International Journal on Future Revolution in Computer Science & Communication Engineering
Volume: 4 Issue: 4
ISSN: 2454-4248
215 – 219

Properties and Applications of Gold Nanoparticles

Jyoti Yadav
Department of Physics, Indira Gandhi University,
Meerpur, Rewari-123401,
Haryana, India

***Abstract*:**--In this paper, properties and applications of gold nanoparticles have been discussed. Gold nanoparticles exhibit outstanding optical properties. These properties show variations with size of gold nanoparticles and their surface features. Gold spheres with dimension greater than 20 nm exhibit purple color. They exhibit red color for 10-20 nm size and appears yellow at 2-5 nm dimension. Gold nanoparticles show single electron tunnelling which describes their excellent conductivity. Gold is non magnetic in bulk size but at nano dimension it shows magnetic behaviour due to change in magnetic coupling. Due to all these outstanding properties, gold nanoparticles have been utilized for various applications like biological tagging, biomedical imaging, catalysis, cancer therapy, food packaging and monitoring, scatterind based imaging, biosensors, sunscreen, drug delivery, DNA labelling etc.

Keywords: *nanotechnology, gold nanoparticles, surface plasmon resonance, biosensors, spectroscopy.*

*****

I. INTRODUCTION

The first discussion about nanotechnology was done by Richard Feynman, a famous physicist, in 1959 in his talk "There's plenty of room at the bottom" [1]. Nanoscience includes materials manipulation at nanometer scale. Materials with bulk dimensions have physical properties like optical, mechanical and electrical, with continuous nature. But the same material at the nanoscale can have different properties as compare to its bulk properties [2]. Nano particles are particles having any of its dimension of nanoscale, have particle radius less than bohr radii and are quantum mechanically confined or have large surface to volume ratio. Nanomaterials have large reactive and exposed surface area [3]. Because of their unique properties, such materials have significant applications in various fields like biomedicine, photochemical and electronics.

Gold is a well known metal which belongs to group 11 of modern periodic table, having atomic number 79. Gold nanoparticles are a suspension of sub micron gold particles dispersed in water. These are also called as colloidal gold [4]. Color of colloidal gold changes from red to brown, yellow and purple according to their particle size. Nanogold has particle size less than 100 nm. These particles exhibits outstanding optical properties. These properties show variations with size of gold nanoparticles and their surface features which are in direct relation with surface to volume ratio. Gold nanoparticles shows single electron tunnelling which describes their excellent conductivity. Gold nanoparticles can be synthesized with size range from 2 nm to 100 nm. Because of this dimension, these are the best choice in manufacturing of electronic devices. Also gold has high reactive surface [5]. Because of all these extraordinary properties, gold nanoparticles are vastly used as a plateform for designing of stable and highly responsive biosensors.

In this paper, properties and applications of gold nanoparticles have been discussed. Gold nanoparticles exhibit outstanding optical properties. Gold nanoparticles show single electron tunnelling which describes their excellent conductivity. Gold is non magnetic in bulk size but at nano dimension it shows magnetic behaviour due to change in magnetic coupling. Due to all these outstanding properties, gold nanoparticles have been utilized for various applications like biological tagging, biomedical imaging, catalysis, cancer therapy, food packaging and monitoring, scatterind based imaging, biosensors etc.

II. PROPERTIES OF NANOPARTICLES

As dimention of nanoparticles lies between bulk materials and atomic scale. Therefore particles at nanoscale have significant applications in various areas. Bulk materials have size independent physical properties. But when a bulk material is manipulated to nanoscale, its properties becomes size dependent [6]. The most significant thing at nanoscale is the percent of atoms at surface of the materials.

Size-dependent properties can be understood by quantum confinement effect. In this effect, motion of holes and electrons is confined in single dimension. Because of this, band gap of nanoparticles increases and wavelength decreases. This reduction in spatial dimention gives rise to changes in physical properties of the nanomaterials in that particular direction [7].

