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Review on Synthesis, Characterization and Applications of Silver Sulphide Quantum Dots

Ambalika Sharma[1], Rahul Sharma[1], Nishat Bhatia[1] and Asha Kumari[1*]

[1]Department of Chemistry, Career Point University, Hamirpur 176041, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author AS wrote the introduction part, prepared the diagrams and wrote the first draft of the manuscript. Authors RS, NB compiled the paper and removed the plagiarism. Author AK designed and managed the literature searches. All authors read and approved the final manuscript.

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Review Article

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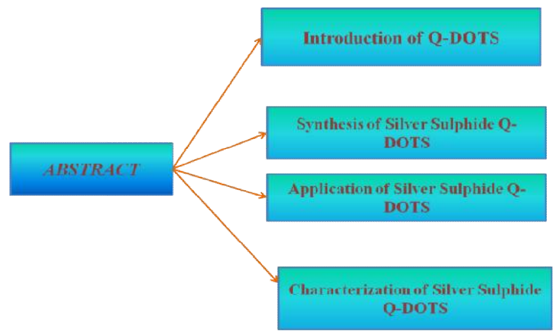
ABSTRACT

Quantum dots (QDs) provide a powerful material to engineer various optoelectronics devices as well as it provides many opportunities in the biomedical field. QDs have received a great attention due to their significant properties. QDs are one of the foremost nanotechnologies to be incorporated with the biological sciences and are extensively projected helpful for application in a number of profitable consumer and clinical products. They exhibit unique luminescence characteristics and electronic properties such as wide and continuous absorption spectra, narrow emission spectra, and high light stability. In this review paper we will focus on synthesis method, characterization techniques for quantum dots and biomedical applications of silver sulphide (Ag_2S) QDs as they are less toxic as compare than CdSe, PbSe, CdS quantum dots. Silver sulphide quantum dots are widely used in bio medical applications.

**Corresponding author: Email: ash885124@gmail.com;*

Ghaph. 1. Graphical Abstract



Keywords: Quantum dot; nanoparticles; characterization; application.

1. INTRODUCTION

Quantum dots (QDs) were discovered during research in the 1980s by Alexie Ekimov in glass matrices and Louis E Brus in colloidal solutions [1]. QDs possess applications of biomedical labeling [2]. Semiconductor QDs have interesting characteristics from both basic research and practical view points and that's why they are extensively studied [3]. QDs nanocrystals have size range lie between 1 to 20 nanometers [4]. Due to emitted regulatory spectrum, it is known that semiconductors have unique optical properties [5]. Structurally and electrically, the QDs are isolated from the outside [6]. Numerous nanostructures and quantum dots of colloidal semiconductor are becoming promising candidate for optical stimulation technology applications, which have generated a wide and accurate absorption within the range visible to organic bonds [7]. Structurally QDs have a mineral crystalline core and sheath that covers and protects the core which is just like as the heart of QDs and makes QD bio-available. These cores can be made of different material [8]. In all synthesis approaches, the surface of QDs (during or after synthesis) is passivated by external factors that make up a layer of functional groups or molecules that bind to the nucleus of a carbon [9]. There are many QDs effective that can emit light [10]. The ability to excite different QDs of a particular system using only one particular kind of wavelength is a lot, and that is difficult to achieve with the organic dyes [11]. The QDs of the semiconductors provide a typical system of nanostructure in applied physics and the essential applications of the technology [12]. Nanocrystals (NC) or quantum dots (QDs), mainly because of the band gaps, have been shown the possibility of achieving this goal in an improved way fluorescent quantum yields and fluorescence expiration dates [13]. QDs can be used in electronics, catalysis, optics and in magnetic storage [14]. To get information on the energy levels of QDs optical methods such as photoluminescence is quite helpful [15]. Biomolecules or special engineering fields can be associated on the surface of nanocrystals or QDs to provide them a group called as side group [16]. Nowadays, commonly used method for synthesizing QDs are the method of thermal water as well as by water-bathing method [17]. QDs can be inevitably developed [18]. Mark Arthur Reed coined the name of the quantum dot at Yale University in 1982 [19]. It is a focus of attention to develop QDs in appropriate confinement and to increase the stability [20]. Different chemical and physical methods were used to assemble semiconductor QDs [21]. Traditional dyes are lighter than the QDs; due to compounded effects the extinction coefficients are larger than those of most pigments [22]. Size and composition is responsible for the band gap of the QDs [23]. Chemical environment is also responsible to affect the physical properties of the quantum dots [24]. Surface impacts of the QDs may be affected by capping ligands [25].

Semiconductor QDs have significant extinction coefficients due to the effect of quantum confinement. QDs contain large dipole moments that may result for fast charging disconnects [26]. QDs are used as photocatalytic pollutants [27]. Water soluble quantum substances were developed for biomarkers, bonding with biomolecules, such as DNA or proteins [28]. Recently, the water synthesis of semiconductor nanoparticles with the capping ligand thiols had been provided an exciting and alternative method to produce semiconductor nanoparticles [29].

