity of the sample. A suitable CPD instrument can help achieve this. Alternatively, you can try using freeze drying. In this regard, freeze drying causes the least amount of sample shrinkage in comparison to air drying or critical point drying. However, freeze drying carries the risk of ice crystal formation on the sample.

## Sample Preparation of Tissue Sections

To observe details from tissue sections, remove the epoxy resin using organic solvents, ion beam etching, or plasma etching. You can also break the sample in the appropriate direction to reveal its internal details.

## Sample Stubs, Adhesives, and Mounting Approach

Sample stubs or supports are available in different diameters making them convenient for imaging different kinds of samples. Be sure the stubs are clean and handle the sample with clean forceps. Also, use gloves during the entire sample preparation stage. The material you use as an adhesive to glue the sample to the stub should be non-toxic and should not tumble into the sides of the sample. Conductive double coated carbon tape is the most common adhesive for this purpose. You need to ensure that a conducting path exists as you mount the sample. If the sample requires a conductive coating, be sure to mount it before coating so that both the sample and plug receive the coating.



## Sample Storage

Store the sample and stubs in a dry, clean environment. Use clean forceps and gloves while handling the stubs.

(iv)

1. Place glass slides in both the sample holder and the reference sample holder of the UV/Vis/NIR spectrophotometer.

2. Select 800 nm as scanning wavelength maximum and 200 nm as minimum in the window for scan settings and carry out baseline correction.

3. Place the film containing lead sulfide quantum dots in the sample holder of spectrophotometer and record the absorption spectrum.

4. Plot the data as absorbance vs. wavelength and draw a tangent to the curve at the point of curvature change, as shown in fig. (This point indicates the energy above which the quantum dot absorbs the incident light).

5. Calculate the band gap of the quantum dot using the following relation:

The exciton Bohr radius is given by the formula[7]:

$$a_b^* = \varepsilon_r \left(\frac{m}{\mu}\right) a_b$$

- $\varepsilon_r$ = dielectric constant (relative permittivity)
- m = mass
- μ = reduced mass
- $a_b$ = Bohr radius (0.053 nm)

### Confinement Energy

The particle in a box model is also used in modeling the exciton. Variance of particle size allows for control of the confinement energy. The solution to the particle in a box model is used to represent the energy of the exciton as follows[7]:

$$E_{confinement} = \frac{\hbar^2\pi^2}{2a^2}\left(\frac{1}{m_e} + \frac{1}{m_h}\right) = \frac{\hbar^2\pi^2}{2\mu a^2}$$

### Bound Exciton Energy

Coulombic attractions persist between the electron of negative charge and hole of positive charge that have an energy proportional to Rydberg's energy, and inversely proportional to the dielectric constant squared. This term becomes important when the semiconductor crystal is smaller than the exciton Bohr radius[7]:

$$E_{exciton} = -\frac{1}{\varepsilon_r^2}\frac{\mu}{m_e}R_y = -R_y^*$$



$$E_{exciton} = -\frac{1}{\varepsilon_r^2}\frac{\mu}{m_e}R_y = -R_y^*$$

A quantum dot is confined in all three spatial dimensions, but semiconductors with other modes of confinement include **quantum wires** (holes or electrons confined in two spatial dimensions with one degree of freedom), and **quantum wells** (confined in one spatial dimension with two degrees of freedom).

Taking into account each of these three terms then, the total energy can be simplified further[7]:

$$E = E_{bandgap} + E_{confinement} + E_{exciton}$$

$$\therefore E = E_{bandgap} + \frac{\hbar^2\pi^2}{2\mu a^2} - R_y^*$$

REF.- Quantum Dots - Engineering LibreTexts

**Magnetic force microscopy (MFM)** is a variety of atomic force microscopy, in which a sharp magnetized tip scans a magnetic sample; the tip-sample magnetic interactions are detected and used to reconstruct the magnetic structure of the sample surface. Many kinds of magnetic interactions are measured by MFM, including magnetic dipole–dipole interaction.

