# Nanomaterials - A Sojourn

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**National Centre for Catalysis Research**
**Department of chemistry**
**Indian Institute of Technology, Madras**

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**Published by B.Viswanathan of the National Centre for Catalysis Research, Department of Chemistry, Indian Institute of Technology, Madras Chennai 600 036**

# PREFACE

The research team of the National Centre for Catalysis Research has been contemplating on a book on '**Nanomaterials**'. This exercise has become a necessity since this subject has taken various manifestations in recent years. The learning and teaching of this subject are expected to take the centre stage in our educational institutions. The team has conceived the contents of this book keeping all these points in view.

As stated, Nanomaterials today have pervaded every sphere of human activity and hence can be presented in various formats. However, sector-wise application of nanomaterials yields a synthesis kind of approach and probably easy to comprehend. Hence this approach is adopted in this presentation.

The team does not claim any originality in the contents of this ebook. The team has strived to present the available material in a cogent, logical and comprehendible form so that the text may be utilized as a source material for a course on '**Nanomaterials**'. It is our hope that this ebook will serve this purpose.

The team will be happy to receive any and all feed back, so that the ebook can be evolved as a useful source material for educational curriculum in our learning institutes.

The team members place on record their grateful thanks to all those who have contributed or will be contributing to the evolution of this ebook. This is a first attempt and hence it requires a proper growth.

At present this ebook is freely accessible to each and every one of us but the contents of this ebook may not be reproduced without prior permission.

It is our hope that this new endeavour will receive your patronage and acceptance. We do hope that the contents of the ebook will be uploaded soon.

**National Centre for Catalysis Research**
**Department of Chemistry**
**Indian Institute of Technology, Madras**
**Chennai**
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Contributors

Ms. S. Chandravathanam
Dr. V. Chidambaram
Miss. M. Helen
Mr.L.Hima Kumar
Mr.P.Indra Neel
Ms.C.M. Janet
Mr. P. S. Kishore
Mr. G. Mahesh
Mr. T. Maiyalagan
Mr. S. Navaladian
Ms. J. Rajeswari
Mr. M.Sankaran
Dr. M. Sathiesh
Mr. Ch.Venkateswara Rao
B.Viswanathan

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**Thanks**

**CHAPTER – II (2)**

# Nanomaterials in Communication sector

## Introduction

Ever since the origin of life, communication in one form or the other was there in the history. Even the minute form of life such as bacterium and fungi are communicating, though the mechanism is different. There was an earlier saying that history cannot be changed. But the technology especially nanotechnology makes the revolutions in the history. There is no present and future, the development was such like a dream come true when one gets up from the sleep. In communication sector always the major factor was the medium. The change was so rapid that no one realized when the pigeon has become electrons. It is really thought provoking that how nanotechnology brings out revolutions in telecommunication as well as computing and networking industries. Forthcoming developments in nanotechnology through which the impossible can be made possible are nanomaterials with novel optical, electrical, and magnetic properties, compact as well as fast non-silicon based chipsets for processors, quantum computing and DNA computing, development of telecom switches which are fast and reliable, micro-electro-mechanical systems and above all the development of imaging and microscopic systems with high resolution. So for these reasons it is not futile to examine the broad range of nanotechnology and the revolutions made by it in the field of telecommunications. Hence a detailed account of the types of communications and the recent development in this field is essential.

## Electronic communication and informatics

Electronic communication can be defined as a communication by means of guided or unguided electromagnetic energy or both. Or it is a general term describing all forms of communication via electronic means such as internet, facsimile, satellite, cable, television, computers, networks, etc. A coherent technology will be required to continue the performance improvements in communication and informatics. Nanotechnology interphased with biological, physical and chemical sciences can bring much faster and powerful information handling equipments. The sudden leap to the nano regime will result in single-molecule and single-electron based transistors. And special devices can be made out of these kinds of transistors. Informatics is primarily concerned with the structure, creation, management, storage, retrieval, dissemination and the transfer of information. Informatics mainly has a processor which translates one programme to another which can be accessed and used. Hence it is the backbone of the communication sector. Each processor will contain definite number of transistors with specific functions associated with it. The first micro processor only had 22 hundred transistors. Now we are looking for the processors with a billion transistors so that the flexibility of designing devices will be enormous. The present communication systems are based fully on the silicon technology. In 1965, Intel co-founder Gordon Moore saw the future and he predicted that the number of transistors on a chip doubles about every two years. His prediction is popularly known as Moore's law. Moore's Law is coming to an end now, since microelectronics has so far not only sustained this pace but it has crossed the limit of the prediction. Recently Intel has introduced 65 nm generation logic technology which helps in improving performance and reducing power. They introduced sleep transistors which conserve power by allowing transistors to sleep when not in use, similar to the human brain. Intel strained silicon enables faster transistors by physically stretching the lattice structure of silicon atoms, allowing electrons to flow faster with less resistance. As can be seen, the silicon technology is entering into a near molecular regime as the current size has gone down to 25 nm. This scenario can even slowdown or even curtail the progress of silicon microelectronics where not only the manufacturing technology but also the fundamental science changes. Intel developed a new, ultra-fast, yet very low power 85 nm prototype transistor using indium antimonide (InSb) that could form the basis of microprocessors and other logic products beginning in the second half of the next decade. The prototype transistor is much faster and consumes less power than previously announced transistors. If it is possible to manipulate light at small scales, photonic technologies will takeover silicon technology. Smart molecules can be integrated into devices for specific applications such as protein based transistors. Novel nano electronic properties of carbon nano tubes are also found suitable for developing an alternate technology.

**Quantum Information processing**

As devices become smaller the principles of quantum mechanics become more and more imperative. Many new theoretical ideas have come into view and fundamental quantum physics researches have progressed in leaps and bounds over the last few years. Consequently, features of genuine Quantum Information Processing could soon begin to be feasible commercially. Quantum Information Processing (QIP) is a major area for research materials such as Gallium Nitride (GaN) or diamond-like-Carbon which can be potentially renovated into efficient devices. Quantum computing which was suggested in 1970s completely relies on quantum physics, which permits the atoms and nuclei to work together as quantum bits or qubits and to be the computers processor and memory. Qubits can execute calculations exponentially faster than conventional computers. One important aspect of the communication sector is the security of information exchange. As the life is going to be networked in all sectors it is crucial to give more emphasis on the confidentiality of the official as well as personal mails. Quantum computing provides us unlimited processing power and secure communications. Those days have come to reality, when we can decode the encrypted conversations by terrorists or others. The compactness and the rapidness were the main achievements that the new developments in this era have brought out. The miniaturization as well as fast and rapid satellite communications, wireless LAN systems, cellular phones etc. are possible only because of the smart nano materials. Now the science and technology has developed to such an extent that a group of scientists were able to flip the electron and they noticed a current change associated with it. They have tried to flip a single electron upside down in an ordinary commercial transistor chip. That was the beginning of the quantum computers where a single electron spin represents a quantum bit, the fundamental building block of a quantum computer. It was amazing that the conventional silicon technology was sufficient and powerful enough to accommodate the future electronic requirements like quantum computing, which will depend on spin. Another recent approach of Jiang and Xiao was that to shine microwave radio frequency to flip the spin of electron. The experiments last but a fraction of second, but required years of work to reach this point.

With 100 transistors, each containing one of these electrons, we could have the implicit information storage that corresponds to all of the hard disks made in the world this year, multiplied by the number of years the universe has been around. As we have discussed quantum computation makes use of atoms as a basis for computation. Unlike classical logical devices, which only exist in two states (0 or 1), atoms can have three states (0 or 1 or 01 where the latter is a superposition of the first two states). Recently developed DNA computing provides an example of long term information storage. It is very compact and replicable; however it is not very fast. So its use as a model for information processing seems to be limited. Even in biological systems short term information storage is an energy consuming process. One example is the brain activity. This information storage timescales are very low when compared with microelectronics. Quantum structure electronic devices (QSDs) can confine electrons into regions of less than 20 nm, enhancing their performance. A principal aim of nanotechnology is to produce three-dimensionally confined quantum structure electronic devices such as quantum wire and quantum dot devices. Some successful devices in this direction are quantum well lasers for telecommunications; High Electron Mobility Transistors (HEMTs) for low noise, high gain microwave applications; and Vertical Cavity Surface Emitting Lasers (VCSELs), for data communications, sensors, encoding and so on. Other application gadgets based on quantum dots, are on the verge of commercialisation.

**Optical communication**

The science and technology of communication at a distance by electronic transmission of impulses, as by telegraph, cable, telephone, radio, or television is known as telecommunication. Optical communication is any form of telecommunication that uses light as the transmission medium. An optical communication system consists of a transmitter, which encodes a message into an optical signal, a channel, which carries the signal to its destination, and a receiver, which reproduces the message from the received optical signal. Optical fiber is the most universal type of channel for optical communications; still other types of optical waveguides are used within communications kit, and have even formed the channel of very short distance (e.g. chip-to-chip) ties in laboratory testing. The transmitters in optical fiber linkages are commonly light-emitting diodes (LEDs) or laser diodes. Infrared light, rather than visible light is utilized more frequently, because optical fibers transmit infrared wavelengths with less attenuation and dispersion. LEDs are mainly restricted to low data rates, up to about 100 Megabits per second (Mb/s). Lasers are exploited for higher data rates. These devices are often directly transformed which means that the light output is controlled by a current applied directly to the device. A group of theoretical physicists at the University of Arkansas has showed that under applied voltages, thin films composed of ferroelectric materials form "nanobubbles". They have the potential to store lots of information in a tiny space. This could force technologies from computers and portable electronics such as cell phones and MP3 players, to radio frequency identification devices. Novel optical properties can be created by mixing of nano particles of lead selenide (PbSe) and iron oxide (FeO).

