Amit K S

Nanotechnology Notes

CNTs

A carbon nanotube is made of carbon, a tube-shaped material and nanometer scale used for measuring its diameters. The thickness of a nanometer is about one-billionth of a meter, or one ten-thousandth of a human hair. In the carbon nanotube graphite layer is rolled-up with continuous unbroken hexagonal mesh in the chicken wire. At the apexes of the hexagons carbon molecules are found. Diameters of the carbon nanotubes have ranging from <2 nm up to 55 nm. The lengths of carbon nanotubes are typically several microns. But in recent advancements the length of nanotubes found longer, and measured in centimeter**.**

Carbon nanotubes are the property of existing in more than one form of carbon with a shaped of cylindrical nanostructure and also known as buckytubes. The ratios of nanotubes have been made with diameter and length up to 1:132,000,000, which is larger than any other material. The cylindrical shape of the carbon molecules have make a highly potentially and useful in many applications such as pharmaceuticals field, electronics, in nanotechnology, and other fields of materials science, also in potential uses in architectural fields. Carbon nanotubes have been applied in the construction of body armor. There are extraordinary strengths of the nanotube used as thermal conductors and also unique electrical properties.

The structures of nanotubes are belonging from the fullerene family, which also includes the spherical buckyballs. The last portion of a carbon nanotube may be covered with a hemisphere of the buckyball structure. The diameter of a nanotube is few nanometers that approximately 1/55,000th of the width of a human hair and length up to 20 centimeters

Types of carbon nanotubes:

(a) Single-walled nanotubes (SWNTs): The diameter of single-walled nanotubes (SWNTs) has approximately to 1 nanometer, and length of the tube about many millions of times longer. Single-walled nanotubes are wrapping with layer of graphite which one-atom-thick layer called graphene into a seamless cylinder. The wrapped graphene sheet is represented by a pair of indices (*n*, *m*) known as the chiral vector.

There are important varieties between the single walled nanotubes that exhibit electric properties but the multi-walled carbon nanotube (MWNT) variants are not able to share this property. There are band gap can vary from zero 3 eV and its electrical conductivity can show semiconducting or metallic nature in the single walled nanotubes, whereas MWNTs are zero-gap metals. Single-walled nanotubes are the most portrait electronics beyond the micro electromechanical scale currently used in electronics.

SWNTs can be used as excellent conductors because the electric wire used as the building block systems [2-3]. Single walled nanotubes are also applicable in the development of the intramolecular field effect transistors (FET). FETs have recently possible for production of the intramolecular logic gate by using

Single walled nanotubes [4]. There are both a p-FET and an n-FET involve to create a logic gate. In SWNTs, p-FETs exposed to oxygen and n-FETs save the half oxygen which exposure from the SWNTs, while another way exposes the half to oxygen.

(b) Multi-walled nanotube: Multi-walled nanotubes (MWNT) are made of multiple rolled layers or concentric tubes of graphite. There are two types of models which can be explained the structures of multi-walled nanotubes. According to the Russian Doll model, the graphite sheets are arranged in concentric cylinders, e.g. a (0, 9) single-walled nanotube (SWNT) within a larger than (0, 18) single-walled nanotube. According to the Parchment model, a single graphite sheet is rolled in around the MWNTs, similar a rolled newspaper or scroll of parchment. The interlayer of multi-walled nanotubes distance is close to the distance between graphene layers in graphite 3.4 Å.

The morphology and properties of double-walled carbon nanotubes (DWNT) must be important in the specific place because they are similar to SWNT but its resistance to chemicals is significantly also improved. This is especially important when grafting of chemical functions is required at the surface of the nanotubes to add properties in the CNT. The covalent function will break when some C=C double bonds, leaving hole in the structure on the nanotube in the case of SWNT. There are modifying both its electrical and mechanical properties in SWNT. Only the outer wall is modified of the DWNT. In 2003 CCVD technique was used for the synthesis of DWNT on the gram scale process and there were reduction of oxide solutions in hydrogen and methane

Applications of Carbon nanotube (CNT):

Cancer Treatment: Cancer is one of the most ravaging diseases that approximately more than 10 million new cases found every year from different countries. There are current treatments of cancer by various methods such as radiation, surgery and chemotherapy that successful in several cases. These appropriate methods are also killing healthy cells and cause toxicity to the patient.