When the magnetic field is not present, emission from quantum dots is often isotropic in terms of its polarization direction [30]. QDs are coated with polymer [31]. QDs have also been shown to create interwoven photon pairs [32]. Most methods for chemical synthesis production of QDs were based on organic [33]. Specific properties of QDs lead to advancements in devices like QD lasers according to the theoretic predictions [34]. Ag_2S QDs emerged recently as the new generation of QD. There is great activity in the Ag_2S quantum dots for imaging and drug / gene delivery due to potentially better cytokhump capabilities and near infrared luminescence. Ag_2S QDs have brightness and photostability suitable for intense and stable biological imaging. In vitro and in vivo studies have verified that Ag_2S QD does not cause serious toxicity, unlike the heavy metals (cadmium or lead).

Here this section is providing an immense Literature survey on Silver sulphide (Ag_2S) QDs since 2013 when authors used silver sulphide for bio application. In 2012 Peng Jiang et al. have synthesized water soluble silver sulphide QDs by one step method. Water soluble silver sulphide QDs were terminated with carboxylic acid group had been reported by them. [2]. Similarly Peng Jiang et al. (2012) synthesized small sized QDs by injecting hexamethyldisilathiane into the mixture of silver acetate, myristic acid, 1-octylamine (OA), and 1-octadecene at a given temperature under argon flow [35]. Ibrahim Hocaoglu et al. 2012 prepared colloidably stable and highly luminescent near – NIR emitting Ag_2S QDs by a simple aqueous method using 2-mercaptoprionic acid as a coating. Emission of Ag_2S-2MPA near –NIR QDs can be tunned between 780 nm and 950 nm. The near – IR QDs have photoluminescence quantum yields around 7-39% and exhibit excellent cytocompatibility even at 600 µg mL^- in NIH /3T3 cells. With such improved properties, Ag_2S-2MPA NIRQDs have a great potential in practical bio-applications [36].

In 2013 Hua-Yan Yang et al. reported a facile and one-pot biomimetic synthesis approach to prepare water-dispersible NIR-II- emitting ultra small Ag_2S quantum dots. [37].

In 2014 Yanxia Zhao et al. reported the facile phase transfer based synthesis to achieve water dispersed NIR-II emitting Ag_2S QDs. After undergoing phase transfer of Ag^+ ions from water to toluene, and the synthesis of Ag_2S in toluene followed by ligand exchange, Ag_2S QDs were favorably prepared. A series of characterizations confirmed that the prepared products were monoclinic α- Ag_2S, showing an average size of 3.7 nm. The Ag_2S QDs exhibited the maximum emission located at 1045 nm, high PL stability and low cytotoxicity, facilitating their biomedical applications, indicating the feasibility of Ag_2S QDs for effective bioimaging in NIR-II biological window [38]. Another researcher Ekpeko Arthur et al. 2014 synthesized the silver sulphide quantum dots by using SILAR (successive ionic layer adsorption and reaction) technique. Different number of SILAR circles ranging from four to ten circles of Ag_2S QDs was synthesized [39]. Similarly Swarup Kumar Maji et. al 2014 synthesized highly mono-dispersed silver sulphide QDs with an average size of 11nm from a single –source precursor, and they aimed to employ them as electrode materials for the detection of phenol. The prepared silver sulphide QDs are immobilized on a glassy carbon electrode, and the electrochemical sensing of phenol. Prepared silver sulphide QDs were immobilized on a glassy carbon electrode and the electrochemical sensing of phenol using the developed silver sulphide QDs/ GC electrode were observed to be within a wide range. A novel non enzymatic amperometric sensor has been constructed by coating silver sulphide QDs on GC electrode [40].

In 2016 Stanislav I. et al. prepared stable colloidal solutions of Ag_2S quantum dots in the dark from reaction mixture with sodium sulphide concentration $C_{Na2S} = (C_{AgNO3}/2) + δ_{1,}$ where $δ_1$=0.01 [41].

In 2017 Qian Wu et al. had developed a facile two-step route to synthesize the water-soluble Ag_2S quantum dots, constituting of a green hydrothermal process and followed surface ligands exchange [42].

Natalia S. Kozhevnikova et. al. (2017), reported one-pot inorganic route to highly stable water-dispersible Ag_2S quantum dots. They reported the low temperature one-pot route for obtaining highly stable aqueous colloid solutions of Ag_2S QDs, using NH_3 molecule as monodentate ligand [43].

In 2019 Donghuni Zhao et al. has synthesized the core/shell Ag_2S QDs by seed-mediated growth methods showed a good linear relationship between fluorescence intensity and pH value in the range 2.1-7.2 [44].

Feng Lu et al. reported a facile one-pot approach for the synthesis of NIR-II emissive Ag_2S quantum dots in year 2019. The effect of ligand was carefully investigated to improve the quality of QDs. It is found that the QDs tend to form clusters when 1-dodecanethiol was used as the only ligand. The addition of oleic acid can greatly improve the dispersity of the nanocrystals but lead to a significantly decrease of the emission intensity [45].

Similarly in 2019 Dong-Hui Zhao et al. synthesized genetically engineered polypeptide capped Ag_2S quantum dots [46]. Table 1 representing the synthesis method studied through the literature. In upcoming section of this review article we are going to discuss different synthetic approaches along with application and characterization techniques.

2. SYNTHESIS METHODS OF QDS

There are several approaches to limit exciton to semiconductors, which lead to different methods for producing quantum dots. QDs are cultivated by means of advanced epitaxial techniques in nanocrystals produced by chemical methods or by implanting ions, or in nanostructures made with modern lithographic techniques. The pathway is the most challenging aspect of QD synthesis to start the reaction [47]. Various methods have been used to integrate QDs but in general, it uses top-down and bottom-up approach [48]. Fig. 2 representing the different synthesis methods of QDs.