**In vivo communication - Nano acoustic messaging and DNA analysis**

Communication inside the body is happening in two ways.

1) Natural triggering - such as reflex action, antibody generation etc. where the neurons are the carriers for the information transfer.

2) Induced triggering – such as targeted drug delivery and isotropic activation analysis where the nano materials are having very significant role, where as in first case bio macro molecules are playing the significant role. In isotropic activation analysis a particular isotopic substitution will be responsible for the communication. The medium of communication will be always an aqueous system inside the body. Hence not only the size but shape also matters. Nano devices to be used in vivo should be designed in such a way that there will be minimum amount of friction.

Even though nanotechnology is in its infancy, scientists & technologists will make use of it in all phases of life like never before. In future, they hope to mould quantum dots to track specific chemical reactions inside nuclei, such as how proteins assist repair DNA after irradiation. They have already visualized the ‘dots’ journey from the area surrounding the nucleus to inside the nucleus, an achievement that opens the door for real-time scrutiny of nuclear trafficking mechanisms. They also anticipate targeting other cellular organelles as well the nucleus, such as mitochondria and golgi bodies. Since, quantum dots emit different colours of light based on their size; they can be used to observe the transfer of material between cells.

**Communication in bacteria:**

Cell –cell signalling of bacteria consequences from the production of signalling molecules by emitter cells followed by its accumulation in the surrounding environment. When a particular threshold concentration is reached, the signalling molecules will bind to the receptors in the bacterial cell, which lead to the changes in gene expression in the responding cell. For intraspecies quorum sensing, the emitter and responder are usually the same type of cells. Often, but not always, the genes that are involved in synthesis and response activate their own expression thus acting as an auto inducer. A signalling molecule is considered to act at low concentrations and not to be involved in primary metabolism.

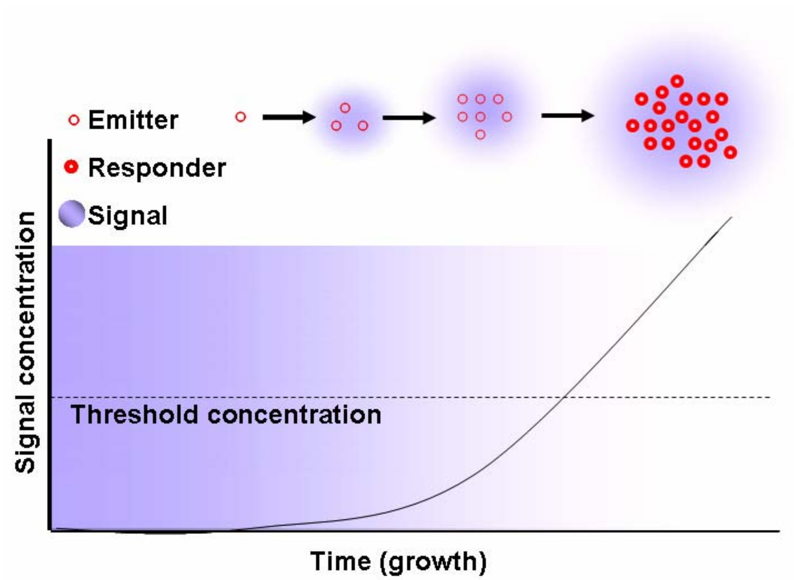



**Fig. 1.** Cell – cell signaling in bacteria above threshold concentration

**Satellite communication**

A satellite is a radio relay station in orbit above the earth that receives, amplifies and redirects analog and digital signals contained within a carrier frequency. They are of three types. Geostationary (GEO) satellites are in orbit 22282 miles above the earth and rotate with the earth, thus appearing stationary. The downlink from GEOs to earth can be localized into small regions or cover up as much as a third of the earth's surface.

Low-earth orbit (LEO) satellites reside 1000 miles above the earth and revolve around the globe every couple of hours. They are in view for a few minutes, and multiple LEOs are required to keep continuous coverage. Medium-earth orbit (MEO) satellites are in the middle, taking about six hours to orbit the earth and can be viewed for a couple of hours. The first communications satellite was launched in 1960 and it was an instrumented inflatable sphere which just reflected radio signals back to the earth.

Semiconductor quantum dots, which cover almost completely the entire spectral region from the ultraviolet to the far infrared, with a small number of substrate materials are suitable candidates in satellite communications. Further advantages of quantum dot lasers are small energy consumption through low threshold current densities, a high modulation range for high-speed applications as well as improved temperature stability. For example InGaAs Quantum dot lasers are already commercialised in communication satellites.

Ken Teo and his team at the University of Cambridge have come up with a much more efficient and compact way to send signals from satellites. They have managed to use an array of carbon nanotubes to create a device that replaces conventional heavy, bulky, high temperature, microwave amplifiers. The new electron source promises to revolutionize telecommunications and satellite communications in space.

Communication, especially to remote areas, is made possible with the use of satellite-based transmitters. There are typically 50 microwave amplifiers on board a satellite, each weighing about 1kg and measuring about 30 cm in length. Currently it costs about 10,000 pounds sterling to send a single kilogram of payload (data) into space. There is an advantage, both in terms of cost savings and extra payload that can be carried, if the weight and size of the microwave devices are reduced.

## Communication: Means and devices in nano regime

### I. Nano/Micro Electro Mechanical Systems

Smart matter is another term for micro-electromechanical systems (MEMS), a technology that combines computers with tiny mechanical devices such as sensors, valves, gears, mirrors, and actuators embedded in semiconductor chips. Microelectronic integrated circuits can be thought of as the "brains" of a system and MEMS do this decision-making capability to allow microsystems to sense and control the environment. It will be the foundation technology of the next decade. Basically, a MEMS device contains micro-circuitry on a tiny silicon chip into which some mechanical device such as a mirror or a sensor has been manufactured. Potentially, such chips can be built in large quantities at low cost, making them cost-effective for many uses.

Presently available uses of MEMS are where one can include sensors that can be used for global tracking of the couriers or parcels. In flights the wing can be fabricated with sensors which can sense and react to the air flow by changing the wing surface resistance by creating indefinite number of tiny wing flaps. The optical lighting system can be made so effective so that the light signals over different paths can be switched on at 20 nano second switching speeds. In engines or in factories a sensor driven heating and cooling system is established that dramatically improve energy savings. And similarly building materials can incorporate sensors based on mems which can alter the flexibility properties of a material based on atmospheric stress sensing. MEMS devices are already used in such fields as the automotive industry, where they are incorporated into airbag and vehicle control; medicine, where they are used to control medication dosing and control medical devices such as pacemakers. They are used to make pressure, temperature, chemical and vibration sensors, light reflectors and switches as well as accelerometers for vehicle control. The technology is also used to make ink jet print heads, micro actuators for read/write heads and all-optical switches that reflect light beams to the appropriate output port. MEMS combine many disciplines, including physics, bioinformatics, biochemistry, electrical engineering, optics and electronics. Typical MEMS devices combine sensing, processing or actuating functions to alter the way that the physical world is perceived and controlled. MEMS devices began to materialize as commercial products in the mid-1990s. Sometimes MEMS and nanotechnology are terms that are used interchangeably, because they both deal with microminiaturized objects. However, they are vastly different. MEMS deals with creating devices that are measured in micrometers, whereas nantotechnology deals with manipulating atoms at the nanometer level. MEMS produce environmental observing capabilities, Commensurate with advances in atmospheric models, Mitigate loss of life and property through improved planning / response; improve weather forecasts especially for high impact weather events. MEMS have a unique ability to collect information, process it, determine a course of action, and then act as a trigger by communicating through an electronic interface. These capabilities allow MEMS to provide the "nuts and bolts" of advanced applications known as "smart devices," such as collision avoidance systems and wireless handsets. MEMS devices do not work in isolation; they are embedded systems that make it possible for a component to perform higher level functions, such as controlling the fuel to air mixture in a car's engine.

