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Gold Nanoparticles: Synthesising, Characterizing and Reviewing Novel Application in Recent Years

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Abstract

In this paper we report the synthesis of gold nanoparticles during laser ablation of a metal gold plate in distilled water. The experiments were performed with a first harmonic (1064 nm, 6 ns, 10 Hz) output of a Nd:YAG laser varying the operative fluency between 5 Jcm^{-2} and 15 Jcm^{-2}. The results indicate that gold nanoparticles are synthesized at room temperature.In this paper we give an overview of the properties of gold relevant to its potential application in molecular-scale devices absorption spectroscopy and Transmission Electron Microscopy (TEM) were employed to determine the optical properties and size of gold nanoparticles. And novel applications of gold nanoparticles have been studied in various fields.

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Keywords: Gold nanoparticles; Synthesising; Laser ablation; Characterizing; Novel Applications

1. Introduction

Nanoparticles, i.e. particles with the sizes in the range of units to hundreds of nanometres, lately attract an comprehensive attention in different fields of physics, chemistry, material science, medicine, and biology, as a result of their unique electronic, magnetic, optical, mechanical, physical and chemical properties. Gold nanoparticles are one of the most useful nanoparticles in industry and medicine [1-3].Gold nanoparticles are synthesised by various methods such as [4-7]. In this work gold nanoparticles synthesised during laser ablation. After the generation of the nanoparticles, the next stage is the characterization. The characterization will give information about the size of nanoparticles, shape of the nanoparticles and spectrum of the plasmon band. Some important ways to characterize nanoparticles are: Electrical Impedance Spectroscopy (EIS), Surface Plasmon Resonance (SPR), Cyclic voltammetry and Conductive measurement. In recent years, chemiresistive sensors based Gold Nanoparticles have been developed for reliable detection [8].Utilization of unmodified gold nanoparticles in colorimetric detection was reported in [9].Gold nanoparticles have found applications in cancer therapy [10-13].Besides cancer therapy gold nanoparticles have been developed in other fields of medicine and biology [9-30].Scientists have discovered novel applications of these metal nanoparticles and reported their studies [8,31-34].

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2. Material processing and characterizing

Nanoparticles are synthesised from various methods. In this work nanoparticles have been synthesised during laser ablation of a metal gold plate in distilled water. The experiments were performed with a first harmonic (1064 nm, 6 ns, 10 Hz) output of a Nd:YAG laser varying the operative fluence between 5 Jcm^{-2} and 15 Jcm^{-2}. The as-prepared products were characterized by UV-vis-NIR spectrophotometry, transmission electron microscopy (TEM). The results indicate that gold nanoparticles are synthesized at room temperature and the average size is about 35 nm with narrow size distribution.The most common characterization methods is high-resolution transmission electron microscopy(HRTEM), which gives a photograph of the gold core of the AuNP (gold nanoparticles) but the core dimensions can also be determined using scanning tunneling microscopy (STM), atomic force microscopy (AFM), small-angle X-ray scattering (SAXS), laser desorption ionization mass spectrometry (LDI-MS), and X-ray diffraction.

Transmission electron microscopy (TEM) is a powerful and straightforward method for the determination of size and shape of nanoparticles that have been used in this work.TEM images have been captured under the following conditions: 100 KV working voltage and 0.34 nm resolution.

The shapes and sizes of the deposited particles were measured using transmission electron microscopy (TEM). TEM images showed that the shapes of nanoparticles are mostly spherical.

Fig.2 shows a single gold nanoparticle. Captured image has been compared with spherical line added to the image.

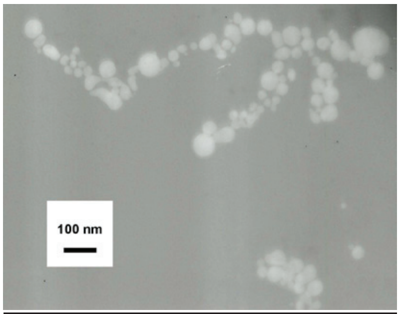

Fig. 1. TEM image of gold nanoparticles, the scale bar is 100 nm, working voltage in 100 KV and resolution in 0.34 nm.