2.1 Top-down Synthesis Process

In descending order, the mass semiconductor is diluted to form a QDs. Electron beam lithography, reactive ion traction, and / or wet chemistry are commonly used to obtain Qdots of diameter ~ 30 nm. Or, focused ion beam or laser beam also has used to make zero-dimensional point array [49]. The main advantage of this approach is that the maintenance of services and equipment does not begin as early as in a downstream system. And the disadvantage of this method is that the cost of implementation may be higher.

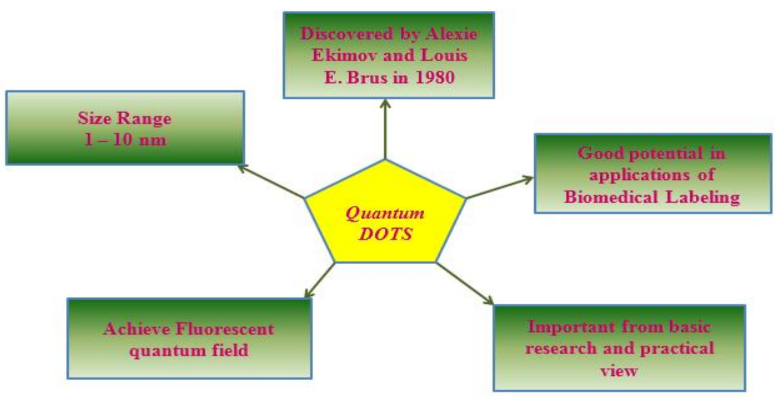


Fig. 1. Diagram representing main points of QDs

Table 1. The synthesis method studied through the literature

Synthesis	Characterization	Results	Reference
Silver Sulphide Quantum Dots were successfully prepared by one pot method.	PL was reported.	510-1221 nm	Peng Jiang et al. 2012
Highly luminescent Ag_2S QDs were successfully prepared by simple aqueous	UV was reported.	780-950 nm.	Ibrahim Hocaoglu et al. 2012

Synthesis	Characterization	Results	Reference
method.			
Water-dispersible NIR-II-emitting ultrasmall Ag_2S QDs were prepared.	Emission spectra reported by PL.	1294-1050 nm	Hua-Yan Yang et al. 2013
Water-dispersed NIR-II-emitting Ag_2S QDs were successfully synthesized.	PL spectra showed the emission peaks.	1045 nm	Yanxia Zhao et al. 2014
Ag_2S QDs were synthezsized successfully by SILAR technique.	UV was reported.	370 nm	Ekpeko Arthur et al. 2014
Monodispersed Ag_2S QDs were synthesized from a single-source precursor.	TEM reported the particle size.	11 nm	Swarup Kumar Maji 2014
Ag_2S QDs were successfully synthesized by facile two step route which includes hydrothermal process followed by surface ligand exchange method.	XPS was reported.	367.9 eV	Qian Wu et al. 2017
They successfully synthesized stable water dispersible Ag_2S QDs by one-pot inorganic route.	TEM was reported.	33 nm size	Natalia S. Kozhevnikova et al. 2017
Core/shell Silver Sulphide Quantum Dots were successfully synthesized by seed-mediated growth method.	TEM was reported.	11.6 nm	Donghuni Zhao et al 2019
Genetically engineered polypeptide capped Ag_2S QDs were successfully prepared, and these QDs possess excellent stability.	TEM was reported.	3.2 nm	Dong-Hui Zhao et al. 2019

2.1.1 Electron beam lithography

This approach has led to the creation of specially designed molds on the so-called opposite electron film. The resist material is usually made up of a polymer compound. If a resist consists of a long-chain polymer with a high molecular weight (~ 10^5 units), it is called a negative tone, while a short-chain polymer is known as a positive tone [50].

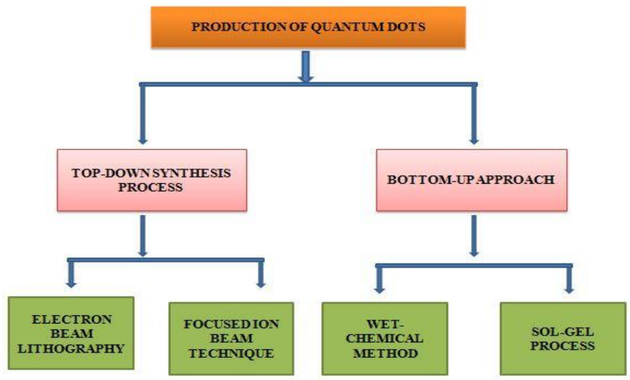


Fig. 2. Diagram representing different methods for the production of QDs

2.1.2 Focused ion beam technique

Focused ion beam (FIB) technologies provide the capability for highly synthesized Qdots of high lateral resolution. Shape, size and the distance between Qdots particles depends on the size of the ion beam, but on a minimum radius a diameter of 8-20 nm has been reported for both laboratories and commercial systems, allowing the attachment dots at dimensions <100 nm [49].

2.2 Bottom-up Approach

There are two types of top-bottom methods: a) wet chemical methods and b) phase vapor methods. The wet chemical method refers to the reactions in the solution phase such as sol-gel process, microemulsion, dissolution of heated solution, etc. while the vapor phase method, molecular beam epitaxy (MBE), sputtering, liquid metal ion source, physical or chemical vapor deposition are important. And the main disadvantage is that due to rapidly changing storage owners and number of users, the output will have a greater impact than before and will require more support.