2.1 MAGNETIC PROPERTIES:

At nanoscale, surface to volume ratio of atoms in materials significantly increases. This increase in surface to volume ratio results in different magnetic coupling of atoms with their neighbourhood. Thus change in magnetic coupling of atoms at nanoscale results in different magnetic properties [8]. For example, gold and platinum are non magnetic in bulk size but at nano dimension they show magnetic behaviour.

2.2 OPTICAL PROPERTIES:

The decrease in dimension of bulk material to nanoparticles effects significantly the energies of highest occupied molecular orbital and lowest unoccupied molecular orbital. The transition between these two states leads to optical emission and absorption processes [9]. Therefore on reduction of dimension, optical properties changes signicantly as shown in fig.1. For example, gold spheres with dimension greater than 20 nm exhibit purple color. They exhibit red color for 10-20 nm size and appears yellow at 2-5 nm dimension [10].

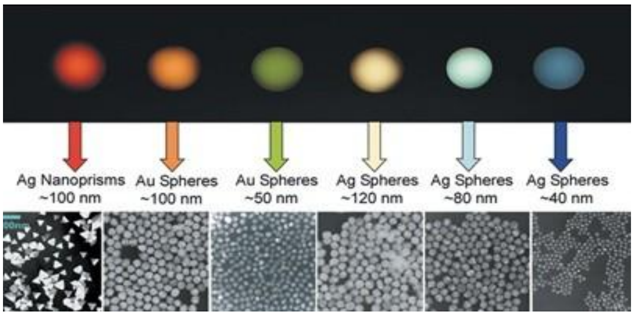

Fig.1: Variation in color of nanoparticles with their dimension

2.3 ELECTRONIC PROPERTIES:

On reduction in dimension of a system to nanoscale, electronic properties of that system changes significantly because of quantum mechanical effects. The energy states shows discretness when dimension of system is comparable with de Broglie wavelength. Therefore certain conducting bulk materials shows insulator behaviour at nanoscale [11]. As electrons exhibits wave like characteristics, therefore there arises possibility of quantum mechanical tunnelling between adjacent nanostructures. This tunnelling current increases abruptly on application of voltage between these two nanostructures. Such conduction processes which involves single electron are known as Coulomb Blockade Effects arising at nanoscale [12].

III. PROPERTIES OF GOLD NANOPARTICLES

Gold is a naturally occurring compound. Naturally occouring gold is bulk material. It has been found that gold nanoparticles have outstanding properties that can be utilized in various fields like medical sciences, biosensors, chemical science etc [13]. Therefore gold nanoparticles have been synthesized in different shapes as shown in fig.2.

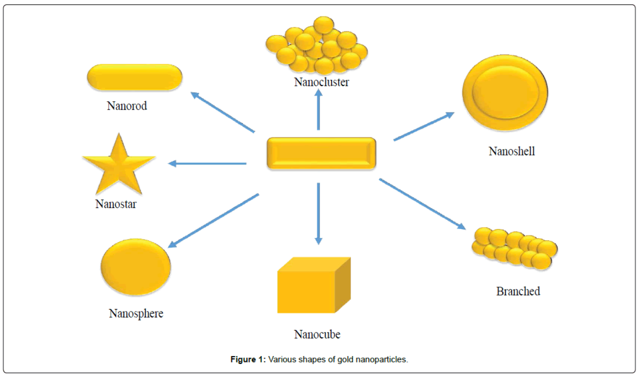

Fig.2: Various shapes of gold nanoparticles

3.1 Catalytic Property

Bulk gold metal shows inert behaviour but it has been found that gold nanoparticles are highly reactive and can be used as catalyst. It has been found that gold nanoparticles with size less than 5 nm shows catalytic property. Also these nanoparticles shows catalytic behaviour at significantly lower reaction temperature as compare to others [14].