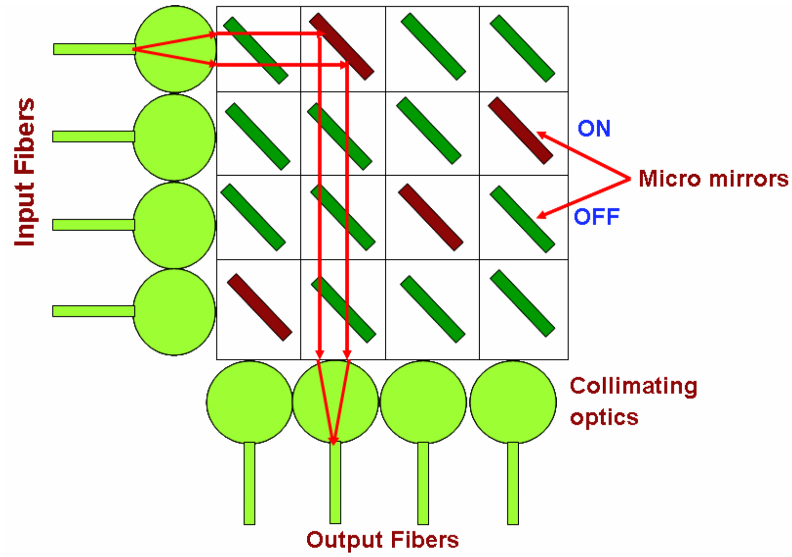



**Fig. 2.** MEMS based optical switch

In an optical switch, MEMS mirrors reflect the input signal to an output port without regard to line speed or protocol. This technology is expected to be the dominant method for building photonic switches which are essential part of the communication devices. In the future, nanotechnology will no doubt enable revolutionary sensors and communication devices although there are as of yet no commercial devices of this type based on true nanotechnology. However, because of the large potential markets, much effort is now being expended to create such devices.

**Accomplishments based on MEMS:**

**1) Weather forecasting**

Using one of the micro-weather stations, we can strip off the radio and can be wired in a laser pointer. This can go to a distant office laptop, where the software decodes flashing lights in the image, and can give the weather information 21 km away.

**2) Large angle MEMS beam-steering**

The laser motes above need to be aimed. A sub-millimeter mirror coupled to two motors on the same silicon chip. The motors can scan a reflected laser beam tens of degrees in either direction.

**3) Silicon maple seeds**

Using a honeycombed layer of silicon only 0.1 mm thick 3x10 mm winglet has been made. With a cubic millimeter of Silicon attached, these wings auto-rotate as they fall, just like a maple seed. The next generation will have solar cells built right in.

**4) Defense-related sensor networks**

**5) Smart dust virtual key board**

Battlefield surveillance, treaty monitoring, transportation monitoring, scud hunting, etc. can be performed and be communicated

**Autonomous sensing and communication in a cubic millimeter**

**Smart Dust**

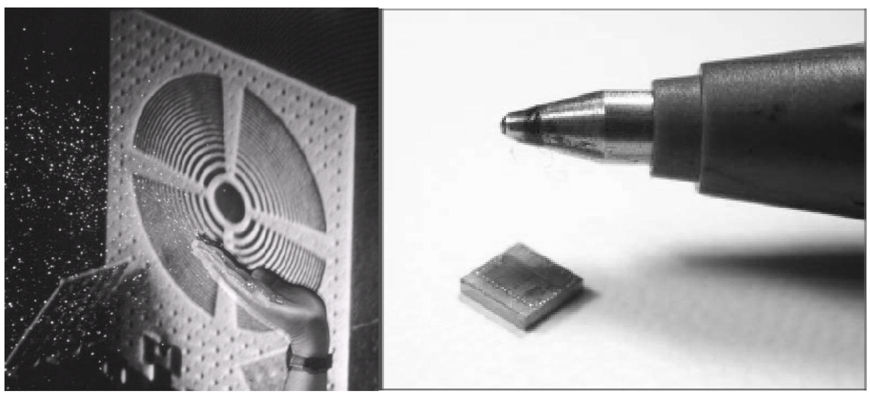


**Fig. 3.** Smart dust –future of communication

It is possible to glue a dust mote on to the fingernails. Accelerometers in the smart dust will sense the orientation and motion of each of the fingertips, and can talk to the computer in real time. Combined with MEMS the display, in entire computer I/O would be invisible to the people around us. Chatting can be done with wireless access and we need never be bored in a meeting again! It is a never ending list of applications such as the product quality monitoring, temperature & humidity monitoring of meat & dairy products, impact, vibration & temperature monitoring of consumer electronics etc. are of in credit to the smart dust. The Center for the Built Environment has fabulous plans for the office of the future in which environmental conditions are tailored to the desires of every individual. Maybe soon we'll all be wearing temperature, humidity, and environmental comfort sensors sewn into our clothes, continuously talking to our workspaces which will deliver conditions tailored to our needs. Social welfare activities like developing interfaces for the handicapped or disabled with the potential benefits of outweighing the risks to personal privacy can be generated. A lot of people seem to be worried about environmental impact. Even in wildest imagination it doesn't appears that we'll be capable of making enough Smart Dust to bother anyone. If Intel stopped producing Pentia and produced only Smart Dust, and we spread them evenly around the country, we would get around one grain-of-sand sized mote per acre per year. If by ill chance we did inhale one, it would be just like inhaling a gnat. We would cough it up. Consider the scale - if we make a million dust motes, they have a total volume of one liter. Throwing a liter worth of batteries into the environment is certainly not going to help it, but in the big picture it probably doesn't make it very high on the list of bad things to do to the planet.

The figure 4 represents how the miniaturization was successful in bringing out a micro mechanical system which is termed as smart dust. It is a cubic millimeter device with a sensor, power supply, analog circuitry, bidirectional optical communication, and a programmable microprocessor.

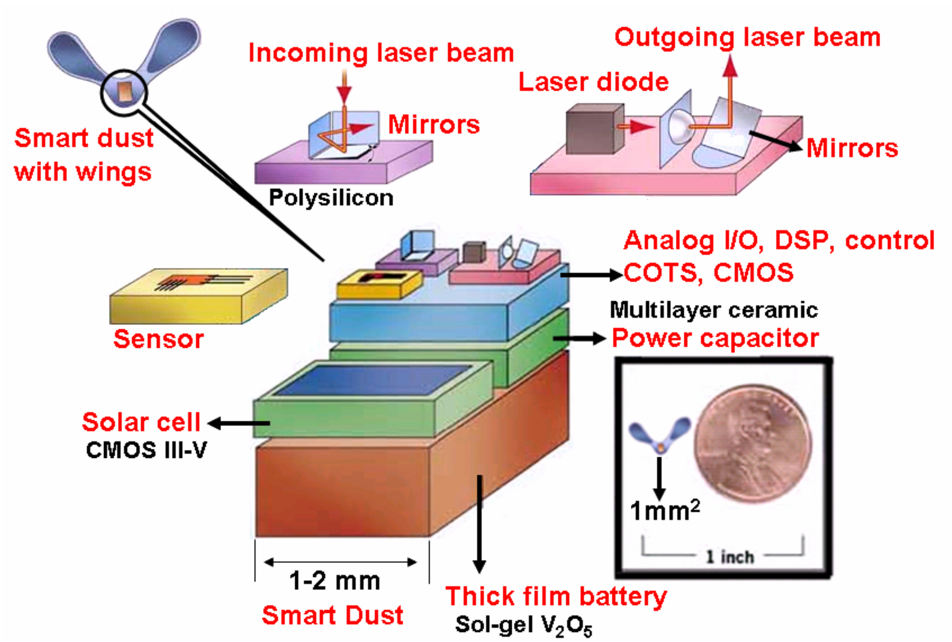



**Fig. 4.** Smart dust -components

A smart dust can act as a distributed autonomous sensor network. Smart dust will facilitate innovative methods for micro fabrication technology and interact with the environment, providing more information from more places less intrusively. Smart dust requires evolutionary and revolutionary advances in miniaturization, integration and energy management. Potential uses include military applications in tracking enemy troop movements from above and detecting chemical warfare agents in the air. Monitoring weather conditions around the globe and detecting fires and earth quakes are among the nonmilitary uses. Stationary motes could be used to monitor the quality of products from factory to consumer.

**MEMS based worldwide Network/Communications Options**

There are three major satellite networks based on MEMS. They are

1. RF-based Satellite Constellation: Probes directly and send discrete data packets to (Low earth orbit) LEO satellite(s) for collection
2. Mobile Ad hoc Network: Data packets hop through mobile network to be distributed at exfiltration nodes.
3. Hybrid: Combination of the two depending upon probe location and conditions

Spreading the energy of the communications signal over a wider range of frequencies can be accomplished in a number of different ways. Two of the methods are frequency hopping spread spectrum (FHSS) and direct sequence spread spectrum (DSSS). Both methods use a related but different approach to spread the signal. Ultra-wideband techniques spread the signal over very large frequency ranges. In each case, the key is to make certain that the transmitter and receiver can lock in quickly and synchronize the spreading and dispreading actions.

**II. High frequency communication devices**

Advanced information and communication networks are constantly evolving to keep up with the popularity of mobile phones, personal computers, and the Internet. High frequency devices are becoming essential for wireless communications with higher speed and higher capacity to provide greater mobility for users.

**a) Monolithic microwave IC (MMIC):**

Micro wave communication is a most popular and widely used means of communication especially in the case of cell phones. The very fact that the microwave also travels with almost the same velocity as that of light, made this momentum possible. Microwave can penetrate earths atmosphere without loss and can travel all the way to mars and even further. Normally used microwave frequency range is around 3-300 GHz. And common source used was silicon transistor of 25 GHz as the source. Much more high frequency and compact sources of GaAs (50 GHz) and InP (180 GHz) are replacing the conventional sources currently. Transistors and passive parts are integrated into the same GaAs substrate provides high functionality and high performance in extremely high frequency (EHF), plus miniaturization by function integration. Demand is increasing for MMIC's in fields of satellite communications, high-speed wireless access, and intelligent transportation systems.