The spread of cancer cells between organs, a process called as metastasis which is responsible to cause of most cancer death. It would therefore be desirable to develop methods to directly target cancerous cells without affecting normal ones [25]. In the drug delivery systems used recent advances to promise for enhance cancer therapy [26].

In advanced drug delivery system there are CNT"s considered as antitumor agents when conventional drug combined with in, then obtained enhancement their chemotherapeutic effect. It has been found that Paclitaxel loaded PEG-- carbon nanotube sare promising for cancer therapeutics [27].

There are aqueous solutions of SWCNTs on exposure to radiofrequency (RF) field experiences efficient heating. This property has been achieved by Gannon *et al* for a noninvasive and selective thermal destruction of treatment for human cancer cells with very less effect or no toxic effects to normal cells. There are carbon nanotubes capable of leading to new suitable directions and approaches in therapeutic human cancer cells [28].

In the next generation of cancer treatments the photo-thermal therapy used and nanomaterials technology has been recently important as an efficient strategy for cancer treatments. SWCNTs are used for potent candidate for the photo-thermal therapeutic agent. It generates sufficient amounts of heat when goes to excitation state with near infrared light (NIR, lambda = 700-1100 nm) which is easily cross to biological systems including skins.

SWCNTs sidewall is highly hydrophobic; they are practically not soluble in water. So SWCNTs are functionally active by covalent or non covalent routes that will help in open the CNT bundles and make them soluble in water [29]. There are demonstrated that DOX loaded SWCNTs (PL-SWCNT- DOX) induced significant treatment for U87 cancer cell death and cell apoptosis. There are the main advantages of SWCNTs which used as drug deliver at the particular site such as drug carrier compared to free drug which is the potential to target delivery for selective destruction of different types of cells and reduce the toxicity to non-targeted cells of different site.

The above method used for the treatment of cancer cells provides an easily to make formulation of the SWCNT–DOX complex which extremely high drug-loading efficiency. They are highly higher than obtained conventional liposome's and dendrimer drug carriers [30]. Carbon nanotubes are an important new stings and this work as a boost to control against cancer after researchers adopted this technology and found that they can improve a treatment against cancer called adoptive immunotherapy.

Apply conventional adopted immunotherapy techniques which can take few weeks, but using carbon nanotubes technology then reduced this time up to two thirds. The researchers found that the antigens of the cancer cell collected around defects on the surface of the carbon nanotubes by using fluorescence resonance energy transfer (FRET) microscopy [31].

Bioengineering: There are many applications of bioengineering proposed by the carbon nanotubes technology, such as energy storage and conversion devices, conductive and high strength composite, radiation sources, sensors, nanometer-sized semiconductor devices and hydrogen storage media [32-33]. The principal of SWCNTs and MWCNTs applied in the industrial and academic for research activity. There are different electronic device focused using in the research activity such as field emission electron source for, lamps, flat panel display and gas discharge tubes applied for surge protection, microwave generations and x-rays.

There are high potential energy applying between a coated surface of carbon nanotube and an anode. They produce high local field effect then results found in small change in radius of the nanofiber tip and small change in length of the nanofiber. These local field effects cause electrons to tunnel the nanotube tip into the vacuum.

Cardiac Autonomic Regulation: There are many times single-walled carbon nanotubes used in the cardiac autonomic regulation. Single-walled carbon nanotubes are portion of physicochemical properties with fine component which may damage cardiovascular autonomic control that proved after the study in rats. Many times SWCNTs may alter the baroreflex function, then affecting the autonomic cardiovascular control regulation [34].

Platelet Activation: The main applications of SWNTs are platelet activation in the macro and microcirculatory thrombus formation. There are platelet P-selectin expression method used in the study on platelet activation *in vitro*, micro and macrocirculatory thrombus formation. This activity has been reported that SWCNTs when injected into anaesthetized mice or rat, light/dye-induced thrombus formation was noted and then platelet activation found [35].