3.2 Surface Plasmon Resonance (SPR)

To study the optical properties of nanoparticles, SPR plays an important role. It is an optical phenomena arising by the interaction of the incident electromagnetic radiation and surface plasmons. There are various factors on which Plasmon sensitivity depends like shape and size of particle, refractive index of medium etc. For the bright red color of gold nanoparticles, SPR is responsible. Gold nanoparticles shows their characteristic SPR peak in between 525 nm and 530 nm which shifts towards higher or lower wavelength depending on the particle shape and size of gold. Also SPR plays a significant role in the interaction of biomolecules and gold nanoparticles [15].

3.3 Light-scattering imaging

Scattering of gold nanoparticles is improved significantly by excitation of surface plasmon resonance. The intensity and frequency of surface plasmon resonance scattering depends on properties of nanoparticles like size, shape, composition and environment of nanoparticles [16]. Scattering of nanoparticles having diameter size 30-100 nm is highly intense that can be detected by a commercial microscope. In fact, scattering of gold nanoparticles with diameter size 40 nm can be easily detected by human eyes. The high scattering cross sections of gold nanoparticles make them oseful for imaging based medical applications. This property of gold nanoparticles has been videly used for cancer imaging [17].

IV. APPLICATIONS OF GOLD NANOPARTICLES

Nanotechnologies provide number of application in the fields of energy development and in medicine or biology sector etc through optimized materials and components [18]. Gold nanoparticles have exclusive optical, electric and magnetic properties depending on their different shapes and sizes. These unique properties of gold nanoparticles have been attracted researchers of various fields like biological tagging, biomedical imaging, catalysis, cancer therapy, food pachaging and monitoring, scatterind based imaging, biosensors, sunscren etc [19].

4.1 BIOSENSORS

A sensor can be defined as a device having capability to recognize a particular species and provides signals regarding activity or concentration of that species. When the sensing is based on bio molecular recognition, it is called a biosensor [20]. There are variety of nanoparticles that can be used as biosensor components like quantum dots, silica nanoparticles, metallic nanoparticles etc. In biosensing applications, some biological molecular species are attached to the surface of the nanoparticles for recognition of interested target. The change in physical property like color or mass of the base nanoparticles signals the presence of target. On the principal of change in colour, sensors based on gold nanoparticles can detect various metal ions [21]. These have baan used for the detection of mercury, lead and copper in water. Also gold nanoparticles based biosensors plays a significant role in monitoring of therapies and cure of diseases [22].

4.2 NANOBARCODES:

Color of specific nanoparticles depends on their particle size. Nanoparticles with different sizes reflects different colors [23]. This unique property of nanoparticles can be used to creat color based codes which play a significant role in the field of medical sciences as shown in fig.3. Such nanobarcodes has been utilized to detect protein in human body. Small levels of cancer has been detected by using nanobarcodes [24]. Nanobarcodes can be utilized for various purposes like pathogen detection, bacterial systems monitoring, detection of water levels, soil nutrients information etc [25].

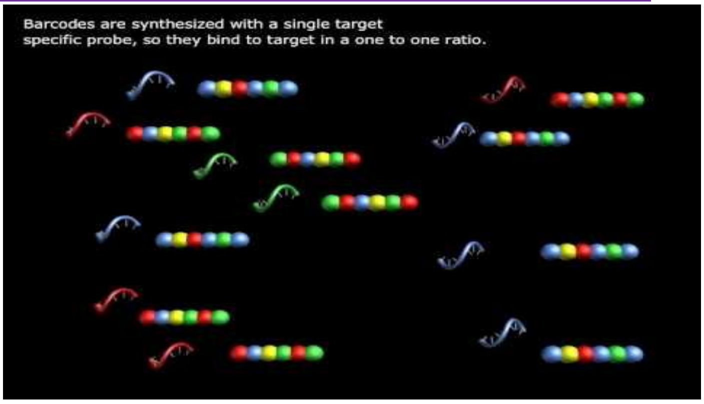

Fig.3: Nanobarcodes showing their one to one targeting concept

4.3 SOLAR CELLS:

Semiconducting compounds have nanoscale clusters known as quantumdots which has been utilized as quantumdot solar cells on behalf of their extraordinary optoelectronic properties. In quantumdots, one photon can produce several electron hole pairs which contributes in electricity generation as shown in fig.4. This property plays a significant role in quantumdots solar cells. Such cells with conversion efficiency of about 60% are feasible now a days [26].