2.2.1 Wet-chemical methods

They are the conventional methods of precipitation from a single solution or mixture of solutions with careful control of the different parameters. Quantum dots of a particular size and shape can be prepared by adjusting the temperature of the reaction medium, the thickness of the electrostatic double layer and the ratios between anionic and cationic species [50].

2.2.2 Vapour-phase methods

In a vapor-phase system the layers of quantum dots are amplified by atoms without any arrangement in the molecular process, but by various-elliptical increments of high-pressure materials. In general, layered materials grow as a uniform, often epitaxial layer. These phases of QDs production begin with processes in which layers are grown in the process of per atom [49].

3. CHARACTERIZATION TECHNIQUES

In previous reported research work different characterization techniques are use to study Structural and optical properties of Quantum dots. In this review paper we are going to discuss about Ultrav-Violet-Visible - (UV- vis) spectroscopy, photoluminescence (PL) spectroscopy, Transmission Electron Microscopy (TEM), X-Ray Diffraction (XRD). Fig. 3 represents the previously reported results obtained through different characterization techniques.

3.1 Ultra-Violet (UV) Spectroscopy

UV-800 nm is one of the most common methods for detecting and characterizing many organic and inorganic substances in analytical techniques. Due to its availability, simplicity, flexibility and wide application in various fields including biochemistry and chemical analysis, the method of ultraviolet-Visible (UV-Vis) analysis has become very important and widely used in various scientific fields around the world. Nowadays it is necessary to reduce the number of samples and reagents for the development of analytical systems, especially for small samples or toxic solvents. Subsequently, UV spectrophotometers were developed [51]. Absorbed spectroscopy is used to determine the optical properties of a solution. The light is sent by a sample solution and the amount of light absorbed is measured. When the wavelength is varied, the absorption is measured for each wavelength. Absorption can be used to measure the concentration of solutions using the Beer-Lamberts law [52]. Ultraviolet spectrophotometers consist of a light source, discharge legacy sample beams, a monochromatic: detector. The UV spectrum for the compound is obtained by leaving the sample of the compound under the influence of ultraviolet light from a light source, such as a xenon lamp [53]. UV-Vis absorption spectroscopy provides ultraviolet absorption of amorphous gels and crystalline ceramic specimens heated to different temperatures [54]. Many molecules absorb visible or ultraviolet light. The absorbance of a solution is directly proportional to attenuation of the beam, i.e., it increases as attenuation of the beam increases. Absorbance is also directly proportional to the path length “b” and the concentration “c” of the absorbing species. Beer’s Law states that A = εbc, where ε is a constant of proportionality, called the absorbtivity. Different molecules absorb radiation of different wavelengths. An absorption spectrum will show a number of absorption bands corresponding to structural groups within the molecule [55]. Ekpeko Arthur et al., has synthesized Ag_2S QDs by using Successive Ionic Layer Adsorption and Reaction (SILAR) technique. They characterized the samples by using UV-SPEC2048 spectroscopy machine and they reported that synthesized Ag_2S QDs with size 2.7 nm having the band gap of 1.41 eV and wavelength of 370 nm, whereas Ag_2S QDs with size 2.9 nm having the band gap of 1.38 eV and wavelength 375 nm. The prepared Ag_2S QDs with size 3.0 nm having the band gap 1.34 eV and wavelength 381 nm, whereas Ag_2S QDs with size 3.1 nm having the band gap 1.32 eV and 385 nm. The synthesized Ag_2S QDs with size with 3.3 nm having the band gap 1.29 eV and wavelength 395 nm, whereas Ag_2S QDs with 3.5 nm having the band gap 1.28 eV and wavelength 400 nm [39]. Table 2 representing the previous results obtained by Ekpeko Arthur et al from UV spectroscopy for Ag_2S QDs.

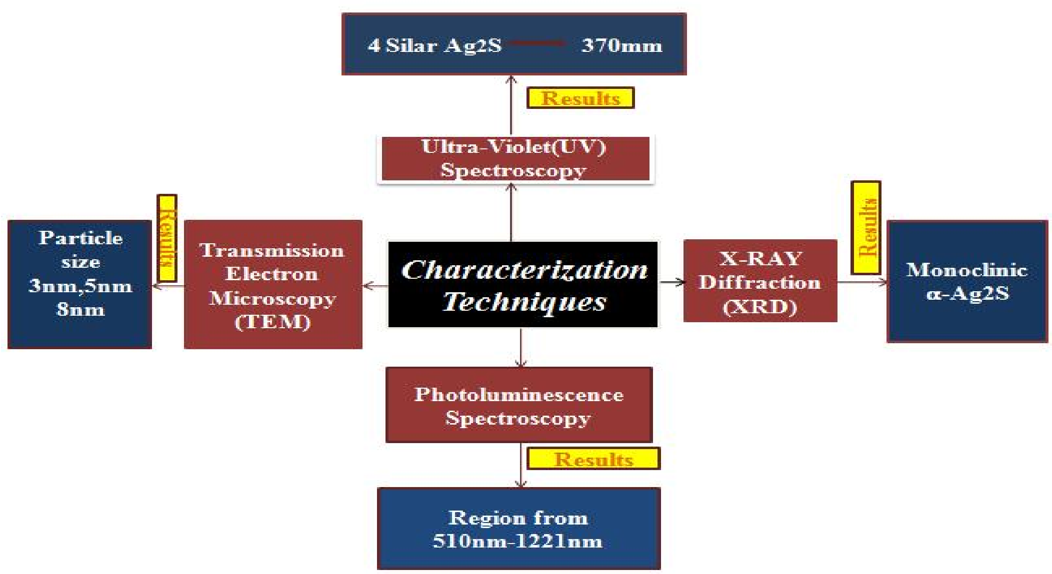


Fig. 3. Diagram representing different characterization techniques of silver sulphide QDs