Blood platelets are activate by MWNTs inducing extracellular Ca^{2+} influx that could be prevented SKF 96365 and 2-APB blockers that comes in the calcium channel blockers. Platelet activation is induced by carbon nanotube that associated with a marked relax of platelet membrane microparticles and secretion of markers CD62P and CD63.

Tissue Regeneration: Carbon nanotubes are composed with various polymers, (such as polylactide and poly-D, poly-l-lactide, Llactide-co-glycolide copolymer) which have been applied as scaffolds in tissue regeneration. Many types of biodegradable polymer are combined with carbon nanotubes that provide new view point in the development of scaffold nano-devices and nanomaterials [36]. There were prepared composite materials comprised of a collagen matrix with embedded carbon nanotubes by mixing solubilized collagen with solution having carboxylated SWCNTs.

Living smooth muscle cell were integrated at the collagen stage to produce cell-seeded collagen carbon nanotubes composite matrices. They accomplished that such collagen carbon nanotubes composite mixtures may be useful as scaffolds in tissue regeneration [37]. It is reported that new composite material considered by combining MWCNTs with craft collagen matrix showed good mechanical characteristics due to the favorable properties of MWCNTs [38].

Recent advancement of carbon nano tube in the pharmaceutical field: A microcapsule carbon nanotube provides targeted delivery of therapeutic application in various diseases. However, their efficacy is limited due to the problems face during their delivery to target tissues. In recent era there are various developments take place in carbon nanotube in different field like carbon nanotube based tissue engineering, where the interaction between living cells/tissues and nanotube takes place and in the organ regeneration techniques.

The better mechanic strength and chemical inert of carbon nanotube also makes it ideal for blood attuned applications, especially for cardiopulmonary bypass surgery.

The applications of carbon nanotubes in these cardiovascular surgeries led to a remarkable development in mechanical strength of entrenched catheters and reduced thrombogenicity after surgery

CNT Interconnects: https://en.wikipedia.org/wiki/Carbon_nanotubes_in_interconnects

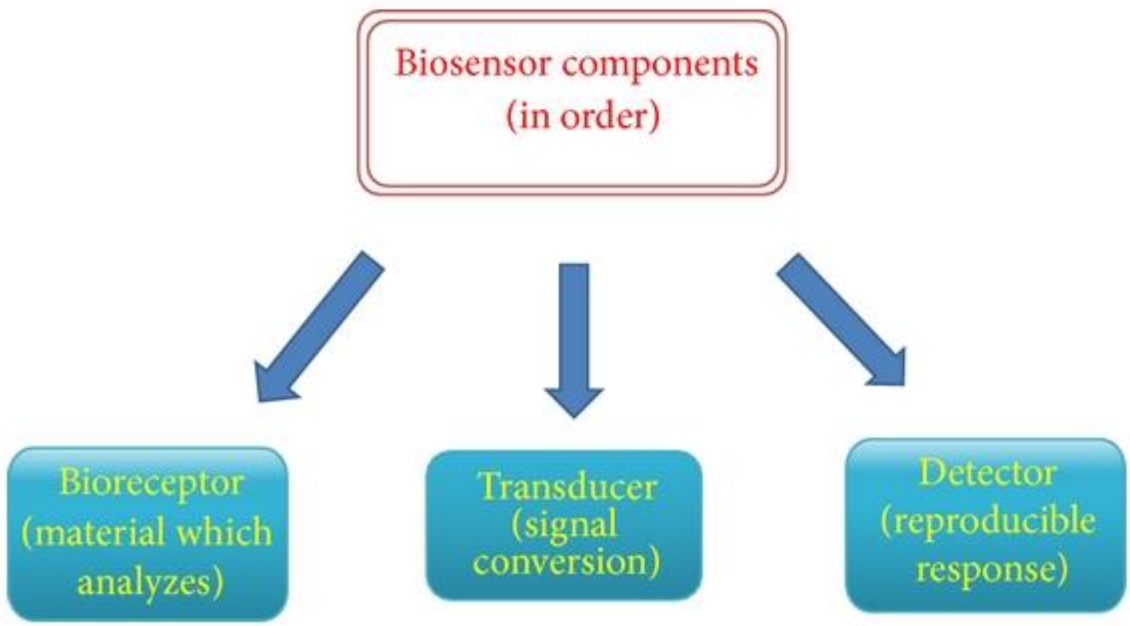
CNTFETs

https://www.engineering.com/story/how-do-cntfets-work-and-why-are-they-so-promising

