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Synthesis and Characterization of Electrodeposited Gold Nanoparticles

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Abstract: Metal nanostructures have attracted a large amount of attention, particularly the synthesis of noble metallic nanoparticles with controlled size, shape, morphology and crystal orientation. Among the noble metals, Gold (Au) had earned great importance due to its chemical stability and unique optical properties. The present work is carried out to synthesize the spherical gold nanoparticles by a very simple electrodeposition technique from an aqueous solution of Chloroauric acid. The as prepared gold nanoparticles were characterized by X-Ray diffraction Spectroscopy and scanning electron microscopy for the structural and morphological evolution. The highly uniform and dense spherical Gold nanoparticles with an approximate size of 52 nm were grown on the substrate. By varying different parameters gold nanoparticles of different sizes can be prepared. These gold nanoparticles can be utilized for vast variety of applications such as chemical sensing, medical therapy, in photovoltaic cells, fuel cells, drug delivery, Surface Plasmon Resonance (SPR) etc.

Keywords: Nanoparticles, Electrodeposition, Gold Nanoparticles, Scanning Electron Microscopy.

1. INTRODUCTION

Nanoscience deals with the manipulating and developing of materials at nanoscale level (1 to 100 nm) that shows the size dependent properties like optical, electrical, magnetic and chemical for diverse set of applications in various fields of science and engineering [1]. The bulk properties of materials often changes dramatically when reduced to nanoscale dimensions. Several phenomena become pronounced as the size of the material decreases. This includes statistical mechanical effects as well as quantum mechanical effects. In quantum size effect, the electronic properties of solids are altered with great reductions in particle size. This effect becomes dominant when the particle size of about 100 nm or less is achieved. Surface area is another important aspect of nanomaterials. When the bulk material is compared to the nanoscale materials of the same mass, then the nanoscale materials will have relatively larger surface area. This increase in surface area to volume ratio can make materials more chemically reactive and affect the strength, thermal, electrical, optical properties of materials etc. Metal nanostructures show a vast variety of remarkable chemical and physical properties, which can be altered by changing their size, composition, morphology, and various preparation parameters [2, 3].Over the past few decades Gold Nanoparticles (Au NPs) have attracted considerable attention because of their extensive usage for various applications such as chemical sensing [4,5], catalysation [6], medical therapy [7], size and shape-dependent surface plasmon resonance (SPR) [8], drug delivery [9], electronic [10], Surface Enhanced Raman Scattering [11] and high electrical conductivity properties [12]. Contrary to their bulk counterpart that has constant physical properties irrespective of mass, nanoparticles offer unique opportunities to control the optical, magnetic and electrical properties by modifying their shape and diameter. Considering exponentially increasing demand of Au NPs, far more attention is given to synthesize monodisperse nanoparticles with controllable size and morphology. A wide range of gold nanoparticles including nanospheres, nanorods, nanocages, nanoshells, nanoprisms, nanocubes, and nanorings have been chemically fabricated with high yield [13–18].

Gold Nanoparticles can be prepared from various materials by relatively simple methods. In recent years, several types of methods have been published and reviewed. Piella et al. Synthesized highly monodisperse, biocompatible and functionalizable sub-10-nm citrate- stabilized Au NPs with a control over their sizes between 3.5 to 10 nm to study the size-dependent optical properties in this size regime lying between clusters and nanoparticles [19]. P. Suchomel et al. Prepared Au NPs in the size range of 6 to 22nm by the reduction of tetrachloroauric acid using maltose in the presence of non-ionic surfactant Tween 80 at various concentrations to control the size of the resulting Au NPs. They observed that with increasing the concentration of Tween 80 there was a decrease in the size as well as size distribution of the prepared Au NPs [20]. M.H. Hussain et al. studied the effect of varying polarity index of the reaction medium on the synthesis of Au NPs by chemical reduction method. They used Ethanol as a polar solvent, ethanol–water mixture as reaction medium, L-ascorbic acid as reducing agent, and polyvinylpyrrolidone as stabilizer were used to synthesize Au

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NPs. They observed that the growth of NPs was gradually increased from 22 to 219 nm with decreasing value of polarity index of reaction medium. Furthermore, the high polarity index of the reaction medium produced smaller and spherical nanoparticles, whereas lower polarity index of reaction medium results in bigger size of Au NPs with different shapes [21].