$$\vec{F} = \mu_o(\vec{m}\cdot\nabla)\vec{H}$$

Where m is the magnetic moment of the tip (approximated as a point dipole),H is the magnetic stray field from the sample surface, and $\mu_0$ is the magnetic permeability of free space. Because the stray magnetic field from the sample can affect the magnetic state of the tip, and vice versa, interpretation of the MFM measurement is not straightforward. For instance, the geometry of the tip magnetization must be known for quantitative analysis.Typical resolution of 30 nm can be achieved, although resolutions as low as 10 to 20 nm are attainable

MFM is operated with the so-called "lift height" method. When the tip scans the surface of a sample at close distances (< 10 nm), not only magnetic forces are sensed, but also atomic and electrostatic forces. The lift height method helps to enhance the magnetic contrast through the following:

- First, the topographic profile of each scan line is measured. That is, the tip is brought into a close proximity of the sample to take AFM measurements.
- The magnetized tip is then lifted further away from the sample.
- On the second pass, the magnetic signal is extracted

**Answer 3.**

| | gold | | silver |
|---|---|---|---|
| Initial temperature T(°c)= | 1050 | | 950 |
| surface coefficient (σ) (J/m2) | 0.5 | | 0.5 |
| density (gm/cc) | 19 | | 11 |
| latent heat (kj/kg) | 63 | | 105 |
| | | | |
| deviation | 17.54386 | | 16.45022 |
| FINAL TEAMP | 1032.456 | | 933.5498 |
| RATIO | 19 | | 1 |
| | | | |
| FINAL TEMP OF MIX | 1027.511 | | |

Calculations are done in the Excel file attached.



**Answer 4.**

Photolithography is the process of transferring geometric shapes on a mask to the surface of a silicon wafer. The steps involved in the photo-lithography process are wafer cleaning barrier layer, formation photo-resist applications soft baking, mask alignment, exposure and development and hard baking.

**Wafer cleaning, Barrier formation and photo-resist application :**

In the first step, the wafers are chemically cleaned to remove particulate matter on the surface as well as any traces of organic, ionic and metallic impurities.

After cleaning, silicon dioxide, which serves as a barrier layer is deposited on the surface of the wafer.

After the formation of the Sio2Sio2 layer, photo resist is applied to the surface of the wafer.

High speed centrifugal whirling of silicon wafers is the standard method for applying photo-resist coatings in MEMS manufacturing.

This technique known as "spin coating" produces a thin uniform layer of photo-resist on the wafer, surface.

**Positive and Negative photoresist :**

There are two types of photo-resist : Positive and Negative. For positive resist the resist is exposed with UV light wherever the underlying material is to be removed. In these resists, exposure to the UV light changes the chemical structure of the resist so that it becomes more soluble in the developer. The exposed resist is then washed away by the developer solution, leaving windows of the bare underlying material.

Negative resists behave in just the opposite manner. Exposure to the UV light causes the negative resist to become polymerized and more difficult to dissolve. Therefore the negative resist remains on the surface. Wherever it is exposed and the developer solution removes only the unexposed portions masks used for negative photo-resist, therefore contain the inverse of the pattern to be transferred.

**Soft - Baking :**

Soft - baking is the step during which almost all of the solvents are removed from the photo-resist coating. Soft baking plays a very critical role in photo imaging. The photoresist coatings become photosensitive, or imageable only after soft baking oversoft - baking will degrade the photo-sensitivity of resists by either reducing the developer solubility or actually destroying a portion of sensitizer.

Under soft-baking will prevent light from reaching the sensitizer. Positive resists are incompletely exposed if considerable solvent remains in the coating. This under soft-baked positive resists then readily attacked by the developer in both exposed and unexposed areas causing less etching resistance.

**Mask alignment and exposure :**

One of the most important steps in the photo-lithography process is mask alignment. A mask or "photo mask" is a square glass plate with a patterned emulsion of metal film on one side. The mask is aligned with the wafer, so that the pattern can be transferred onto the wafer surface. Each mask after the first one must be aligned to the previous pattern once the mask has been accurately aligned with the pattern on the wafers surface, The photo-resist is exposed through the pattern on the mask with a high intensity UV light.



There are 3 primary exposure methods:

Contact, proximity and projection.