Biosensers

Definition and Conceptual Idea

A biosensor can be defined as a sensing device or a measurement system designed specifically for estimation of a material by using the biological interactions and then assessing these interactions into a readable form with the help of a transduction and electromechanical interpretation. Figure 1 gives us information about the three main components of a biosensor. In terms of the conceptual and fundamental mode of operation, these components are, namely, bioreceptor, transducer, and the detector. The main function or purpose of a biosensor is to sense a biologically specific material. Often, these materials are antibodies, proteins, enzymes, immunological molecules, and so on.



It is done by using another biologically sensitive material that takes part in the making of bioreceptor. So, a bioreceptor is that component of a biosensor which serves as a template for the material to be detected. There can be several materials which can be used as bioreceptors. For instance, an antibody is screened using antigen and vice versa; a protein is screened using its corresponding selective substrate and so on. The second component is the transducer system. The main function of this device is to convert the interaction of bioanalyte and its corresponding bioreceptor into an electrical form. The name itself defines the word as trans means change and ducer means energy. So, transducer basically converts one form of energy into another. The first form is biochemical in nature as it is generated by the specific interaction between the bioanalyte and bioreceptor while the second form is usually electrical in nature. This conversion of biochemical response into electrical signal is achieved through transducer. The third component is the detector system. This receives the electrical signal from the transducer component and amplifies it suitably so that the corresponding response can be read and studied properly. In addition to these components, a very essential requirement of the nanobiosensors is the availability of immobilization schemes which can be used to immobilize the bioreceptor so as to make its reaction with bioanalyte much more feasible and efficient. Immobilization makes the overall process of biological sensing cheaper, and the performance of the systems based on this technology is also affected by changes in temperature, pH, interference by contaminants, and other physicochemical variations

Applications of Nano Biosensers

The definition and description of the concept of operation of nanobiosensors do not leave any room for their applications as they are highly versatile and multifunctional, so many and perhaps endless. From the estimation and diagnosis in the health related *in vivo* aspects, biosensors can also be used for environmental monitoring of pollutants, toxicants, and physical aspects like humidity, heavy metal toxicity, and even presence of carcinogens.

(1) *Biomedical and Diagnostic Applications*. Biosensors have been used for biological detection of serum antigens and carcinogens, and causative agents of so many metabolic disorders since time immemorial. The routine applications in diagnosis are best described by the use of biosensors in the detection of disorders like diabetes, cancer, allergic responses, and so many other disorders on the basis of serum analysis. To talk about most of the studied and effectual applications of nanobiosensors from clinical point of view, there are numerous clinical applications that are principally being enabled using biosensors in routine. These applications include the detection of glucose in diabetic patients [54, 55], detection of urinary tract bacterial infections [47, 56], detection of HIV-AIDS [57, 58], and the diagnosis of cancer [59–61]. Indeed, all of these are highly critical health problems affecting the mankind at present throughout the world. Prior to the use of biosensors, the detection and diagnosis of these diseases were very difficult, time consuming and costly. The advent of biosensors has really improved the diagnosis of all these diseases and related malfunctions. With the addition of nanoscale interventions, this diagnosis has further been benefitted and made more precise. The incorporation of nanomaterials has enabled the detecting enzyme systems to be immobilized, and this has allowed the recycling and reuse of costly enzymes. Besides, they have improved sensitivity and accuracies that make them hot candidates for being tapped upon. The implementation of nanoscale innovations like NEMS and MEMS has enabled several advantages to the overall testing procedures. Extremely sensitive inroads like those of lab-on-a-chip based assays have been developed using smart sensing nanoscale materials only. Biochips and microarray based testing have enabled the testing of more than one disease in perhaps no time. With controlled synthesis, even magnetic nanoparticles have been synthesized and used for isolating and heavy metals resembling in properties with iron from the blood serum of living organisms. The evaluation of biochemical responses has been highly versatile and it has been so selective with the use of magnetic nanoparticles. This argues well for blood related disorders considering the involvement of iron