Table 2. Absorption peaks obtained from UV results of silver sulphide QDs

Name of nano particles	Wavelength (nm)	Band gap (eV)	Diameter (nm)
4 SILAR Ag_2S	370	1.41	2.7
5 SILAR Ag_2S	375	1.38	2.9
6 SILAR Ag_2S	381	1.34	3.0

Ozkan Vardar et al., had synthesized the DMSA/Ag_2S QDs in one step reaction. They have reported the absorbance spectra of these QDs in the range of 300-1000 nm [56].

3.2 Photoluminescence (PL) Spectroscopy

PL spectroscopy uses fluorescent and phosphorescent. Biochemistry and molecular biology are widely used to describe complex molecules, their environment, or their location. Photoluminescence (PL) spectroscopy has been a major focus of optical characterization techniques due to its ability to provide valuable non-destructive information: both internally and externally. Peng Jiang et al. reported the range of PL emission of Ag_2S quantum dots which are terminated with the carboxylic acid was reported in region from 510 nm to 1221 nm [57].

Qing Liu et. al., reported the photoluminescence (PL) emissions of the sample were measured and 980 nm wavelengths was reported by them. The extension of Ag_2S QD speakers over different wavelengths is identified by the Perki Elmer Lambda 950 UV / VIS spectrometer [58].

3.3 Transmission Electron Microscopy (TEM)

Transmission electron microscopy is a technique in which an electron beam is transmitted through a sample to form an image. A transmission electron microscope (TEM) uses strong electrons to deliver morphological, compositional and crystallographic information to the samples. With potential amplitude of up to 1 nanometer, TEMs are the most powerful microscope. TEM is responsible to create high-resolution, two-dimensional images, allowing a wide range of applications in the field of educational, science and industry. Silver sulphide QDs which were synthesized by the Jiang Xue by one pot reverse microemulsion under ambient temperature. When the reaction was preceded for 8 h then the particle size of Ag_2S QDS were reported 3 nm, 5nm and 8 nm for Ras = 1:4, 1:1 and 2:1 with the help of TEM [59].

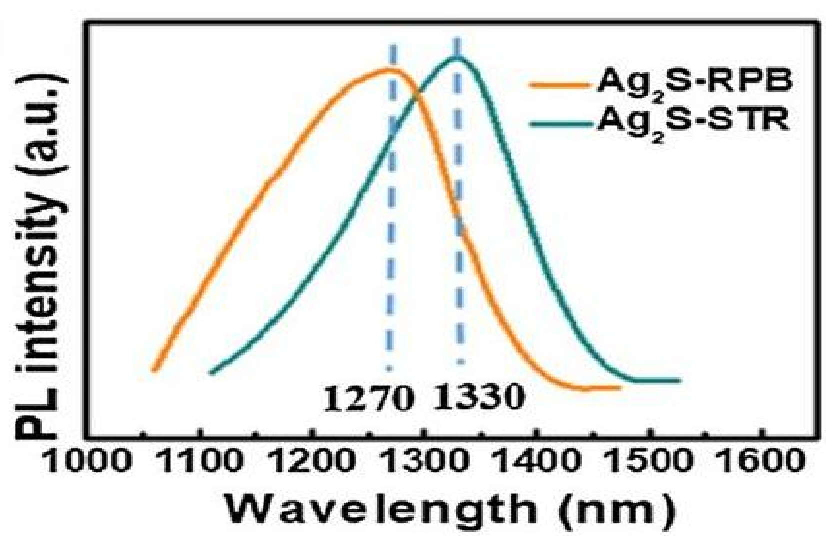


Fig. 4. PL Graph representation of silver sulphide QDs

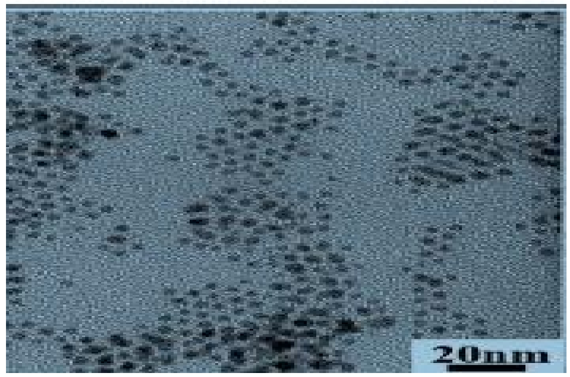


Fig. 5. Diagram representing TEM results of silver sulphide QDs

3.4 X-Ray Diffraction (XRD)

XRD is a fast analytical technique mainly used for semiconducting material phase identification and helpful for unit cell measurements and atomic spacing detail. The X-ray is produced by a cathode ray tube, filtered, collimated to concentrate, and guided towards the sample to produce monochromatic radiation. When conditions satisfy Bragg's Law $n\lambda = 2d \sin\theta$, the interaction of the incident monochromatic rays with the sample produces constructive interference (and diffracted ray). Jiang Xue reported that the silver sulphide QDs synthesized by one pot reverse microemulsion and crystalline nature of silver sulphide qds was confirmed by XRD analysis. Intense peaks of XRD was observed at (-101), (-111), (111), (-112), (-121), (-103), (031) and so on. And silver sulphide QDs were observed to be monoclinic α-Ag_2S [59].