Development :

At low exposure energies the negative resist remains completely soluble in the developer solution. As the exposure is increased above a threshold energy move of the resist film remains after development. At exposures two or three times the threshold energy, very little of the resist film is dissolved. For positive resist, the resist solubility in its developer is finite even at zero exposure energy. The solubility gradually increases until, at some threshold, it becomes completely soluble.

Hard - Baking:

Hard - Baking is the final step in the photolithography process. This step is necessary in order to harden the photo-resist and improve adhesion of photo-resist to the wafer surface.

(ii)

Electron lithography uses a focused beam of electron to form the circuit patterns needed for material decomposition on the wafer.

Algorithm of circuit printing method by using electron lithography setup :

An electron gun or electron source that supplies the electrons

An electron column that shapes and focuses the electron beam

A mechanical stage that positions the wafer under the electron beam

Wafer handling system that automatically feeds wafer to the system and unloads them after processing

A computer system that controls the equipment

## Pros and cons of lithography

Pro: Speed of Production

Today, almost all high-volume, mass-produced texts are made via lithography, including books, newspapers, maps, magazines and posters. Once the lithography plate is treated properly it can be used over and over again in rapid succession. Furthermore, the plates themselves are easier to produce than traditional raised-letter printing presses as the process is chemical.

Pro: Economies of Scale

Given the speed with which prints can be made, lithography (specifically offset lithography) is the cheapest way to produce large-scale commercial print runs. Moreover, the long-life of lithographic plates and ability to reuse them further reduces the cost associated with this process.



Con: Not Good for Small Print Runs

Though the time and cost associated with producing plates and setting up the printing press are low compared to traditional raised-letter printing presses, they are still significant enough to make small-scale print runs impractical. For this reason, smaller-scale operations are moving toward digital printing.

Con: Cannot Produce High Quality Prints

While the quality of prints produced through lithography are generally high, they cannot compare with prints produced via rotogravure or photogravure printing. Similarly, as lithographic plates degrade over time when not properly maintained (particularly with aluminium plates that slowly oxidise) and this can lead to deteriorating image quality.

## Nanoimprinting

the creation of circuits by pressing the imprinting of a nanometer-scale mask onto the substrate in a process called “nanoimprinting”.

Nanoimprint technology has become an alternative to conventional lithographic technology and manufactures nanostructures for various applications in many areas of nanoscale device manufacturing, from more standard semiconductor devices.

The principle of Nanoimprint lithography is straightforward. Nanostructured silicon or polymer hybrid mold is pressed with controlled pressure and temperature on a substrate coated with a defined layer of polymeric material. After the removal of the mold, an inverse reproduction of the characteristic will then be directly imprinted on the substrate.

## Applications of Nanoimprinting

Nanoimprinting provides a cost-effective pathway for much more precise control of surface optical properties and has been exploited for numerous applications such as fabrication of active photovoltaic layer in solar cells, control of polarization, color, media for hard-disk drives. As well as being used in biological applications include sensing, nanofluidic devices for DNA stretching, tissue engineering.

Nano imprinting is capable of replicating features below 10 nm over large area substrates, is a leading candidate to allow nanostructures manufacturing for advancing ICs. Smart devices are displacing personal computers and current household devices. The semiconductor industry has shifted design goals to include minimizing of power consumption. The market for mobile dynamic RAM continues to grow owing to smartphone demand for upgrading memory efficiency and performance; the industry will continue to struggle for process improvements beyond the 14 nm to reduce feature size.



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## Answer 5)

(i)

a. **Magnetic storage** is a form of the non-volatile memory that uses different patterns of magnetization in a magnetizable material to store data. Magnetic storage stores data by magnetizing microscopic iron particles on the surface of the device. These are polarized in two directions by giving a magnetic charge. The direction of the particle indicates whether it's a '1' or a '0', representing the binary bits of data. There are several types of magnetic storage devices such as: Hard Disks, Floppy Disks, and Tapes.

b. Initially the random arrangement of dots/particles means no data is stored. But after passing current, the magnetized particles become organized, representing stored data (**electromagnetization**). In the case of magnetic tape, the dots are arranged along the length of a long plastic strip which has been coated with a magnetisable layer. In the case of floppy disk and hard disks, the dots are arranged in circles on the surface of a plastic, metal or glass disc that has a magnetisable coating.

c. **Nanotechnology** plays a vital role in such devices. The disk read/write heads used to access the memory operate at a clearance of close to 3 nanometres above the disk. The magnetic regions on the surface is composed of a few hundred magnetic grains. Magnetic grains are typically

10 nm in size. Furthermore, new techniques like nanolithography have been devised to build memory chips that are 20nm in size. Magnetic nanowires are being increasing used to build memory devices.