**b) Low Noise HEMT (High Electron Mobility Transistor)**

Used for BS/CS broadcast reception; meets requirements for lower noise characteristics in a higher frequency for interactive digital satellite broadcasting systems. Lead-less structure provides excellent high frequency characteristics and stable performance.

**c) High Power FET (Field Effect Transistor)**

Used for transmission of terrestrial microwave communications and satellite communications, plus communications between base stations for cell phones and wireless Internet access. Their high power, high efficiency, and low noise are ideal for applications in base stations for high-speed and high capacity digital information, an expanding market.

**III. Semiconductor lasers**

Semiconductor lasers are said to be "the laser of the future". The reasons are: they are compact, they have the potential of mass production, they can be easily integrated, their properties are in rapid improvement, they are becoming more and more powerful and efficient and they have found a widespread use as pumps for solid–state lasers. The majority of semiconductor materials are based on a combination of elements in the third group of the periodic table (such as Al, Ga, In) and the fifth group (such as N, P, As, Sb) hence referred to as the III-V compounds. Examples include GaAs, AlGaAs, InGaAs and InGaAsP alloys. The laser emission wavelengths are normally within 630~1600 nm, but recently InGaN semiconductor lasers were found to generate 410 nm blue light at room temperature. The semiconductor lasers that can generate blue-green light use materials which are the combination of elements of the second group (such as Cd and Zn) and the sixth group (S, Se). The principle of semiconductor laser is very different from $CO_2$ and

Nd: YAG lasers. It is based on "Recombination Radiation". We can explain this principle by referring to the Fig. 5.

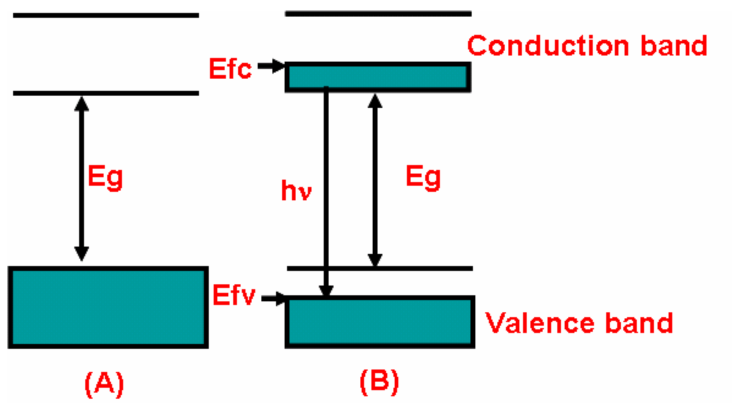



**Fig. 5.** Basic principle of semiconductor lasers

The semiconductor materials have valence band V and conduction band C, the energy level of conduction band is Eg (Eg>0) higher than that of valence band. To make things simple, we start our analysis supposing the temperature to be 0 K. It can be proved that the conclusions we draw under 0 K applies to normal temperatures. Semiconductor photon sources come in two major categories laser diodes and light-emitting diodes. Semiconductor lasers are the most basic of the existing laser types. In their simplest form they consist of a small rectangular slab of semiconductor material with two cleaved facets to act as mirrors. The other facets are destroyed in some way (etched, ground, sawn, ion implanted) in order to avoid spurious laser modes.

**IV. Photonic Crystals and Photonic Integrated Circuits**

Photonic crystals and photonic integrated circuits could pack in individual components a million times more densely than conventional ones. The tighter confinement and novel dispersion properties also open up many new applications, particularly for nonlinear (optical) devices and very low power devices in communication sector. The role of nanotechnology is fundamental to such exploitation, because quantum effects appear on small length and time-scales. Photonic nanocrystals are periodic dielectric or metallic structures having photonic bands in analogy to electronic bands of semiconductors. The presence of photonic band-gaps, where the propagation of photons of certain frequencies is prohibited, and the variety of photon dispersions give rise to novel and unusual optical phenomena. Examples of such photonic nano crystals include InGaAsP/InP 2D photonic crystals, 2D AlGaAs, silicon nitride/silicon-oxide etc.

**V. Light emitting diode materials**

**GaN based lighting**

GaN based lighting has potential to give a huge financial reward all over the world. The penetration of GaN based LED lighting to all lighting applications would imply a major improvement in efficiency and this would reduce the world power consumption by ~1000 TWh pa. with 10 % of world energy worth $100 bn used to produce light, efficiency savings would have a major impact on energy efficiency. Replacement of car headlights, fluorescent tubes, and street lights require the quality of white LEDs to improve - if white LEDs were as efficient as current red ones, all lights would be replaced. Other nano materials in light emitting devices which are used in the communication sector are GaN, GaAlAs, GaAs, InGaAsP, and GaP, AlAs etc. Among nano organic LED’s Poly [2-methoxy-5-(2’-) ethylhexyloxy)-1, 4-Phenylenevinylene] (MEH-PPB) is one example.

Liquid Crystals as well as having applications in displays have potential applications for improving switching speeds in telecoms by replacement of silicon. They also have potential as photonic materials leading to improved optical materials with higher resolution. LCDs continue to develop and underpin many applications – laptops, mobile phones, etc. Constant advances are being made in low power-consumption devices and displays. Further to this, development of non-display applications is becoming increasingly important: e.g. lasing and photonics, telecoms, biology / medicine, control of microwaves. Soap is an example of liquid crystal. Cyanophenyl materials, fluorinated tolans, biological membranes, phospholipids and the protein solution that is extruded by the spider to generate silk is a liquid crystal phase.

**VI. Carbon nanotube emitters**

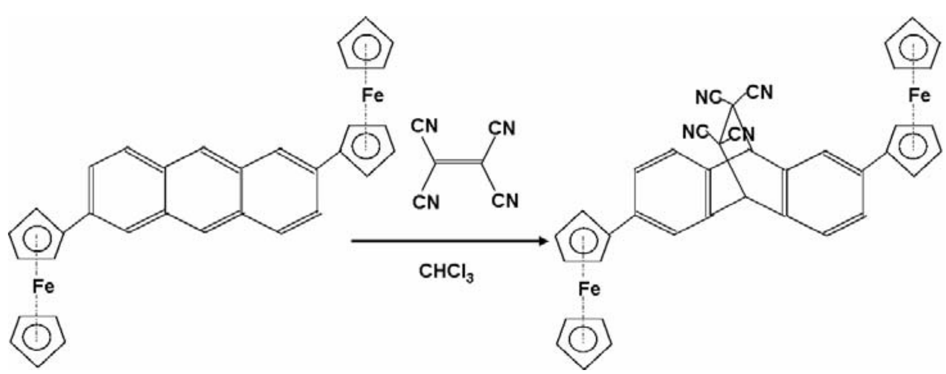
Standard electron emitters are based either on thermionic emission of electrons from heated filaments with low work functions or field emission from sharp tips. The latter generates monochromatic electron beams; however, ultrahigh vacuum and high voltages are required. Further the emission current is typically limited to several micro amperes. Carbon fibers typically 7 μm in diameters have been used as the electron emitters; however they suffer from poor reproducibility and rapid deterioration of the tip. Carbon nano tubes have high aspect ratios and small tip radius of curvature. The ability to emit electrons from the body of nano tubes was attributed to the small radius of the tubes and the presence of defects on the surface of carbon nano tubes.

**VII. Wireless communication**

Most of the communication systems are either based on radio frequency or on microwave. If proven to be effective, nano-materials will eventually replace the current materials used in all these devices. NTT Electronics Corporation has endeavored to commercialize new laser emission sources that are optimum for next-generation communication systems and applications in non-communication fields such as medicine and the environment. Wireless is an old-fashioned term for a radio receiver, referring to its use as a wireless telegraph; now the term is used to describe modern wireless connections such as in cellular networks and wireless broadband Internet. A wireless LAN or WLAN is a wireless local area network that uses radio waves as its carrier. The backbone network usually uses cables, with one or more wireless access points connecting the wireless users to the wired network. Materials in its nano form show peculiar electric and magnetic properties. Hence nanomaterials are incorporated into wireless LAN systems to attain a magnetic resonance of suitable frequency.

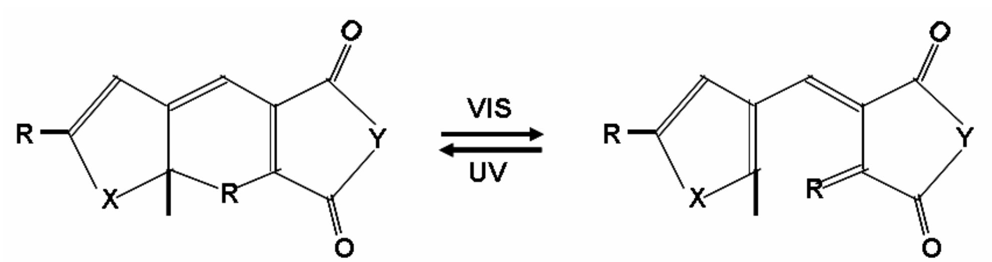
**VIII. Molecular switches for communication sectror**

The principle is to insert in the structure of a mixed valence compound a molecular bridge with two possible states: "ON" (i.e. a non-zero electronic coupling between extremities), and "OFF" (i.e. no coupling). Thus we monitor the photo induced electron transfer process where an electron moves from one end to the other of the molecule.