The present research work is an effort to synthesize the gold nanoparticles by using Electrodeposition technique for the uniform distribution of Au NPs on the substrate. Relatively, electrodeposition technique is inexpensive and very simple. By controlling different parameters nanoparticles of very small size and shape can be obtained.

2. EXPERIMENTAL

2.1 Synthesis

Electrodeposition of Au NPs was carried out by immersing Aluminium substrate in an aqueous electrolyte prepared from 1mM $HAuCl_4.H_2O$ at room temperature. The electrodeposition was performed with a two electrode system. The Aluminium substrate was used as the working electrode and graphite rod as a counter electrode. The electrodeposition was carried out at 5V using a supply for the deposition time of 30 minutes at room temperature. After deposition, the samples were dried out in the air.

2.2 Characterization

The X-ray diffraction (XRD) spectra of the as synthesized gold nanoparticles was recorded on a Rigaku D/max-2400, CuKα = 0.154nm X-ray diffractometer. The morphology of the gold nanoparticles were characterized with a JEOL-JSM 6360-A scanning electron microscopy (SEM). To know the Chemical composition of the prepared nanoparticles energy dispersive X-Ray analysis (EDAX) was performed.

3. RESULTS AND DISCUSSIONS

3.1 XRD Analysis

In order to study the crystal structure and crystalline quality of the electrodeposited gold nanoparticles XRD measurements were performed. The XRD spectra confirmed the crystalline nature of the samples.

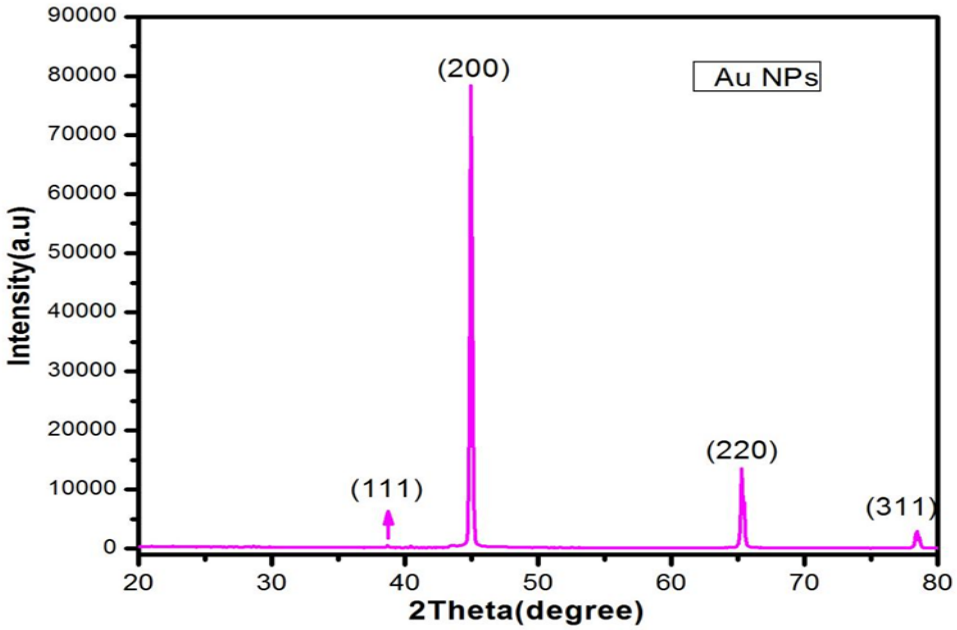

Fig. 3.1. XRD of Au Nanoparticles.

In order to characterize the crystallographic orientation of electrodeposited Au nanostructures, XRD measurements were performed. Fig. 3.1 shows the XRD patterns of Au nanostructures electrodeposited on Aluminium substrate. The peaks at 2θ equal to 44.48^0, 64.64^0, and 77.67^0 match exactly with JCPDS data (File No. 04-0748) of Au respectively. These peaks represent (200), (220) and (311) planes of the Au respectively. Theses peaks are important as they represent the important crystal lattices of Au indicating that the electrodeposited sample consists of pure crystalline Au with face centred cubic (fcc) structure that grow without any strain and compression.

The average crystallite size of the electrodeposited Au NPs was calculated to be around 52nm according to the half width of (200) diffraction peak using Debye Scherrer formula.

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3.2 SEM Analysis

Fig. 3.2 represent the typical beautiful SEM images of as prepared Gold nanoparticles at room temperature with two different magnifications.