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(ii)

a. The structure of carbon nanotubes is cylindrically shaped, which are formed by wrapping a hexagonal lattice/sheet of crystalline graphite with certain cut. To easily explain the structure and geometry of a nanotube, we can focus on its unit cell. The unit cell can be defined by two terms, $\mathbf{C_h}$ **(chiral vector)** and T(translational vector).
The **chiral vector** is the vector which connects two crystallographically equivalent sites on a two-dimensional graphene sheet. It is described by:-

$$\mathbf{C_h} = n\mathbf{a_1} + m\mathbf{a_2}$$

*; Where a1 and a2 are the unit vectors and n and m are the zig zag nanotubes of the cell*

b. The chiral vector is used to express the circumference of any Carbon nanotube. This is given by the equation for **diameter** : -

$$d_{CNT} = \frac{|\mathbf{C_h}|}{\pi} = \frac{\sqrt{3}a_{C-C}(m^2 + mn + n^2)^{1/2}}{\pi}$$

*; Where $a_{c-c}$ is the bond length between two carbon atoms of the cell =* ***1.42A°***



Also it can be said a carbon nanotube is conducting in nature if the value of *"n-m" is a multiple of 3* ***[n-m =3q]***

So from the question we can find out the following :-

| ***S. No*** | ***Carbon Nanotubes*** | ***Diameter ($a_{c-c}$=1.42A)*** | ***"n – m" value*** | ***Conducting nature*** |
|---|---|---|---|---|
| 1. | (3,9) | 0.8468 nm | 6 | Yes |
| 2. | (14,18) | 2.1752 nm | 4 | Semi-conducting |
| 3. | (20,23) | 2.9177 nm | 3 | Yes |

So, the nanotubes (3,9) and (20,23) are conducting in nature as their "n-m" value is a multiple of 3. The (14,18) nanotube is semi-conducting in nature.

c. Carbon nanotubes are very important in nanotechnology due to a combination of unique and extreme properties : -
   i. Carbon nanotubes are the strongest and stiffest materials yet discovered in terms of tensile strength and elastic modulus. This strength results from the covalent $sp^2$ bonds formed between the individual carbon atoms.

ii. The resistivity of carbon nanotubes is constant. So, they are excellent materials for high current applications, so much that they are almost 1000 times better than silver or copper.
iii. They have very high thermal conductivity and their thermal stability is also excellent.
iv. There is great potential for application of carbon nanotubes in the future due to their useful optical properties like absorption and photoluminescence (nanotube-based LED etc.).

These properties and characteristics make the carbon nanotubes a very versatile nanomaterial for use in a number of applications.

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**Answer 6)**

| 1. Scherrer's method | final L= | 22.61439 |
|---|---|---|

| Peak positions(°) | q | FWHM(°) | Br | sin(@) | cos(@) | Br*cos(@) | L(nm) |
|---|---|---|---|---|---|---|---|
| 18 | 9 | 0.36 | 0.006286 | 0.156356 | 0.987701 | 0.006208405 | 23.31678 |
| 30 | 15 | 0.34 | 0.005937 | 0.258691 | 0.96596 | 0.00573443 | 25.24401 |
| 36 | 18 | 0.37 | 0.00646 | 0.308866 | 0.951106 | 0.006144445 | 23.55949 |
| 43 | 21.5 | 0.39 | 0.00681 | 0.366324 | 0.930487 | 0.006336175 | 22.84659 |
| 53 | 26.5 | 0.41 | 0.007159 | 0.445988 | 0.895039 | 0.006407342 | 22.59283 |
| 57 | 28.5 | 0.49 | 0.008556 | 0.476937 | 0.878937 | 0.007519798 | 19.25052 |
| 62 | 31 | 0.45 | 0.007857 | 0.514803 | 0.857309 | 0.006735996 | 21.49051 |

