Gold Nanoparticles: Fabrication, Modification and Biomedical Applications

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Abstract

Gold nanoparticles (AuNPs) have obtained interest of scientists for many years. Their features exhibit enhanced optical and electromagnetic properties. For this reason, they are mostly applied for biomedical diagnosis and imaging. Besides that, they are being functionalized as a drug delivery system due to their small size. Since, this size gives them possible penetration into hard tissues. Furthermore, they are more suitable for specific targeting to mitochondria and nucleus. Recently, AuNPs can be modified by surface coating or by being doped with different metals. The results enhanced their potential use in many fields especially for plasmon resonance and bio-imaging. In our review, modification of AuNPs was overviewed.

INTRODUCTION

Gold nanoparticles (AuNPs) have been prepared as a suspension in nanoscale bar ranging from 1-150 nm [1]. These nanoparticles contain gold (Au) as a core and surface that could be functionalized later. This advantage draws the feature of nanoparticle versatility enabling them to be synthesized in fine tailoring of the particle size, shape and surface properties [2]. Further, to control their morphology and chemical structure, the surface can be modified to control particle stability, solubility and interaction with the biological environment [3,4]. The possible modification of AuNP surface gives unique properties. Since their surface can easily bind, thiols and amines provides a convenient way to introduce reactive functional groups that can be utilized for contrast agents (e.g. imaging probes), targeting (e.g. antibodies, peptides), and conjugating therapeutic agents (e.g. drugs, radionuclides [5-7] (Figure 1).

In addition to previous descriptions, AuNPs have several properties enabling them to be used in photothermal applications such as plasmon resonance tunability; high photothermal conversion efficiency [8,9], and simple surface functionalization or encapsulation chemistry. AuNPs can be designed in many dimensions such as nanoshells (NSs), nanorods (NRs), nanocages (NCs), and nanostars. This morphology gives AuNPs wide range for applications. For instance, nanospheres and nanorods used for drug delivery system. While nanostars are more efficient for photothermal transducers [10,11].

PREPARATION AND FUNCTIONALIZATION OF GOLD NANOPARTICLES

Reduction of gold by using citrate is a common method can be used to fabricate AuNPs. Since, citrate acts as both reducing and stabilizing agent. This method has been applied to fabricate stable spherical AuNPs with diameters of 10 to 20 nm [12]. However, irreversible reaction can be done resulting in aggregation. Many strategies introduced to control AuNPs during fabrication including to add a surfactant Tween 20, or to use thioctic acid as an intermediate [13].

Recently, green photosynthesis of gold nanoparticles has been emerged using extract of Baker’s yeast. By identification of metabolites of Baker’s yeast, many nanomaterials might be synthesized. Gold nanoparticles were further functionalized by polyethylene glycol and then used to encapsulate doxorubicin [14]. Moreover, transferring attached AuNPs was tested in breast cancer resulting in higher cellular uptake. Also gallic acid capped with AuNP produced phytochemical reduction of breast cancer [15]. AuNPs functionalized with curcumin have been recently introduced with clear drug efficiency [16]. Moreover, by using thiol bond, AuNP functionalized by oligonucleotide and then being derived into cancer cells [17].

APPLICATIONS OF GOLD NANOPARTICLES

Imaging

Gold nanoparticles can be used widely in medical bio-imaging due to their good contrast. For this reason, they are applied for...
computed tomography (CT) [18], Dark-field light scattering [19], optical coherence tomography (OCT) [20], photothermal heterodyne imaging technique [21], and Raman spectroscopy [22]. It was demonstrated that, the feasibility of AuNPs could enhance the in vivo vascular contrast in CT imaging [23]. Further, immuno-targeted AuNPs was designed to selectively target tumor specific antigens [24]. In more advancement, a prostate specific membrane antigen aptamer has been conjugated AuNPs and then used to establish a molecular CT image for the specific imaging of prostate cancer cells [25]. Gold nanoparticles also designed to prepare surface-enhanced Raman scattering nanoparticles for small-animal Raman imaging [26,27].

Cancer treatment

Gold nanoparticles have been demonstrated as important carriers for the creation of transfection agents in gene therapy to cure cancer and genetic disorders [28]. It has studied the use of AuNP oligonucleotide complexes as intracellular gene regulation agents for controlling protein expression in cells. In this therapeutic way, the cationic AuNPs can be used for DNA transfection. Lysine-based motif coating AuNPs provided effective non-toxic transfection vectors for DNA delivery. Their efficiency reached to more than 28 times compared to polylysine [29].

Electrochemical biosensors

Gold nanoparticles are useful in electrochemical bioassays, in particular to connect enzymes to electrode surfaces, mediate electro-chemical reactions as redox catalysts and amplify recognition signals for biological processes [30]. Their first use as labels for immune-sensors was reported by the group of Degrand and Limoges [31], which was followed by hundreds of electrochemical bioassay articles including excellent reviews [32,33].

Sensing and memory devices

Gold nanoparticle have been functionalized by using calixarene derivatives, crown ethers DNA and peptides to enable them to recognize amino acids, quaternary ammonium ions and pyridinium [34]. In advanced work, Indium tin oxide electrode modified with gold nanoparticles/TiO2 composites can be used to estimate catechol and hydroquinone [35]. Recently, gold nanoparticles can be applied as memory devices. Since, gold nanoparticles coated with suitable insulator exhibit excellent stability for memory devices and this insulation helps in prevention of accumulation of charges when the applied field has been removed [36-38].

CONCLUSION

Gold nanoparticles exhibit good physical and chemical properties enabling scientists to use them in a wide range of applications. AuNPs can accept the modification to be established as biosensor, bio-contrast for medical imaging and bio-device for memory. Further, they can be used as drug delivery system with limitation due to their not biodegradation.

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AUTHOR CONTRIBUTIONS

Fatma Sami El-banna designed the paper, generated figure and wrote the manuscript; Magdy Malouf corrected the manuscript.
Maged El-Kemary revised the manuscript; Nemany Abdel hamid Nemany Hanafy supervised and revised the manuscript.

REFERENCES