**Example 1**. 2, 6-diferrocenylanthracene and its Diels-Alder adduct with TCNE

Alternative materials and operating principles for the elaboration and communication of data in electronic circuits and optical networks must be identified. Organic molecules are promising candidates for the realization of future digital processors. Their attractive features are the miniaturized dimensions and the high degree of control on molecular design possible in chemical synthesis. Indeed, nanostructures with engineered properties and specific functions can be assembled relying on the power of organic synthesis. In particular, certain molecules can be designed to switch from one state to another, when addressed with chemical, electrical, or optical stimulations, and to produce a detectable signal in response to these transformations. Binary data can be encoded on the input stimulations and output signals employing logic conventions and assumptions similar to those ruling digital electronics. Thus, binary inputs can be transduced into binary outputs relying on molecular switches. Presently, these simple "molecular processors" are far from any practical application. However, these encouraging results demonstrate already that chemical systems can process binary data with designed logic protocols. Further fundamental studies on the various facets of this emerging area will reveal if and how molecular switches can become the basic components of future logic devices. After all, chemical computers are available already. We all carry one in our head! And the molecules which can act as the molecular switches are fullerene derivatives, biological molecules, DNA base guanine etc.




**Example 2**. Coherent control -Molecular switches

**IX. Lithography**

The process of imprinting patterns on semiconductor materials to be used as integrated circuits is defined as lithography. This new concept in nanolithography is based upon the transport of a chemically reactive material or "ink" from the tip of a conventional silicon nitride Atomic Force Microscope (AFM) to the surface of interest or "paper." Civilization has advanced as people discovered new ways of exploiting various physical resources such as materials, forces and energies. The history of computer technology has involved a sequence of changes from one type of physical realization to another --- from gears to relays to valves to transistors to integrated circuits and so on. Today's advanced lithographic techniques can squeeze fraction of micron wide logic gates and wires onto the surface of silicon chips. However, when one wants to precisely position atoms or molecules on surfaces many problems occur some of which are due to the quantum nature of atoms. Nano materials used for the lithography includes carbon nano tubes, fullerenes etc.

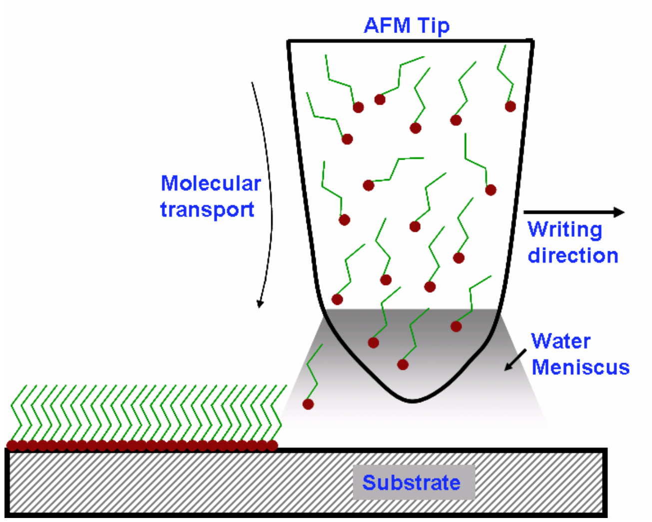



**Fig. 6.** Schematic of the dip pen lithography process – the wiggly lines are molecular "ink."

## Conclusions

Nano technology offers an extremely broad range of potential applications in communication sector. Even though it is not sure which pathway the nano technology can take and bring the fantasies real, it is certain that nanotechnology is penetrating into every aspects of our life and will make the world different from what we know now. As sure as the sun rises each day, information and the technology behind it continue to flow and transform at breakneck speed.

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## CHAPTER – IV (2)

# Gold, Silver and Platinum Nanomaterials

### 1. Introduction

Metal nanomaterials have received considerable attention in the last decade in science and technology. The nature and behavior of the metal nanomaterials are different from that of the bulk material. Metal nano particles find wide application in various fields. Metals are unique in their physical and chemical properties as compared to other compound materials such as metal oxides, sulphides and nitrides. Metals have ductility, malleability, luster, high density, fewer defects and are generally crystalline in nature. Though the metal nanoparticles were synthesized and used from the ancient days even in the era of the Alchemists, lack of enough characterization techniques such as electron microscopes has left the nanoscience unexplored till recently.

In ancient days, the only characterization of metal nanoparticles is naked eye. The colouring nature of Au and Ag nanoparticles was fundamental identification for their nanoparticle colloid formation. Making use of this, they have been used as coloring agents in decorative glasses and clothing. This is due to light-absorbing nature of the surface of Au and Ag nanoparticles because of the surface plasmon resonance.

Pt nanoparticles are catalytically active for oxidation and reduction reactions. As a result, these nanomaterials find applications for catalytic use. Since Au, Ag and Pt nano particles have considerable stability as compared to other metals, they have gained importance. However, in the near future, all metals will be possibly shaped in nanosize by using suitable stabilizing agents and medium. In this chapter nature and applications of the nanomaterial of chosen metals are described. However, closer to each other in the periodic table, the physical properties of the nanosize materials of these metals vary drastically. To begin with, it is essential to comprehend fundamental properties of these (Ag, Au and Pt) metals.

**2. 0. General properties**

The general properties of these chosen metals are given in Table 1.

Table 1. General properties of the Ag, Au and Pt metals

| **Metal** | **Ag** | **Au** | **Pt** |
|---|---|---|---|
| Atomic Number | 47 | 79 | 78 |
| Mass number | 107.86 | 196.97 | 195.08 |
| Electronic configuration | $[Kr]4d^{10}5s^{1}$ | $[Xe]4f^{14}5d^{10}6s^{1}$ | $[Xe]4f^{14}5d^{9}6s^{1}$ |
| Structure | FCC | FCC | FCC |
| Lattice constant (nm) | 0.409 | 0.408 | 0.392 |
| Metallic radius (nm) | 0.16 | 0.1442 | 0.1385 |
| Density $g.cm^{-3}$ | 10.5 | 19.32 | 21.41 |
| Melting temperature °C | 961.8 | 1064 | 1769 |
| Boiling temperature °C | 962 | 2808 | 4170 |
| First Ionization energy kJ/mol | 731 | 890 | 866 |
| Standard reduction potentials | $Ag^{+}/Ag$ +0.799 | $Au^{3+}/Au$ 1.498<br>$Au^{+}/Au$ 1.692 | $Pt^{4+}/Pt$ 1.0<br>$Pt^{2+}/Pt$ 1.18 |
| Conductivity $mohm\text{-}cm^{-1}$ | 630.5 | 446.41 | 94.34 |

Gold and silver belong to Group 11 (IB) of the periodic table of the elements and often being referred to as the "coinage metals," whereas Pt is in the Group 10 and is referred to as "noble metal". The physical appearance of Ag and Pt are white whereas Au is yellow. Gold and platinum are not soluble in mineral acids, but they are soluble in aqua regia (Con. HCl and Con. $HNO_3$ in 3:1 ratios). Ag is soluble in mineral acids, but the reaction is slow. This can be understood from the charge and reduction potentials. $Ag^+$ is very soft acid whereas the $Pt^{4+}$ and $Au^{3+}$ are hard acids. The co ordination complexes are known for Pt and less for gold and silver.

Gold is unique in a number of respects. It is the most electronegative metal, comparable to selenium, and only slightly more electropositive than sulfur and iodine. Its electron affinity is greater than that of oxygen. The $Au^+$ /Au° has a reduction potential value of +1.62 V. As per the reduction potential values shown in Table 1, the order of reducibility will be Au > Pt > Ag. Reducing agents that can reduce $Au^{3+}$ may not reduce Pt or Ag. The inertness towards oxygen also follows the same order. This explains why the preparation of Au nanoparticle is more favorable than that of Pt and Ag. Gold is one of the few metallic elements that can be used in nanoscale devices and systems due to its resistance to oxidation. In addition, gold at the nanoscale has a variety of additional and unexpected properties not observed at the macro scale. For example, its colour changes from the bright yellow of the bulk phase to the reddish-purple of its nanoparticles, its electrical conductivity decreases to the point where it becomes a semiconductor, its strength soars but its melting point falls to not far above room temperature and, also the crystal structure of gold nanoparticles is not even necessarily face centered cubic.

**2.1. Energetic and Electronic Factors**

It is clear that an atom at the surface will exhibit enhanced but anharmonic vibrations due to the absence of a repulsive force from atoms above it. For small particles, where the number of surface atoms is a significant proportion of the total, the unique properties of the surface will influence the behavior of the particle. Surface gold atoms may well be mobile at room temperature, because excitation of the vibrational motion normal to the surface will lead to mobility. Direct observation of a marked effect of size on melting temperature, $T_m$, has been made by observing the disappearance of diffraction rings in transmission electron microscope. Particles between 2 and 25 nm were examined, and the rate of decrease of $T_m$ became greater with decreasing size, the 2-nm particles melting at about 300 ºC. These observations carry  implications for the interpretation of catalysis by small gold particles, which may well consist of a crystalline core covered by a few disordered layers of mobile surface atoms.