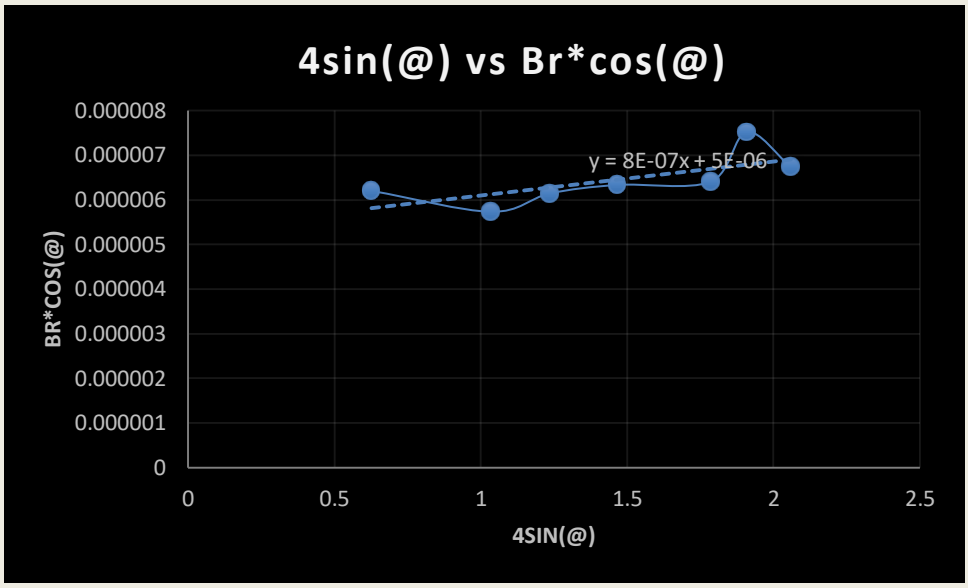


| K = | 0.94 |
|---|---|
| l (A°) = | 1.54 |

L(nm) = 27.09593 Final L= 2)WH METHOD

| 4*sin(@) | Br*cos(@) |
|---|---|
| 0.625423249 | 6.21E-06 |
| 1.034763376 | 5.73E-06 |
| 1.23546208 | 6.14E-06 |
| 1.465296894 | 6.34E-06 |
| 1.783951848 | 6.41E-06 |
| 1.907748535 | 7.52E-06 |
| 2.059211771 | 6.74E-06 |

| intercept | 5.3425 |
|---|---|
| slope | 0.0008 |




Calculation of the question can be verified through Excel sheet attached.

**Answer 7)**

A nanometre (nm) is one billionth of a metre and so this kind of engineering involves manipulating individual atoms. We can do this, for example, by firing a beam of electrons at a material, or by vaporising it and depositing the resulting gaseous atoms layer by layer onto a base.

The real challenge is using such techniques reliably to manufacture working nanoscale devices. The physical properties of matter, such as its melting point, electrical conductivity and chemical reactivity, become very different at the nanoscale, so shrinking a device can affect its performance. If we can master this technology, however, then we have the opportunity to improve not just electronics but all sorts of areas of modern life

The following are the depiction for future of nano materials-

i.Wearable fitness technology means we can monitor our health by strapping gadgets to ourselves. There are even prototype electronic tattoos that can sense our vital signs. But by scaling down this technology, we could go further by implanting or injecting tiny sensors inside our bodies. This would capture much more detailed information with less hassle to the patient, enabling doctors to personalize their treatment.

The possibilities are endless, ranging from monitoring inflammation and post-surgery recovery to more exotic applications whereby electronic devices actually interfere with our body's signals for controlling organ function. Although these technologies might sound like a thing of the far future, multi-billion healthcare firms such as GlaxoSmithKline are already working on ways to develop so-called "electroceuticals".

ii. These sensors rely on newly-invented nanomaterials and manufacturing techniques to make them smaller, more complex and more energy efficient. For example, sensors with very fine features can now be printed in large quantities on flexible rolls of plastic at low cost. This opens up the possibility of placing sensors at lots of points over critical infrastructure to constantly check that everything is running correctly. Bridges, aircraft and even nuclear power plants could benefit.