The SEM images confirmed the deposition of gold nanoparticles on the Aluminium substrate. The gold nanoparticles are uniformly distributed throughout the aluminium substrate and are spherical in nature. The gold nanoparticles are well defined and uniform in size with no agglomeration.

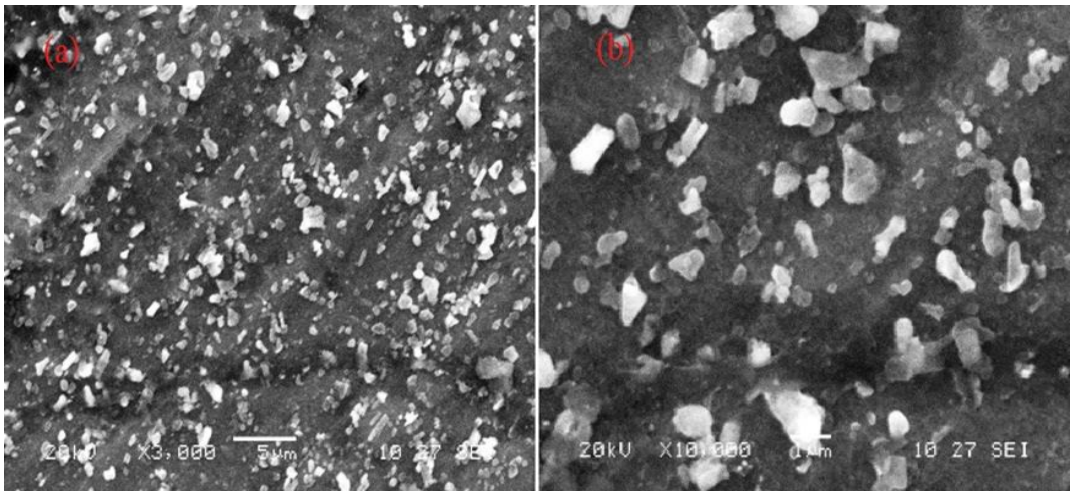

Fig. 3.2. SEM Images of the Au nanoparticles at different magnifications.

3.3 Energy Dispersive X-Ray Analysis (EDXA)

The energy dispersive X-ray analysis (EDXA) was carried out to know the elemental composition of the sample. The EDXA spectrum confirms the presence of elements of Al, Au, Si and O without any impurities. The atomic percentage of Au on the aluminium substrate is 0.03%.

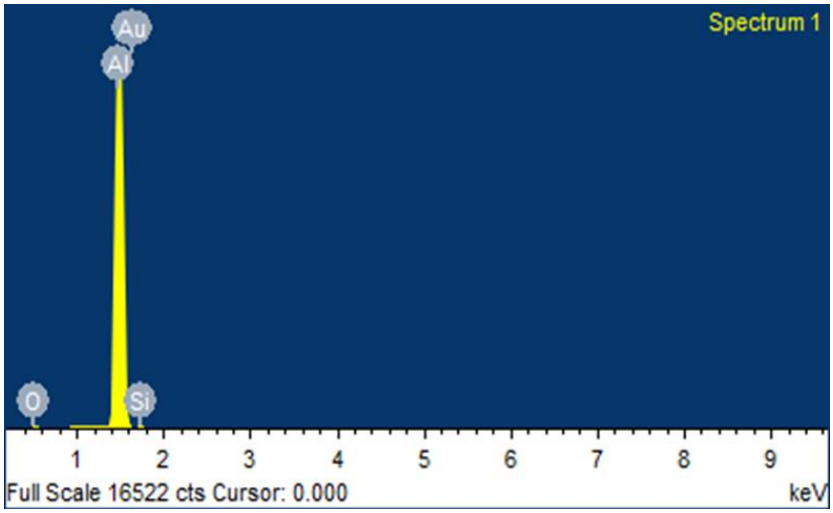

Fig. 3.3. EDX Spectra of Au nanoparticles.

CONCLUSION

Electrodeposition is a very simple and cost effective method of synthesis of Nanoparticles. Highly dense, pure and uniform spherical Gold Nanoparticles of size 52 nm were synthesized. By varying the different parameters Au NPs of very small size can also be obtained. This Electrodeposition method can be used for the uniform deposition of Nanoparticles on any substrate to enhance physical the properties of the materials. The as prepared Gold nanoparticles can be utilized for vast variety of applications such as chemical sensing, medical therapy, in photovoltaic cells, fuel cells, drug delivery, Surface Plasmon Resonance (SPR) etc.

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