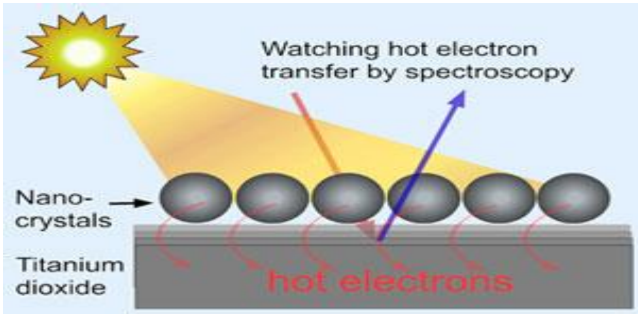

Fig.4: Quantumdot solar cell using Titanium dioxide compound

4.4 FOOD PACKAGING AND MONITORING:

On food packaging and monitoring, nanotechnology have incredible impact. Latest technology includes embeddness of nanoparticles inside the plastic used for packaging to sense the food spoiling factors like bacteria [27]. Also nanosensors have capability of detecting ultra small amount of material. Nanomaterials can detect chemical species like oxygen and responds very fast.These particles can also detect chemicals that are responsible for food spoilage like bacteria or ethanol [28]. Therefore nanotechnology plays a significant role in food packaging and monitoring as shown in fig.5.

 ISSN: 2454-4248
215 – 219

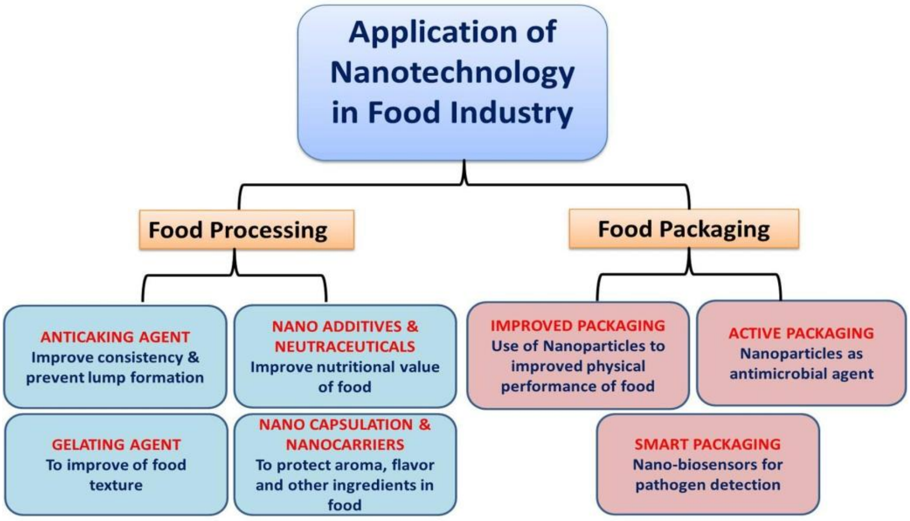

Fig.5: Application of nanotechnology in food industry

4.5 SUNSCREEN:

Sunscreen includes either titanium dioxide or zinc oxide nanoparticles. In early days, particles in sunscreen have larger size so the cream appears white. Now a days, sunscreen creams were colorless. UVB rays affects only the upper layer of skin but it causes many diseases like cancer, DNA damage etc. UVA rays have less intensity as compare to UVB but they are also very harmful to our skin [29]. Sunscreen protects us from such harmful radiations as shown in fig.6. Nanosized zinc oxide particles blockes UV light. Their size is comparable to wavelength of visible light so they do not scatter and appears white. Titanium dioxide also protects from UV radiations [30].