Because surface atoms are somewhere between being free and being inside the crystal, depending on their coordination number, their electronic configurations should also have an intermediate character, and for small particles this should affect the electronic character of the particle. Both theory and experiment indicate that the full band structure characteristic of bulk metal, only appears when particles contain more than about 150 atoms. The spacing, between adjacent energy levels in a band is given by the approximate relationship

$$\sigma \approx E_F / n$$

Where, $E_F$ is the energy of the Fermi level and $n$ is the number of atoms in the particle. The spacing therefore increases as size decreases, and when it becomes greater than the thermal energy $kT$, the atoms begin to behave as individuals, and the particle may lose its metallic properties. A spacing of $2.5 \times 10^{-2}$ eV exceeds the thermal energy at room temperature when $n$ is less than 400 (i.e., 2 nm in diameter). It has now been confirmed that with Au/$TiO_2$ prepared by vacuum evaporation of gold onto $TiO_2$ (110)–(1 × 1), a band gap starts to appear at 4 nm diameter and increases in width as the size is further decreased. If catalysis by gold depends critically on metallic character, significant changes should be seen at particle sizes below 4 nm.

Colloidal dispersions of gold have recently been made by metal–vapor synthesis. The atoms so produced were co-condensed with 2-butanone at 77 K, and on warming, a sol was produced which was brown in color when the particles were 1–3 nm in size (like colloidal platinum), and purple–red when they were larger than 5 nm; these showed the plasma absorption at 540 nm, characteristic of metallic gold. The smaller particles, deposited on magnesium oxide, were octahedral or cubo-octahedral in form, whereas larger particles were multiply twinned.

**2.2 Surface area and chemical reactivity**

At the nanoscale, there is an increase in the surface-to-volume ratio of any material. A significant proportion of the atoms in nanoscale structures are actually surface atoms. Therefore, the extent of any phenomenon or chemical reaction that occurs on the surface will be amplified in nanoparticulate or nanoporous materials. The increase in surface area is possible merely by reducing the diameter of spherical particles of gold. It is obvious that rather large values of specific surface area can be achieved, especially in carbon, due in its very low density relative to that of gold. The huge increase in surface area available from nanoscale materials can be exploited catalysts, and specialized filters.

Of course, in many practical situations the carbon materials are used as a nanoporous aggregate, rather than as little spheres. Ordinary activated carbon can exhibit over 1000 $m^2/g$, while the special forms of graphite known as a nanoscrolls can show over 2000 $m^2/g$. Gold, of course, is considerably heavier element than carbon and hence this is a handicap in terms of specific surface area. However, the figures of 2 $m^2/g$ for mesoporous gold cited in some literature  can be boosted to just over 20 $m^2/g$ by careful synthesis, and it is evident that in principle at least, a loose aggregate of gold nanoparticles of, for example, 2 nm diameter could exhibit as much as 150 $m^2/g$. It is believed that the interesting heterogeneous catalytic ability of gold is intimately linked to its surface properties at the nanoscale, although it is not that simple to discover whether this is  an effect of increased specific surface area, or of changed electronic properties, or of an increase in the number of special active sites.

**2. 3.  Electronic configurations**

Bulk gold is a renowned conductor of electricity, with a conductivity value that is beaten only by copper and silver. This property arises directly from its electronic configuration. However, even this familiar ‘fact’ is overturned at the nanoscale. Gold structures at the bottom end of the nanoscale may, depending on shape and substrate, actually be semi-conductor with a significant value of band gap. The transition occurs somewhere between 1 and 3 nm, corresponding to a hemispherical cluster containing between 15 and 150 atoms. The special electronic configuration of small nanoparticles results, from the fact that their physical dimensions are smaller than the characteristic dimension of the electron wave function of the bulk material. Such tiny particles, termed as quantum dots or artificial atoms if they are disc-shaped, have been proposed as the basis of a new generation of nanoscale electronic devices. Recently the electronic properties of gold nanoparticles have been examined on the basis of density functional theory (DFT). They have shown that for $Au_8$ , the energy difference between HOMO and LUMO is highest and the frontier wave function has considerable mixing of s and d character. The catalytic activities of such exceedingly small clusters have been found to be acutely size dependent, peaking in one example at a cluster diameter of close to 3 nm, and falling sharply within 0.5 nm either side . One interpretation of this is that the best catalytic activity is actually derived from a particular value of the band gap, and too great a gap, or none at all, is less favorable. It should be noted that gold is not unique in this respect, and that other noble metals, such as Pd and Pt, exhibit similar properties.

**2. 4. Surface plasmon resonance and colour**

The optical properties of these Au and Ag nanoparticles are interesting. The colour of the metal nanoparticles is mainly based on the surface plasmon resonance.

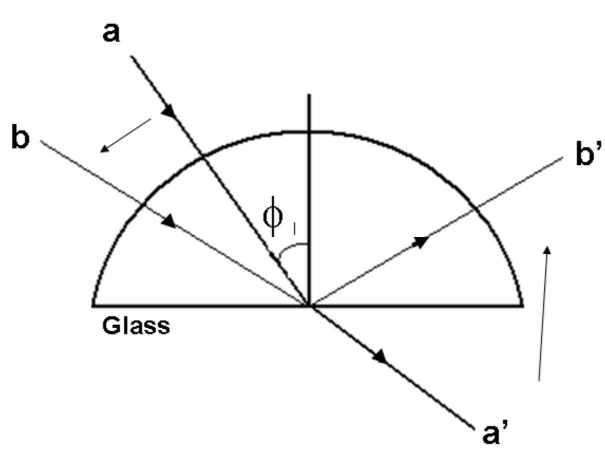


Fig. 2.1. Schematic representation of total internal reflection in the spherical prism (ref.4)

Surface Plasmon Resonance (SPR) is a physical process that can occur when plane-polarized light hits a metal film under total internal reflection conditions. But SPR is confined to Au, Ag, Cu and alkali earth metals. It is accounted with the presence of loosely bound conduction electron present in these elements.

**Total internal reflection**

When a light beam falls on a half circular prism, the light bends towards the plane of interface, when it passes from a denser medium to a less dense one. Changing the incidence angle changes the out coming light until a critical angle is reached. At this point all the incoming light is reflected within the circular prism (angle 'a' moves to angle 'b'). This is called total internal reflection (TIR) and it is represented in Fig.2.1.Although no light is coming out of the prism in TIR, the electrical field of the photons extends about a quarter of a wavelength beyond the reflecting surface. Consider the prism is coated with a thin film of a gold film on the reflection side. At TIR situation, when the energy of the photon electrical field is just suitable, it can interact with the free electron constellations in the gold surface. Photon and electron behavior can only be described when they have both wave and particle properties. In accordance with the quantum theory, plasmons are electron density waves. Therefore, when in a TIR situation the quantum energy of the photons is suitable, the photons are converted to plasmons leaving a 'gap' in the reflected light intensity as shown in Fig. 2.2.

As can be seen from the Fig. 2.2, light ray 'a' at the angle $\theta_1$ has no loss in the intensity of the light, whereas in the case of 'b' there is a decrease in the intensity of the incident

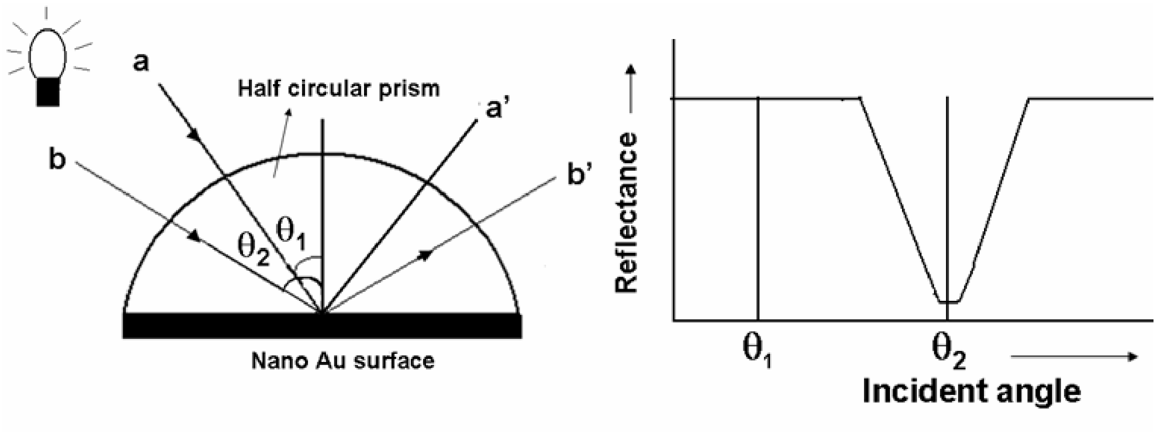


Fig. 2.2. Surface plasmon on Au nanoparticles coated surface showing reduction of reflectance at TIR angle. (ref. 4)

light due to surface plasmon resonance. This shows the importance of TIR of incident light. Like all conversions, the transformation of photon to plasmon is taking place on the nanoparticle surface. This is shown in the Fig. 2.3.