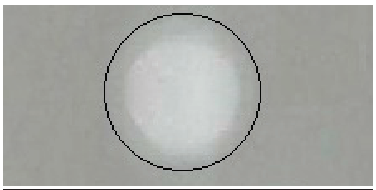

Fig. 2. Single gold nanoparticle captured by TEM.

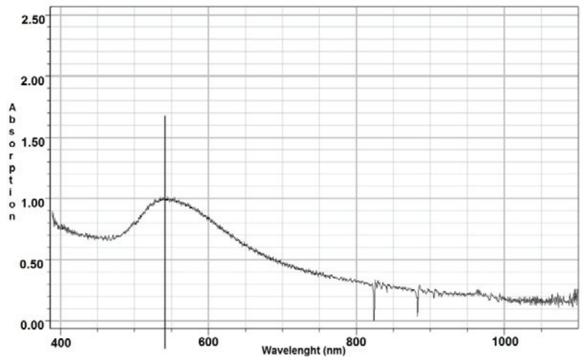

Fig. 3. Absorption spectrum of gold nanoparticles characterized by spectrophotometry.

Produced gold nanoparticles have been characterized by spectrophotometry in range of 400 to 1100 nm.

3. Why gold nanoparticles?

This section explores the answer of this question: why is gold so unique and useful at the nanoscale? Nanoparticles would display electronic structures, reflecting the electronic band structure of the nanoparticles, due to quantum- mechanical rules. The resulting physical properties are neither those of bulk metal nor those of molecular compounds, but they strongly depend on the particle shape and size, interparticle distance, nature of the guarding organic shell.

Nanoparticles contain small enough several constituent atoms or molecules that they vary from the properties natural in bulk .They contain a high enough several constituent atoms or molecules that they cannot be dealt with as an isolated group of atoms or molecules. Hence, nanoparticles present electronic, magnetic, optical, physical and chemical properties that are completely different from both the bulk and the constituent atoms or molecules. Applications of gold nanoparticles are based on their unique properties, and this uniqueness can be interpreted in terms of the high relativistic contraction of its 6s orbitals resulting in a very small atomic radius. These unique properties of gold nanoparticles provide many applications in various fields.

4. Gold nanoparticles in medicine and biology

One of the basic prerequisites for using gold nanoparticles in biomedical application is that they are non-toxic and biocompatible to both in vivo and in vitro environments. For biomedical applications that require lower concentrations of gold nanoparticles, it is crucial that dilution of gold nanoparticles does not change the properties. Moreover, different gold nanoparticles synthesized by different methods must be stable under an in vitro environment that mimics in vivo conditions. Nanoparticles in range of 1 to 500 nm are extremely smaller than human cells which are about 10-20 μm. Nanoparticles have sizes similar to that of the biomolecules encountered at the cellular level. This specific size of nanoparticles promotes development of nanodevices and nanosensors that can go into cells to probe proteins or the DNA both inside and outside the cell. Gold and DNA are also frequently suggested for nanotechnological devices. The specific properties of nanostructured materials supply good prospects for coordinating biological identification events with electronic signal transduction and for making a new generation of bioelectronics devices with novel functions.

Gold nanoparticles and bio sensors: The primary principle involved in the design of a biosensor based on gold nanoparticles is that the gold nanoparticles are functionalized with a thiolated biomolecule which upon recognizing the perfecting biomolecule brings about change in the optical absorption of gold nanoparticles.

Antimicrobials: Although silver has a long history of being used as an antimicrobial, in recent years gold has also become a good rival for silver. For example gold nanoparticles can fight against ‘E. coli’ bacteria.