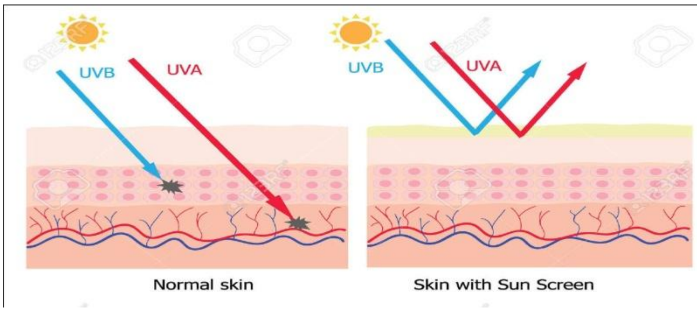

Fig.6: Protection of skin by sunscreen cream

CONCLUSIONS

In this paper, properties and applications of gold nanoparticles have been discussed. Gold nanoparticles exhibit outstanding optical properties. These properties show variations with size of gold nanoparticles and their surface features. Gold spheres with dimension greater than 20 nm exhibit purple color. They exhibit red color for 10-20 nm size and appears yellow at 2-5 nm dimension. Gold nanoparticles show single electron tunnelling which describes their excellent conductivity. Gold is non magnetic in bulk size but at nano dimension it shows magnetic behaviour due to change in magnetic coupling. Due to all these outstanding properties, gold nanoparticles have been utilized for various applications like biological tagging, biomedical imaging, catalysis, cancer therapy, food packaging and monitoring, scatterind based imaging, biosensors, sunscreen, drug delivery, DNA labelling etc. Gold nanoparticles can also be used for making memory devices, to detect biomarkers in the identification of heart diseases, cancers. Highly dense property of these particles made them useful as probes for transmission electron microscopy.

REFERENCES

[1] Feynman R. There's plenty of room at the bottom. InFeynman and Computation 2018; 63-76. CRC Press.
[2] Schmid G. Nanoparticles. Wiley VCH; 2005.
[3] Ghosh Chaudhuri R, Paria S. Core/shell nanoparticles: classes, properties, synthesis mechanisms, characterization, and applications. Chemical reviews. 2011; 112(4): 2373-433.
[4] Eustis S, El-Sayed MA. Why gold nanoparticles are more precious than pretty gold: noble metal surface plasmon resonance and its enhancement of the radiative and nonradiative properties of nanocrystals of different shapes. Chemical society reviews. 2006; 35(3): 209-17.
[5] Benelmekki M. An introduction to nanoparticles and nanotechnology. InDesigning Hybrid Nanoparticles 2015. Morgan & Claypool Publishers.
[6] Hainfeld JF, Slatkin DN, Focella TM, Smilowitz HM. Gold nanoparticles: a new X-ray contrast agent. The British journal of radiology. 2006; 79(939) :248-53.
[7] Raty JY, Galli G, Bostedt C, van Buuren TW, Terminello LJ. Quantum confinement and fullerenelike surface reconstructions in nanodiamonds. Physical review letters. 2003; 90(3): 037401.
[8] Kolhatkar AG, Jamison AC, Litvinov D, Willson RC, Lee TR. Tuning the magnetic properties of nanoparticles.

International journal of molecular sciences. 2013; 14(8): 15977-6009.

[9] Averitt RD, Westcott SL, Halas NJ. Linear optical properties of gold nanoshells. JOSA B. 1999; 16(10): 1824-32.

[10] Aizpurua J, Hanarp P, Sutherland DS, Käll M, Bryant GW, De Abajo FG. Optical properties of gold nanorings. Physical Review Letters. 2003; 90(5): 057401.

[11] Grieve K, Mulvaney P, Grieser F. Synthesis and electronic properties of semiconductor nanoparticles/quantum dots. Current opinion in colloid & interface science. 2000; 5(1-2): 168-72.

[12] Andersson OE, Prasad BL, Sato H, Enoki T, Hishiyama Y, Kaburagi Y, Yoshikawa M, Bandow S. Structure and electronic properties of graphite nanoparticles. Physical Review B. 1998; 58(24): 16387.