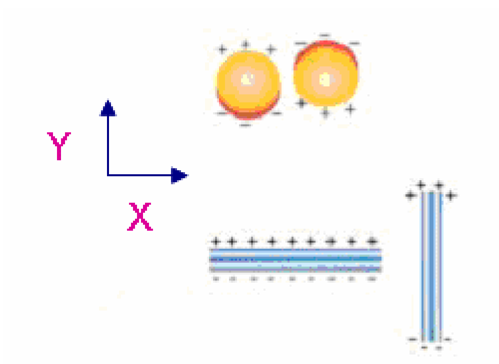


Fig. 2.3 Schematic representation of the interaction of an electromagnetic radiation with a metal nanoparticles. Surface free electrons of metal nanoparticles are dipole induced and they oscillate in phase with the electric field of the incident light in spherical (Top). Transverse and longitudinal oscillation of electrons in a metal nanorod (Bottom). (ref. 6)

This conversion must conserve both momentum and energy in the process. The collective oscillation of conduction electrons resulting from the interaction with electromagnetic radiation.. The electric field of the incoming radiation induces the formation of a dipole in the nanoparticle. A restoring force in the nanoparticle tries to compensate for this, resulting in a unique resonance wavelength. Plasmons have a characteristic momentum defined by factors that include the nature of the conducting film and the properties of the medium on either side of the film. Resonance occurs when the momentum of incoming light is equal to the momentum of the plasmons (momentum resonance). Thus, the energy and the angle of incident light must be right to form surface plasmon resonance. The position of the surface plasmon band in optical spectrum mainly depends upon the (1) nature of the metal, (2). Size of the metal particle (3). Nature of the medium (dielectric constant and refractive index) (4). Nature of the capping agent and (5). Average distance between the neighboring particles. The number of the peaks obtained in the SPR spectrum depends up on the shape of the particle as shown in the Fig.2.3.

**2. 4. 1 SPR dependencies and colour**

The angle at which surface plasmon resonance occurs mainly depends on the nature of the metal, the wavelength of the incident light and the refractive index of the medium on either side of the metal surface. Because the refractive index is sensitive to temperature, it is important to perform the measurements at defined temperatures. In some cases, this dependency can be exploited. The metal must have conduction band electrons capable of resonating with the incoming light at a suitable wavelength. Metals that satisfy this condition are silver, gold, copper, aluminum, sodium and indium. In addition, the metal surface must be free of oxides, sulphides and not react with other molecules on exposure to the atmosphere or liquid. Of the metals, indium is too expensive, sodium is too reactive, copper and aluminum are too broad in their SPR response and silver is too susceptible to oxidation. This leaves gold as the most practical metal. Gold is resistant to oxidation and other atmospheric contaminants, but it is compatible with a lot of chemical modification systems. The light source should be monochromatic and p-polarized (polarized in the plane of the surface) to obtain a sharp dip as shown in Fig. 2.2. All the light, which is not p-polarized, will not contribute to the SPR and will increase the background intensity of the reflected light. In Table 2.2. data on the surface plasmon band and colour characteristics of these metallic nanoparticles are given.

Table 2.2. Surface plasmon and colour characters of Ag, Au ad Pt nanoparticles

| Property | Ag | Au | Pt |
|---|---|---|---|
| Surface plasmon band | 350- 800 nm | 500 – 800 nm | ----- |
| Colour of colloid | Greenish yellow, Red and yellow | Purple, orange Red, violet, blue, | Brown and black. |

Bulk gold has a familiar yellow colour, caused by a reduction in reflectivity for light at the blue end of the spectrum. However, if one sub-divides the gold into smaller and smaller particles, there comes a point at which the particle size becomes smaller than the wavelength of the incident radiation. This effect has been used to colour glass, even in Roman civilization. However, if such tiny particles are allowed to

coalesce in a controlled fashion; their colour can be systematically varied from pink through violet to blue. This is due to a change in their absorption spectrum on aggregation, caused by increasing absorbance of the red wavelength of light. The particles other than the spherical particles will show more than one absorption band in

UV-Visible spectrum. For example, metal nanorods will show SPR bands due to the transverse and longitudinal absorption of light. This shows the anisotropic nature of the particles. That means surface plasmons created in both transverse and longitudinal directions are energetically different. In addition, these structures absorb light in the near infrared rather than in the visible, and are under development for possible medical applications, such as in tumor destruction. Similar unusual optical tuning may be achieved with gold nanorods of varying aspect ratios as shown in Fig. 2.4. Aspect ratio is the ratio between the length and diameter.

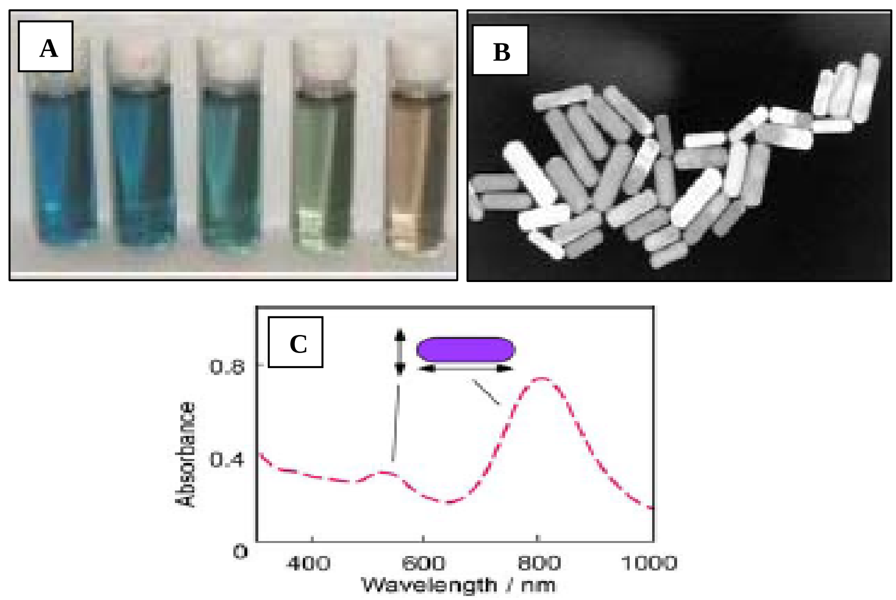


Fig. 2.4 (A). Photograph of colloids of Au nanorods with increasing aspect ratio, (B). TEM picture of Au nanorods and( C). UV-Visible spectrum of Au nano colloid containing nanorods (ref. 8)

Other morphological structures like triangle and disk show the broad SPR band in the region of Far- visible and Near IR region. If the colloid of metal contains monodispersed rods (rods of similar aspect ratio), the aspect ratio of nanorods can be calculated from SPR band positions of longitudinal and transverse absorptions. Anisotropic nature of the particles can be understood by shape of the surface palsmon band as seen in Fig. 2.5.

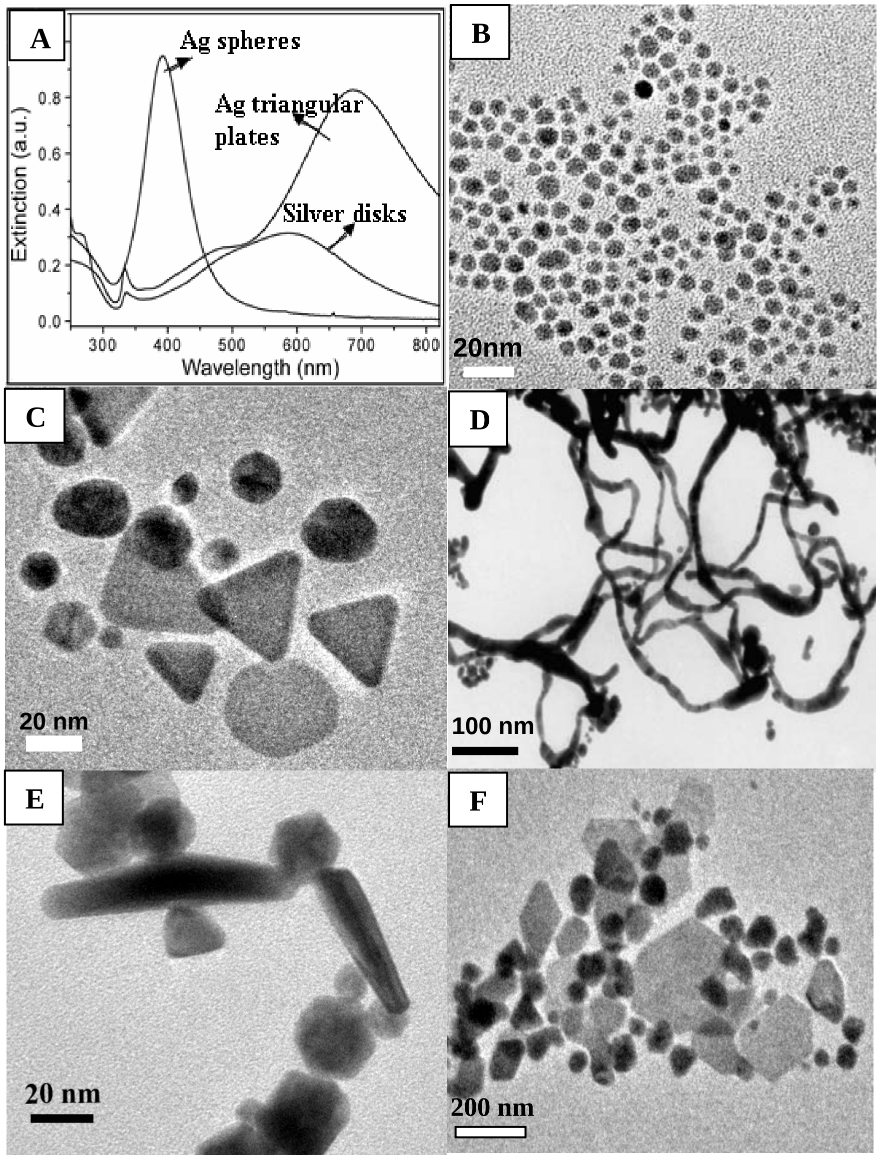


Fig. 2.5. (A) UV-Vis spectrum of spherical nanoparticles, triangular nanoplates and circular nanodisks of silver that were stabilized with PVP and citrate.(ref. 9) (B) TEM image of the spherical silver nanoparticles (C) triangular nanoplates of gold and (D) Gold nanowires (E) nanorods (F) nanodisks. (ref.10)