4. APPLICATIONS OF SILVER SULPHIDE QUANTUM DOTS

For centuries, silver has been widely used to treat burns and wounds. Still 1000 B.C. Silver was used to make water portable [60]. From the nineteenth century, silver-based compounds have been widely used in bacterial applications, burns and wound therapy, etc. In the last decades silver nanoparticles, structures have been engineered in the form of 1 to 100 nm. Due to their small size, the total surface area of the nanoparticles has been maximized, leading to a higher value-to-weight ratio. As this property is uniquely separated from bulk metals, silver nanoparticles have attracted a lot of attention and have been applied in various fields including treatment, catalysts, textile engineering, biotechnology, water treatment, electronics and optics [61]. Fig. 7 representing the uses of silver in different fields.

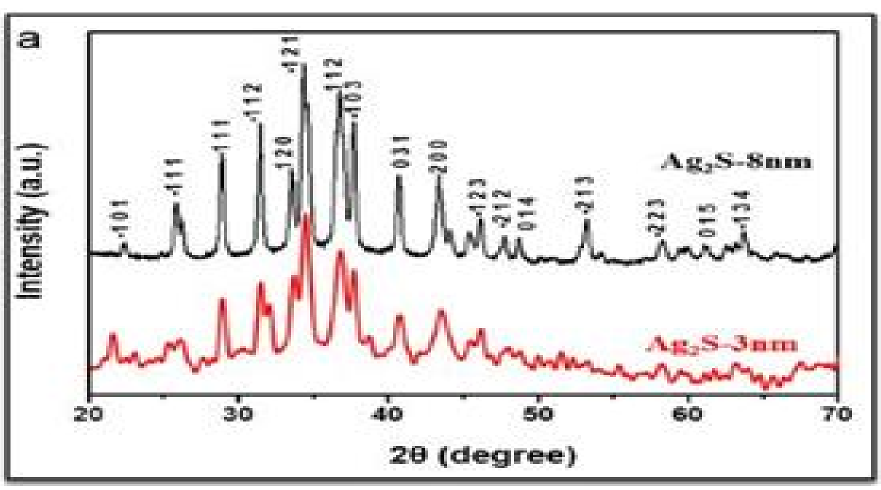


Fig. 6. XRD graph of silver sulphide QDs

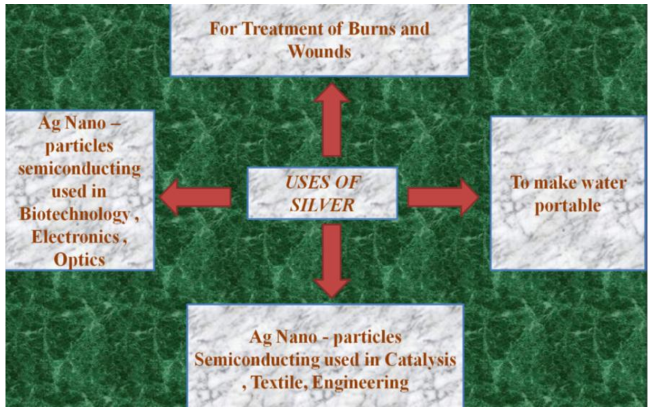


Fig. 7. Diagram representing the uses of silver

Ag_2S QDs recently emerged as the new generation QDs [8]. Ag_2S QDs have become unique nanomaterials showing unprecedented advantages and superior properties in medicine due to their unique structural and physico-chemical properties [62]. QDs of Ag_2S act as a promising candidate for detecting the ions of a metal due to its low toxicity and have an attractive fluorescence capacity, covering the area between the red and near infrared (NIR) [63]. QDs have become a popular visualization medium, competing with other fluorescent nanomaterials and other coatings (dyes) [64]. Ag_2S (QDs) quantum dots have become a focus of interest in recent years because of properties like their infrared (NIR) attraction with infrared light (PL) in another window (NIR-II, 1000-1400 nm), that gives a deeper look at imaging in vivo penetration and greater proportion in a correlation with the noise signal against optical probes in NIR-I window (650-950 nm) [65]. The family of the future QDs for biomedical applications (especially in NIR) are the chalcogenides of silver QDs (Ag_2X, with X = S, Se, Te) which have less toxicity as compared to normal QDs. In addition, high solubility is presented by silver chalcogenide QDs, which allow them to obtain minimum Ag ion in the desired applications. QDs of silver chalcogenide present a narrow band gap, which is approximately 0.9-1.1 eV for Ag_2S [4]. The QDs, of Ag_2S are the non-toxic QDs, having the ability to photograph the micro-organisms in the high acid environment and pH detection [66]. Ag_2S QDs have emerged as a unique nanomaterial that shows the unexpected benefits and better performances in biomedical due to its unique structural, physical and chemical features [53]. Structurally, the ordinary QDs are a metal crystal core covered by an organic outer layer [67]. The preparation of non-toxic QDs that emit NIR that are emitted directly into aqueous solution will greatly simplify the preparation [37]. Recently, silver sulphide (Ag_2S) QDs have been shown to, for the first time, be an attractive alternative to traditional NIR-II-emitting for in vivo due to photoluminescence in the NIR-II region (1.0-1.4 µm), greater efficiency and good biocompatibility. Major efforts have been focused on acquiring various synthetic methods associated with Ag_2S QDs [43]. Ag_2S QDs are a promising candidate for the detection of metal ion due to its very low i.e. negligible toxicity and attractive fluorescence properties covering the region between red and near infrared (NIR) [54]. Ag2S photoluminescence emission quantum dots could be tuned from 510 to 1221 nm [68]. Ag_2S QDs have been reported to provide larger quantities yield and stability more than most organic fluorophores [69]. However, the achievement of NIR-II Emissive Ag_2S QDs was not insignificant. Lots of synthesis methods did not result in NIR-II emissions [45]. Ag_2S is the only semiconducting sulphide having three polymorphous modifications (α-Ag_2S, β-Ag_2S, Ƴ-Ag_2S) within rather close temperature intervals [70]. Here in this review we are mainly considering biomedical application of silver sulphide QDs due to NIR emitting tendency of these QDs.