[13] Rotello VM, editor. Nanoparticles: building blocks for nanotechnology. Springer Science & Business Media; 2004.

[14] Haruta M. Catalysis of gold nanoparticles deposited on metal oxides. Cattech. 2002; 6(3): 102-15.

[15] Srivastava AK, Yadev R, Rai VN, Ganguly T, Deb SK. Surface plasmon resonance in gold nanoparticles. InAIP Conference Proceedings 2012; 1447(1): 305-306). AIP.

[16] Jain PK, Lee KS, El-Sayed IH, El-Sayed MA. Calculated absorption and scattering properties of gold nanoparticles of different size, shape, and composition: applications in biological imaging and biomedicine. The journal of physical chemistry B. 2006; 110(14): 7238-48.

[17] El-Sayed IH, Huang X, El-Sayed MA. Surface plasmon resonance scattering and absorption of anti-EGFR antibody conjugated gold nanoparticles in cancer diagnostics: applications in oral cancer. Nano letters. 2005; 5(5): 829-34.

[18] Giljohann DA, Seferos DS, Daniel WL, Massich MD, Patel PC, Mirkin CA. Gold nanoparticles for biology and medicine. Angewandte Chemie International Edition. 2010; 49(19): 3280-94.

[19] Salata OV. Applications of nanoparticles in biology and medicine. Journal of nanobiotechnology. 2004; 2(1): 3.

[20] Cornell BA, Braach-Maksvytis VL, King LG, Osman PD, Raguse B, Wieczorek L, Pace RJ. A biosensor that uses ion-channel switches. Nature. 1997; 387(6633): 580.

[21] Myung S, Solanki A, Kim C, Park J, Kim KS, Lee KB. Graphene-encapsulated nanoparticle-based biosensor for the selective detection of cancer biomarkers. Advanced Materials. 2011; 23(19): 2221-5.

[22] Li Y, Schluesener HJ, Xu S. Gold nanoparticle-based biosensors. Gold Bulletin. 2010; 43(1): 29-41.

[23] Stonas W, Dietz LJ, Walton ID, Natan MJ, Winkler JL, inventors; Nanoplex Technologies Inc, assignee. Method of manufacture of colloidal rod particles as nanobarcodes. United States patent US 6,919,009. 2005.

[24] Li Y, Cu YT, Luo D. Multiplexed detection of pathogen DNA with DNA-based fluorescence nanobarcodes. Nature biotechnology. 2005; 23(7): 885.

[25] Kubik T, Bogunia-Kubik K, Sugisaka M. Nanotechnology on duty in medical applications. Current pharmaceutical biotechnology. 2005; 6(1): 17-33.

[26] Wang CC, Choy WC, Duan C, Fung DD, Wei EI, Xie FX, Huang F, Cao Y. Optical and electrical effects of gold nanoparticles in the active layer of polymer solar cells. Journal of Materials Chemistry. 2012; 22(3): 1206-11.

[27] Thirumurugan A, Ramachandran S, Shiamala Gowri A. Combined effect of bacteriocin with gold nanoparticles against food spoiling bacteria-an approach for food packaging material preparation. International Food Research Journal. 2013; 20(4).

[28] Duncan TV. Applications of nanotechnology in food packaging and food safety: barrier materials, antimicrobials and sensors. Journal of colloid and interface science. 2011; 363(1): 1-24.

[29] Cross SE, Innes B, Roberts MS, Tsuzuki T, Robertson TA, McCormick P. Human skin penetration of sunscreen nanoparticles: in-vitro assessment of a novel micronized zinc oxide formulation. Skin pharmacology and physiology. 2007; 20(3): 148-54.

[30] Benítez-Martínez S, López-Lorente ÁI, Valcárcel M. Determination of TiO 2 nanoparticles in sunscreen using N-doped graphene quantum dots as a fluorescent probe. Microchimica Acta. 2016; 183(2): 781-9.