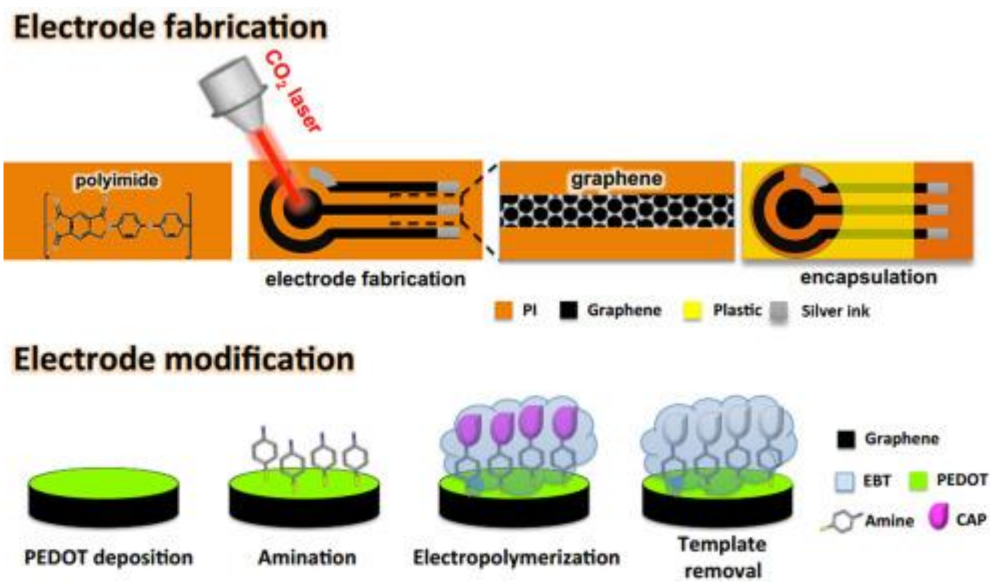
protein hemoglobin. Such invasions have been collectively termed as diagnostic magnetic resonance as they use the optimization of magnetic coupling to the *in vivo* antigens of the body [62]. Much more sophisticated responses have been observed for detection via nanobiosensors using different ways of their incorporation in sensing mechanisms.

(2) *Environmental Applications*. This is a relatively broader area of application. This is so as environment undergoes so many rapid scale changes almost every second. The detection of pollutants, toxic intermediates, heavy metals from waste streams and the monitoring of weather conditions like the estimation of humidity and many other vital features are really highly detailed and comprehensive tasks. The sensors based on nanomaterials can be very versatile in terms of their detection and monitoring. The use of devices such as cantilever based electronic probes and the provisions which require very little amount of analyte are very good invaders of the technology. The nanomaterials based sensing tools can be used to find the particular kind of damaging extent of a material present or prevailing in the environment. In one such study, a Chinese hamster ovary cell line has been coupled with fluorescent reporter system and used to monitor various toxicants in highly diverse aqueous environments. Carcinogens and harmful intermediates leading to the disruption of proper hormonal systems in the living beings have been isolated through the use of highly sophisticated and specific compounds, particularly named as endocrine-disrupting compounds [63]. Similarly, in one such study, Purohit et al. have used biosensors to monitor the abiotic conditions that are essential for optimization of biological recovery applications like those of bioremediation [64]. In this way, the technique of bioremediation can be scaled up and used to optimize the environmental quality and decontaminate the hazardous contaminants. These applications when engineered with the use of nanomaterials can be far more useful and beneficial. Using the substrate specific detection mechanism, biosensors have been developed for detection of nitrates [65], inorganic phosphates [66, 67], and biological oxygen demand like parameters and have been proved to be environmentally restoring in their working mechanisms. These applications can be integrated and a single sensor can be developed by the use of nanomaterials which can sense the different contaminants equally well in only a single operation. In this manner, there are endless environmental parameters for the evaluation of which the nanobiosensors can be used and developed. These applications are highly energy saving, economical and time saving in nature.