4.1 Biomedical Applications

Over the centuries, mankind has shown great scientific interest in metal compounds, especially silver (Ag) and its alloys, because silver has unique physicochemical properties. For thousands of years, silver has been used in a wide range of fields, from jewellery making to coinage to explosives. Throughout history humanity has used particles of silver despite their lack of scientific knowledge. Perhaps the most famous example is the Lycurgus Bronze Cup, which dates from the fourth century AD. This cup has a decorative glass that is able to disperse green light and transmit red light because it contains around 70 nm metal nanoparticles, which can be synthesized thanks to an alloy of silver (70%) and gold (30%) [71]. Fig. 8 representing the few important biomedical applications of silver based nano materials.

4.1.1 Bioimaging

Imaging techniques have their own Strengths and weaknesses - as terms resolution, sensitivity and penetration Depth - and dealing with this change. The materials that enable their application Science enters into itself in the field of bioimaging. Imaging includes the realization of all types of diagnostic and therapeutic tests where equipment is used to obtain images of an organism. Among the techniques used every day to get images are computerized axial tomography, nuclear magnetic resonance, ultrasound, radiology and microscopy for disease diagnosis. Imaging techniques have been used for the observation and investigation of the shape, size and movement of cells, microorganisms or specimens associated with various diseases by imaging techniques [72]. Imaging techniques have their own Strengths and weaknesses - as terms Resolution, sensitivity and penetration Depth - and dealing with this change. Bioimaging is the field of methods and tools or process analysis and understanding the biology, general medical image. In the bioimaging process, interesting biomolecules are labeled with contrast agents using specific biochemical strategies to be detected by the reading system. So, in general, bioimaging investigations consist of labels and biorecognition elements. The appropriate label must meet the following requirements, namely

a) Provide a good analytical signal.
b) Soluble and stable in relevant buffers or bio matrices.
c) Have functional groups for site specific labeling.
d) Reporting data about its photophysics.
e) Available in reproducible quality [73].

4.1.2 Detection of cancer cell MCF-7

Silver sulphide QDs is applied to detect the cancer cell MCF-7. Breast cancer cells are the MCF-7 cells and these cells make an over exploitation of their membrane. Thus monitoring of surface area production on cell surface provides reasonable indices of the dynamic changes in tumor, metastasis and diagnostics. For this purpose, 3 APBA (3-Aminophenyl boronic acid) was bounded by a silver sulphide electrode surface. The interaction between boronic acid and the existing terminal on the biological membranes of cells of the cell MCF-7 could then be captured on this low toxic photoelectric interface. The photoelectric interface made with low toxic silver sulfur hydroxide could be well applied to the detection of bioactive compounds [74]. In the 21st century, cancer is a major threat to public health. Cancer continues to be a global health problem as the leading cause of death in developed countries and the second leading cause of death in provincial development. This disease affects different tissues, but is usually characterized by an undistributed distribution of abnormal cells, as well as the ability to attack surrounding tissues and eventually metastasize. Since biocompatible QDs were introduced in 1998 for in vitro imaging of cancer cells. Researchers have developed cancer-specific ligands, antibodies or peptides in vitro and QD-based diagnostic tests. Molecular biomarkers play an important role in diagnosis cancer study. Biomarker studies may be useful for screening and diagnosis of cancer, if it is a set of marker molecules they can be quantified and statistically distinguish between cancer cells and normal cells. Photoluminescence (PL) and square wave voltmeters (SWV) were used to quantify MCF-7 cells. MCF-7 cells in human breast cancer are widely used to study tumor biology and the mechanism of action of hormones. Fig. 9 is representing the detection of cancer cells when Ag_2S QDs are applied.

4.1.3 In vivo imaging of the lymphatic system and real time tracking

Infrared silver sulphide was successfully used to obtain images of vasculature of the hind limbs and tumor detection in a high-spatial solution of 30 μm and a temporary solution of 50 ms. Li et al. reported real-time vivo reproduction of tissue blood flow and angiogenesis by using QDs of silver sulphide emitted in the quasi-infrared window (NIR-II) [4]. It is used in identification and dissection of lymphoma systems in cancer patients, including lymph vessels and lymph nodes. The use of many silver sulphides in lymphography was examined. Anatomy of lymph and lymph vessels observed with silver sulphide Qds as imaging agent is much sharper [75].