Gold Nanoparticles in Cancer Diagnosis and Therapy: The main problem with many currently available cancer treatments is that they cannot be precisely targeted. As it is very hard to get an effective drug, such as paclitaxel, directly to the tumour, large doses are needed in the hope that enough of the drug will reach the diseased cells where it is needed. Recently gold nanoparticles have found a role to deliver drug easily. Cancer therapy has various routes such as chemotherapy, photo-thermal therapy and radiotherapy. Gold nanoparticles have been investigated for potential candidates to aid in photo-thermal therapy and radiotherapy. It is important to understand the difference between normal and cancerous tissue to efficiently improve hybrid nanoparticles in cancer diagnosis and treatment. Optical and electronic properties of gold nanoparticles can be used to improve the contrast in molecular imaging for the detection of cancer at early levels.

Needle-free drug delivery: Gold-based technologies are also provide a unique needle-free delivery system, a technique that used gold nanoparticles and allowed vaccines to be delivered through the skin making use of the fact that small particles can pass through gaps between cells while large ones cannot.

Gold nanoparticles against HIV/AIDS: One of the most efficient usages of gold nanoparticles in recent years is detecting and fighting against HIV.

5. Gold nanoparticles and environment

Gold nanoparticle-based technologies provide solution to some of environmentally great issues, such as greener production methods, pollution control and water purification.

Gold is indeed one of the stable metals, and it is resistant to oxidation. This ability of gold nanoparticles provides conditions to make many catalyst containing: Catalysis of CO Oxidation, Catalysis of Hydrogenation of Unsaturated Substrates, Electrochemical Redox Catalysis of CO and CH3OH Oxidation and O2 Reduction, Catalysis by Functional Thiolate-Stabilized gold nanoparticles etc.

Mercury control and sensing: Nanotechnology can control and sense mercury using gold nanoparticles. Mercury is one of very toxic material that exists all over the world. Mercury can cause some diseases such as Alzheimer and autism. Almost over 100 tonnes of mercury finds its way into the atmosphere every year, mercury exit from some boilers in the utilities industry. Gold-based catalysts can provide a solution. Gold nanoparticles have considerable promise as mercury oxidation catalysts.

Improving water and air quality: One of the most useful applications of gold nanoparticles is increasing water and air quality, Carbon monoxide is a colourless, odourless gas which is very toxic to humans. Gold nanoparticles provide a simple solution. Gold nanoparticles allow the oxidation of CO to carbon dioxide (CO_2) that transforms an acutely dangerous gas to a far less toxic substance. Recent years have seen a sharp rise in the use of noble metal nanoparticles for water purification and contaminant detection. Gold nanoparticles have also been shown to be efficient adsorbents for the removal of significant levels of mercury from drinking water.

6. Gold nanoparticles in technology

In recent years gold nanoparticles have found novel abilities in various fields of science such as coating glasses to change their properties and multicolor optical coding for biological assays. Gold nanoparticles are being used to enhance electroluminescence and quantum efficiency in organic light emitting diodes. Application of nanoparticles for signal amplification is another novel and developed applications. The use of nanoparticles materials, with scale of a few nanometers, has enabled new types of new sensors that are able of detecting very small amounts of analytes such as chemical vapors in the range of few ppm. Besides, gold nanoparticles are used in making advanced dyes and pigments. Gold nanoparticles have also occasionally been used to dye textiles Aid to provide clean energy (by solar cell) and making high density data storage (flash memories and discs) is another interesting application of these nanoparticles.

7. Conclusion

Gold nanoparticles have been syntesised during laser ablation and then characterized using transmission electron microscopy and UV-vis-NIR spectrophotometry.In next section different application of gold nanoparticles have been studied. Such as use in making bio sensors, detecting systems. The gold nanoparticles were evaluated for their in vitro stability and in vivo biodistribution. In addition, gold nanoparticles were conjugated with cancer seeking peptides to impart target specificity in hybrid gold nanoparticles for their potential applications in cancer imaging and therapy. Gold nanoparticles have found novel abilities in various fields of science such as making high density data storage. Increasing applications of nanoparticles especially metallic nanoparticles show that this science plays an important role in the new age. One of the most useful metallic nanoparticles is the gold one.

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