(3) *Miscellaneous Applications*. Nanobiosensors can also be employed to optimize several other detections. In the industrial operations, feeding of nutrient media and substrate mixtures into the bioreactors for diverse applications can be regulated using these sensors. On an industrial scale, many commercial preparations and separations can be enhanced with these sensors. For instance, in the metallurgical operations requiring separation of impurities existing in a complexed form combined in the form of ores, nanobiosensors can be used to separate the impurities selectively by trying out different configurations of the sensing enzymes. Developing microbiological and biochemical assays coupled with bioengineering based innovations are really very handy applications of these sensing materials.

Electrochemical sensors

An electrochemical sensor is a device that quantitatively detects a particular chemical species as an oxidation or reduction current [3,25,26]. An electrochemical sensor has advantages such as simple measurement procedure, short response time, and sufficient sensitivity and selectivity. Although chemical sensor systems, utilizing chemical reactions to convert target species to detectable ones (e.g., by UV-vis spectroscopy), have attained quite high sensitivity, they are not feasible to *in situ* measurements because of indirect detection of target species. On the other hand, an electrochemical sensor system can easily monitor changes in concentration with time. In order to establish high performance electrochemical sensors, modifications to electrode surface should be carried out. For example, modification by electrocatalytic materials has been proposed to attain high sensitivity [27]. In order to attain high selectivity, an electrode surface is coated with films as well as modified with enzyme or mediator, which show specific affinity to target chemicals [27]. Carbon is the preferred electrode material for such modifications because it has reactive functional groups on the surface available for chemical modification. Clearly, preparation and pretreatment history of carbon electrodes strongly affect the performance as a sensor, such as electron transfer kinetics, background current, reproducibility, and adsorption properties. Among various carbon materials, carbon fibers (CF) or activated carbon fibers (ACF) are used extensively as microelectrodes which can be used in very small spaces and to establish chemical events occurring inside single biological cells, such as neurotransmitter in living brain tissue



Electrochemical sensors are widely used for the detection of toxic gases at the parts per million (ppm) level and for oxygen in levels of percent of volume (% vol). Toxic gas sensors are available for a wide range of gases, including carbon monoxide, hydrogen sulfide, sulfur dioxide, nitrogen dioxide, chlorine, and many others.

Although the sensors are designed to be specific to each gas, there are often some cross-interferences with other gases present. Overall, electrochemical sensors offer very good performance for the routine monitoring of toxic gases and percent of volume oxygen present in both portable and fixed gas monitors.

Electrochemical sensor systems ensure fast, precise, selective, sensitive, and easy-to-use analytical tools for the analysis of environmental samples. These sensor systems are effective and ideal for the detection and monitoring of pollutants in environmental samples since they need a very small amount/volume of the sample for the electrochemical analysis. In addition, pretreatment procedures are not needed. Future directions for the design and development of novel electrochemical sensor systems can be summarized as:

- validation of the developed electrochemical sensor systems for the detection of target environmental pollutants by using approved international standard protocols;
- rational design of electrodes involving bioengineering and nanotechnology that provides to increase in selectivity and sensitivity toward the target compound/s;
- design and preparation of new sensors platforms for the simultaneous analysis of multicomponents in complex environmental samples;
- miniaturization of the electrochemical sensor systems;
- implementation of automated electrochemical sensor systems with remote control for the continuous detection of environmental pollutants; and
- fabrication and commercialization of the electrochemical sensor systems.

