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Review

# "Gold rush" in modern science: Fabrication strategies and typical advanced applications of gold nanoparticles in sensing

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ABSTRACT

Gold nanoparticles (AuNPs), the huge potential functional nanoparticles in scientific research, have attained tremendous interest for their unique physical–optical property since they have been discovered. They have been very popularly used as labels in diagnostics, sensors, etc. The use of AuNPs in sensor fabrication is widespread, and so many papers have been reported over the past years. The development of AuNPs used in sensor has been reviewed in some previous papers. Most of them tend to review a certain kind of analyte using one kind of technique. However, few of these reviews include the detection of inorganic and organic contaminant, as well as biomolecules at the same time. Besides, the development for AuNPs application is very fast in modern science. Therefore, in this review we summarize some recent progresses made in the field of AuNPs research. We summarize the typical synthetic strategies of AuNPs, classify the mechanism analysis of AuNPs-based sensors, and expound the role of AuNPs in these sensors. Typical advanced examples of the newly developed AuNPs-based colorimetric and electrochemical sensors and their applications in detection of various analytes, including biomolecules, metal ions, and organic environmental hormones are presented and discussed.



**Contents**



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## 1. Introduction

Recently, nanomaterials are emerging as revolutionizing materials of research with multiple disciplines of science like physics, chemistry, materials, medical science, and biology [1–8]. Gold nanoparticles (AuNPs), one kind of promising functional nanomaterial, have gained increasing scientific interests since the potable gold was found and believed to have excellent medicinal properties by Paracelsus in 4th century A.D [9,10]. However, the real scientific research on gold sol did not start until the gold hydrosols have been discovered by Michael Faraday in 1857 [11]. Later, people showed great interest in investigating the color, shape, size, synthetic strategies, optical property, and applications of AuNPs [12–15]. It can be viewed as a "gold rush" in modern science.

AuNPs can be the remarkable scaffold for novel biological and chemical sensors owing to the fascinating electrical, chemical, optical, and catalytic properties like easy synthesis, high surface-to-volume ratio, high extinction coefficients, strong distance dependent optical features, and excellent biocompatibility, as well as the characteristic of suitable surface functionalization [16–20]. Number of papers concerning the keywords "gold nanoparticles + detection" on indexed journals are increasing year by year and account for approximately one-fifth of all "gold nanoparticles" in the past twenty years (Fig. 1). Many excellent reviews have been published on the use of AuNPs as sensor. For example, Kim et al. reported a review about the fluorescent and colorimetric sensors for detection of three heavy metal ions and mentioned some typical sensors based on AuNPs [21]. Pingarron et al. reported a paper concerning AuNPs-based electrochemical biosensors, which discussed the application of AuNPs-based electrochemical enzyme biosensors, immunosensors, and DNA biosensors [22]. Recently, some papers reviewed the application of AuNPs on metal ions, anions, small molecules, proteins, and nucleic acids using various techniques [23–28]. However, most of these reviews tend to describe a certain kind of material or use one kind of technique. Few of them describe the inorganic and organic contaminants, as well as biomolecules at the same time. In addition, the new review of AuNPs is very necessary for its rapid development in recent years.

As the development of nanotechnology, more and more papers focus their attention on detecting different kinds of substances simultaneously, as well as using not only one analytical technique [29,30]. In addition, the development for the application of AuNPs is very fast and the reports of AuNPs-based sensors are increasing enormously [31]. Therefore, this review presents a brief overview on the recent advances of AuNPs in relation to the fabricating strategies and typical advanced applications on the development of chemo- and bio-sensors for metal ions, anions, biomolecules, and organic environmental hormones using colorimetric and electrochemical techniques. Because of the explosion of papers published in this field, we could not mention all of the published reports, but rather a description and summary of these methods are discussed. On the other hand, the application of AuNPs-based sensor on colorimetric detection is a relative independent part, which uses the optical properties of collective oscillation of electrons on surfaces for AuNPs (known as the "surface plasmon resonance", SPR or "localized surface plasmon resonance", LSPR) and their color change [32–34]. The typical application using the properties of good catalysis, huge specific surface area, and wonderful electron transfer is located in electrochemical sensor [35,36]. Other applications of AuNPs-based sensors such as fluorescence sensor and micro-electronic balance sensor are not mentioned here.

Thus, the purpose of this review is to investigate the synthetic strategies for AuNPs and to derive some general strategies with the basic understanding of sensing application, to summarize the results of their basic properties in a vast variety of applications on chemical, environmental, and medical science, and finally, also

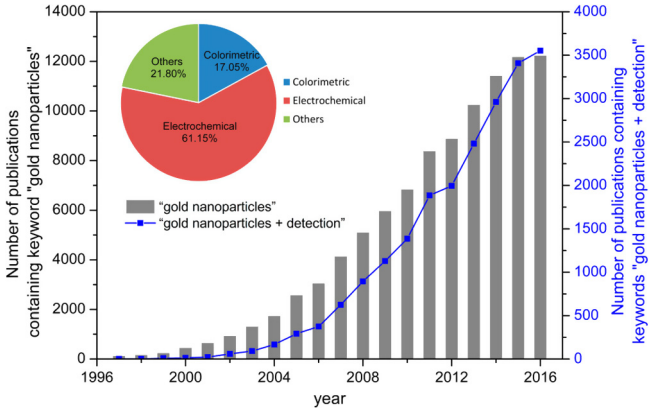


**Fig. 1.** Evolution of the number of publications concerning the keywords "gold nanoparticles" and "gold nanoparticles + detection" on indexed journals between 1997 and 2016. The insert pie graph exhibits the percentage of the available scientific reports which concerned the AuNPs-based sensors using different techniques from 1997 to 2016. The data comes from the research on "web of science".