## 2. 5. Unusual crystal structures

Bulk gold is face centered cubic (fcc) lattice, and the occasional rare crystals of native gold exhibit the highly symmetrical cubic, octahedral or rhombododecahedral crystal forms associated with the fcc structure. This generalization remains true down to particles of size about 10 nm in size (which contain about 28,000 atoms for gold particle) but for even smaller sizes, the situation is complex. There is considerable debate regarding the structure and external form of nanoparticles of between 1 and 10 nm. This debate is centered on decahedra, which have re-entrant facets, are said to offer a compromise between surface area and strain energy. Studies of gold nanoparticles have showed that all the above structures are possible with their presence seemingly dependant on the particular experimental conditions employed for the preparation. However, it has been said that icosahedra and Marks decahedra (see Fig. 2.6) will tend to dominate for particle dispersion in the sub- 5 nm range. The catalytic activity of gold is normally attributed to this size range.

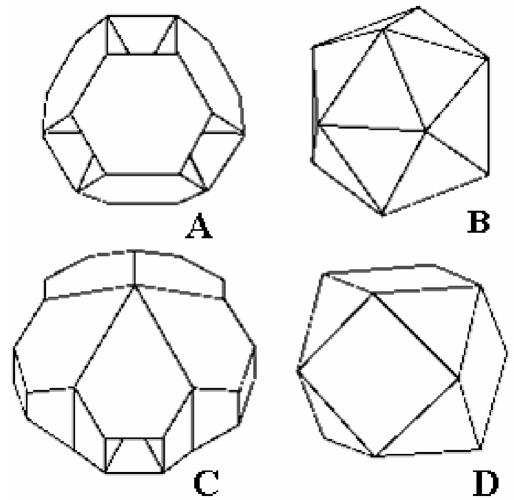


Fig. 2.6. Some shapes of gold nanoparticles, (A) truncated octahedron, (B) icosahedron, (C) Marks decahedron and (D) cuboctahedron (ref. 11 )

To put this in context, a hemisphere of 5 nm diameter would contain about 2,600 gold atoms, whereas one of 3 nm diameter would contain only about 500 atoms. A Krugerrand coin of one troy ounce however contains about 95,090,000,000,000,000,000,000 atoms of gold.

**2. 6. Anomalous melting points**

Bulk gold melts at 1064 °C, however, not even this property is constant as the scale of the structure is shrunk into the nanoscale. The melting point of gold nanoparticles is depressed from that of the bulk material. The reason for this phenomenon is the large increase in surface area of gold nanoparticles. The results of two studies on the melting point for particles of varying sizes are shown in Fig. 2.7

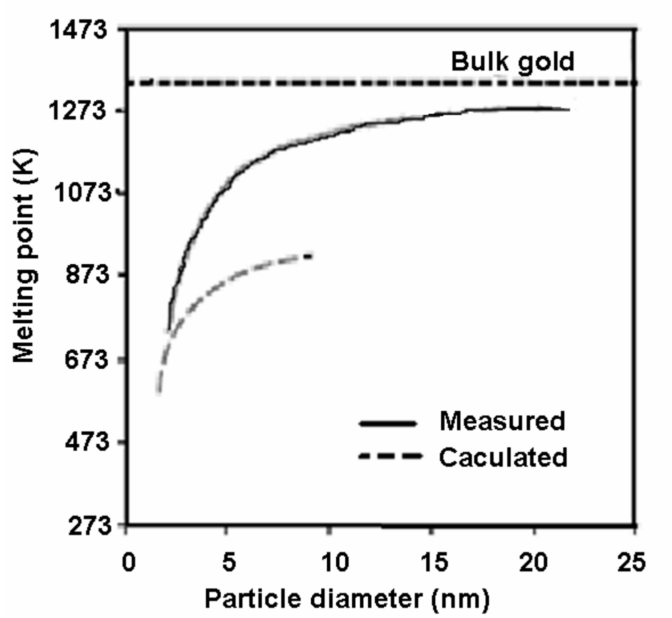


Fig. 2.7. Effect of melting on the particle size (ref. 12)

. There is considerable difference between the calculated and measured values of the melting point as a function of size of the particle. These calculations indicate that catalytically active gold particles in the 5 nm size range, would be molten at about 830°C, particles of about 2 nm would liquefy at 350°C and, by extrapolation, particles of about 1 nm diameter would be molten at 200 °C. The melting point of Au nanoparticles exponentially decreases as the particle size goes below 5nm. This is referred to as "melting point depression". This effect is not peculiar to gold of course, and direct observation of it under a microscope has been made in the case of the element indium, the bulk state of which melts at 152 °C. The melting point of 8 nm diameter nanoparticles of indium has been directly observed to be only 25 °C. The melting point of even smaller particles of this element may lie below 0 °C, a truly strange property.

**2. 7. Enhanced strength and toughness**

The strength and toughness of both ceramics and metals can be enormously enhanced if they are made out of nanoscale crystallites rather than the usual micron-sized grains. This effect is already widely exploited to make superior ceramics and tungsten carbide-cobalt composites. Ceramics made from nanoscale $TiO_2$ particles not only sinter together even at 600°C, but also possess enhanced strength and toughness. There is a similar effect in metal systems. Nanocrystalline copper, for example, is up to five times stronger than ordinary copper. In this case, the explanation relies upon the observation that deformation in metals is generally carried by lattice defects called dislocations, and nanoscale copper crystals are actually too small to even contain dislocations. Aluminum also shows the same effect. A process called as equiangular extrusion is used to refine the grain size of the aluminum into the nanoscale, so that it will be hard and lose the ductility. Similar behavior is exhibited by gold.

**2. 8. Magnetic properties**

Bulk gold and Pt are non-magnetic, but at the nano size they are magnetic. Surface atoms not only are different to bulk atoms, but they can also be modified by interaction with other chemical species, that is, by capping the nanoparticles. This phenomenon opens the possibility to modify the physical properties of the nanoparticles by capping them with appropriate molecules. Actually, it should be possible that non-ferromagnetic bulk materials exhibit ferromagnetic-like behavior when prepared in nano range. One can obtain magnetic nanoparticles of Pd, Pt and the surprising case of Au (that is diamagnetic in bulk) from non-magnetic bulk materials. In the case of Pt and Pd, the ferromagnetism arises from the structural changes associated with size effects. However, gold nanoparticles become ferromagnetic when they are capped with appropriate molecules: the charge localized at the particle surface gives rise to ferromagnetic-like behavior. Surface and the core of Au nanoparticles with 2 nm in diameter show ferromagnetic and paramagnetic character, respectively. The large spin-orbit coupling of these noble metals can yield to a large anisotropy and therefore exhibit high ordering temperatures.

More surprisingly, permanent magnetism was observed up to room temperature for thiol-capped Au nanoparticles. For nanoparticles with sizes below 2 nm the localized carriers are in the 5 d band. Bulk Au has an extremely low density of states and becomes diamagnetic, as is also the case for bare Au nanoparticles. This observation suggested that modification of the d band structure by chemical bonding can induce ferromagnetic-like character in metallic clusters.

## 3. Important applications

The optical property of the Au and Ag nanopartices has received attention for making use of them in optical sensors, colour glasses, photo electrochemical cells. One of the big advantages associated with these metal nanoparticles is surface enhanced Raman scattering (SERS). In general, it is difficult to receive Raman signals for the single molecule. But when the same molecule is present on the nano metallic surface the Raman signal intensity will be of at least 14 orders of magnetite. By utilizing this property, one can enclose DNA like molecules on the surface of the nano metal. Metal nanowires and nanoparticles are used in the nanocircuits. In medicine, Au nanopartciles are utilized for drug delivery and identification of affected cells. Cancer cells can be easily identified using the triangular nanoparticles. Since they possess sharp edges, they easily penetrate the cancer cells; not only that, the cancer cell can be destroyed using the same. The moment triangular particles are bound to cell; they will be killed using the Far- IR radiation. Because the Au nanotriangles will adsorb Far IR radiation due to surface plasmon resonance and therefore heated up. Ag nanoparticles are acting as antimicrobials.

Gold and Platinum nanoparticles act as good catalysts. Gold nanopartcles of size less than 5 nm are found to be active for carbon monoxide oxidation to carbon dioxide even at 273 K. Platinum nanoparticles of size < 5 nm is found to be a better catalyst for both oxidation and reduction reactions. Silver is the best catalyst for olefin epoxidation reaction.

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