Smart Dust-Sensors of the future

https://www.theneweconomy.com/technology/microscopic-smart-dust-sensors-are-set-to-revolutionise-a-range-of-sectors

Applications

https://www.allerin.com/blog/3-industrial-applications-of-smart-dust

Arc Discharge Method

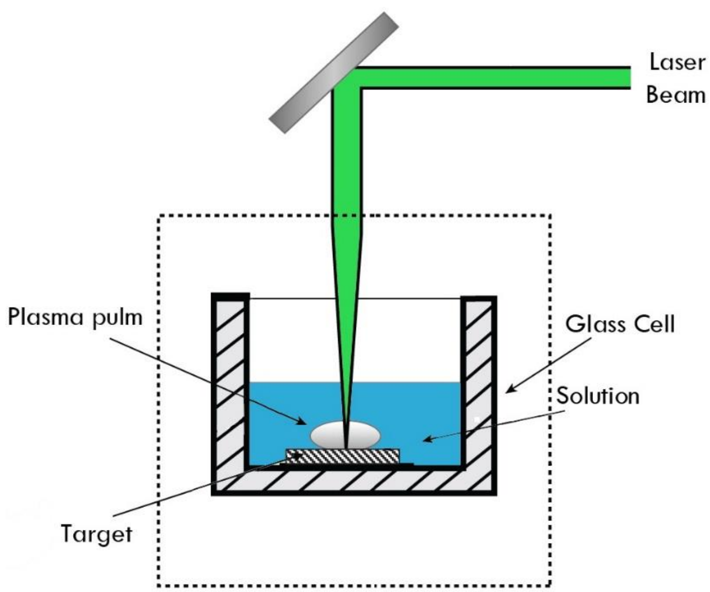
https://www.sciencedirect.com/topics/engineering/arc-discharge

Laser Abiation

Laser ablation or **photoablation** is the process of removing material from a solid (or occasionally liquid) surface by irradiating it with a laser beam. At low laser flux, the material is heated by the absorbed laser energy and evaporates or sublimates. At high laser flux, the material is typically converted to a plasma. Usually, laser ablation refers to removing material with a pulsed laser, but it is possible to ablate material with a continuous wave laser beam if the laser intensity is high enough. Excimer lasers of deep ultra-violet light are mainly used in photoablation; the wavelength of laser used in photoablation is approximately 200 nm.

The depth over which the laser energy is absorbed, and thus the amount of material removed by a single laser pulse, depends on the material's optical properties and the laser wavelength and pulse length. The total mass ablated from the target per laser pulse is usually referred to as ablation rate. Such features of laser radiation as laser beam scanning velocity and the covering of scanning lines can significantly influence the ablation process.[1]

Laser pulses can vary over a very wide range of duration (milliseconds to femtoseconds) and fluxes, and can be precisely controlled. This makes laser ablation very valuable for both research and industrial applications.