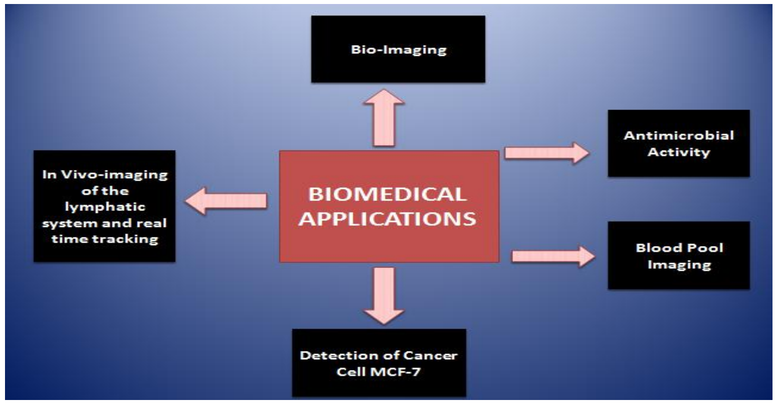


Fig. 8. Diagram representing the biomedical applications of silver quantum dots

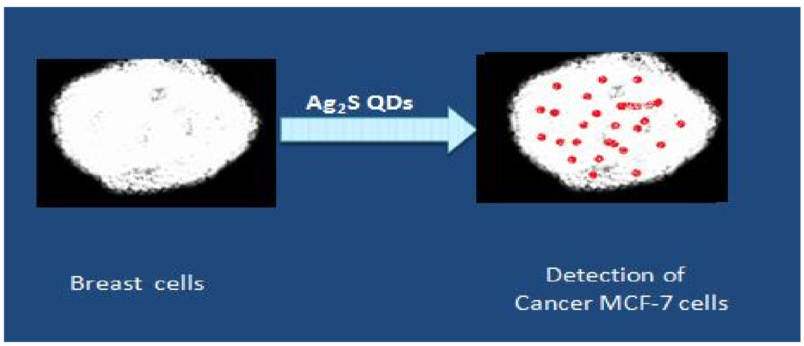


Fig. 9. Diagram representing detection of cancer cells by Ag_2S QDs

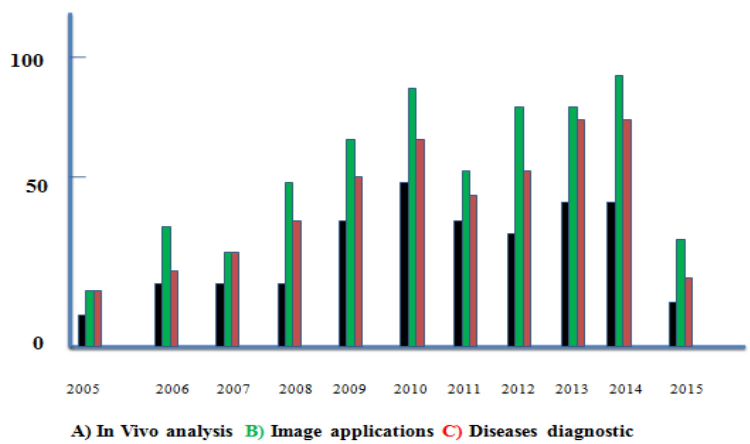


Fig. 10. Diagram representing the uses of silver sulphide QDs

4.1.4 Blood pool imaging

Angiography is another important method of imaging a circulatory system and has a strong interest in cancer diagnosis and therapy. The possibility of silver sulphide PEGs can be directed at NIR-II imaging. 200 µg of PEGylated silver sulphide QDs was suspended in mouse internally. Intense fluorescence was detected within a few minutes after the injection under an excitation of 808 nm with lighting of 45 Mw /cm^2 [75].

4.1.5 Antimicrobial activity

Antimicrobial activity means the process of killing or preventing the disease that causes microbes. Many antimicrobial agents are used for this purpose and they may be anti-bacterial, anti-fungal or anti-viral agents. Silver sulphide QDs were tested against the positive gram bacteria, S. aureus and the gram negative bacteria, E.coli and P. aeruginosa. Fig. 10 represents the graphical representation of the uses of silver sulphide QDs in different applications. Here blue bar in the graph represents the uses of silver sulphide QDs in vivo analysis. Green bar represents the uses of silver sulphide QDs in image applications. Red bar represents the applications of the silver sulphide QDs in the diagnosis of disease.

5. CONCLUSION

In this review paper, the attempts of introducing QDs, silver sulphide QDs, literature and the methods adopted by the different scientists for the preparation of silver sulphide QDs, applications of silver sulphide QDs as well as results of synthesized silver sulphide QDs achieved by different techniques has been explained. Many scientists have synthesized silver sulphide QDs by using different kinds of organic solvents. But the literature of synthesis of silver sulphide QDs in water as a solvent is extremely limited. There may be a lot of reasons for this. It can be a great choice of interest to synthesize silver sulphide QDs in water as solvent. Silver sulphide QDs has lot of applications in many fields and has been-serve in the field of antibacterial applications and anticancer. Hence, they have lot of present as well as future scopes in different areas of development.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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