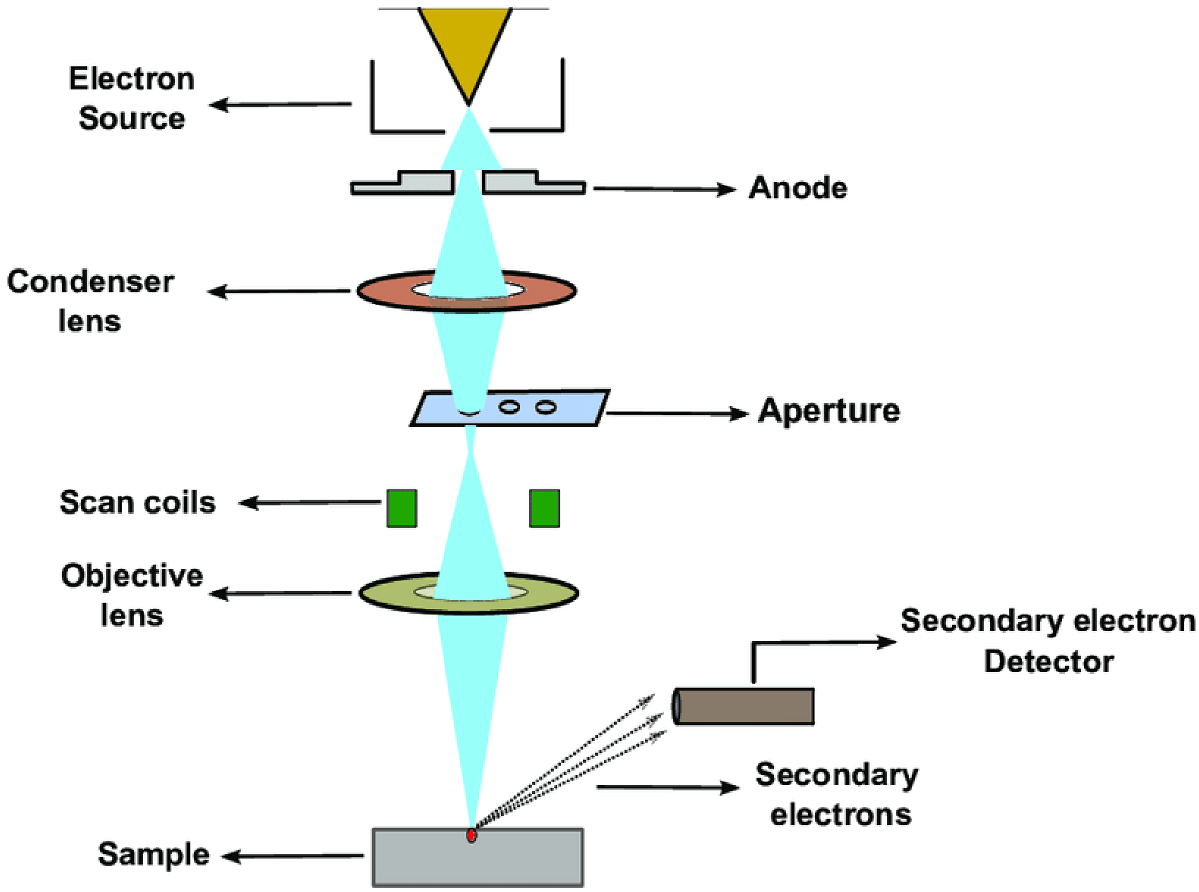


Ion Implantation

https://www.twi-global.com/technical-knowledge/faqs/faq-what-is-ion-implantation

SEM

https://serc.carleton.edu/research_education/geochemsheets/techniques/SEM.html



Quantumn Size Effect

The so-called quantum size effect describes the physics of electron properties in solids with great reductions in particle size. This effect does not come into play by going from macro to micro dimensions. However, it becomes dominant when the nanometer size range is reached. Quantum effects can begin to dominate the behavior of matter at the nanoscale - particularly at the lower end (single digit and low tens of nanometers) - affecting the optical, electrical and magnetic behavior of materials. Materials can be produced that are nanoscale in one dimension (for example, very thin surface coatings), in two dimensions (for example, nanowires and nanotubes) or in all three dimensions (for example, nanoparticles and quantum dots).

The causes of these drastic changes stem from the weird world of quantum physics. The bulk properties of any material are merely the average of all the quantum forces affecting all the atoms that make up the material. As you make things smaller and smaller, you eventually reach a point where the averaging no longer works and you have to deal with the specific behavior of individual atoms or molecules - behavior that can be very different to when these atoms are aggregated into a bulk material.

Materials reduced to the nanoscale can suddenly show very different properties compared to what they show on a macroscale. For instance, opaque substances become transparent (copper); inert materials become catalysts (platinum); stable materials turn combustible (aluminum); solids turn into liquids at room temperature (gold); insulators become conductors (silicon).

Surface area

Another important aspect of nanomaterials is surface area. When compared to the same mass of material in bulk form, nanoscale materials have a relatively larger surface area. This can make materials more chemically reactive (in some cases materials that are inert in bulk form are reactive when produced in their nanoscale form), and affect their strength or electrical properties.

https://www.slideshare.net/Mugilannarayanasamy/size-effect-of-nanomaterials-81194250

AFM

https://www.nanoscience.com/techniques/atomic-force-microscopy/

STM

https://www.nanoscience.com/techniques/scanning-tunneling-microscopy/