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Saudi Pharmaceutical Journal

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REVIEW ARTICLE

Biopharmaceutical applications of nanogold

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Received 10 February 2010; accepted 4 May 2010

Available online 24 July 2010

KEYWORDS

Gold;
Nanotechnology;
Nanogold;
Drug delivery;
Gold catalysis

Abstract The application of nanogold in biopharmaceutical field is reviewed in this work. The properties of nanogold including nanogold surface Plasmon absorption and nanogold surface Plasmon light scattering are illustrated. The physical, chemical, biosynthesis methods of nanogold preparation are presented. Catalytic properties as well as biomedical applications are highlighted as one of the most important applications of nanogold. Biosensing, and diagnostic and therapeutic applications of gold nanoparticles are evaluated. Moreover, gold nanoparticles in drugs, biomolecules and proteins' delivery are analyzed. Gold nanoparticles for the site-directed photothermal applications are reviewed as the most fruitful research area in the future.

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1. What is nanogold?

The term nano originates from the greek word “nanos” which means dwarf or small. When nano is used as a prefix it means one billionth part of (10^{-9}). In nanotechnology, nano refers to things in the range of 1–100 nanometers (abbreviated as nm) in size. Atoms are less than one nm in size; molecules and cells vary in size from one to several nanometers. One definition of nanogold is that it concerns itself.

2. Properties of nanogold

2.1. The nanogold surface plasmon absorption

A strong absorption band in the visible region is shown with gold nanoparticles when the frequency of the electromagnetic field is resonant with the coherent electron motion, which is called surface plasmon resonance absorption (Ivan et al., 2005). Interaction with the electric field results in a polarization of the electrons with respect to and relative to the ionic core of a nanoparticle (Fig. 1). The dipole oscillations of the free electrons with respect to the ionic core of a spherical nanoparticle result in the so-called surface plasmon absorption (Stephan and Mostafa, 2003). When the frequency of the electromagnetic field becomes resonant with the coherent electron motion, a strong absorption band around 520 nm in the spectrum is observed, which is the origin of the observed brilliant color of the nanoparticles in solution (Gustav and Mie, 1908).

The peak intensity and position of the surface plasmon absorption band are dependent on the size, the shape of nanoparticles and the dielectric constant of the metals as well as the medium surrounding the particles (Stephen and Mostafa, 2000). As the size increases, the absorption maximum is red

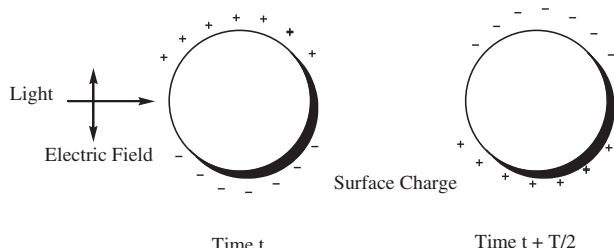


Figure 1 A scheme of surface plasmon absorption of spherical nanoparticles illustrating the excitation of the dipole surface plasmon oscillation.

shifted slightly. Link and El-Sayed (Stephen and Mostafa, 1999) have shown that the bandwidth decreases with the increase of the nanoparticles' size particularly when the nanoparticles are lesser than 20 nm in diameter. On the other hand, the bandwidth increases with the increase of the nanoparticles' size when the nanoparticles are larger than 420 nm. They also found that the absorption coefficient is linearly dependent on the volume of the nanoparticles which is in agreement with the Mie theory (Gustav and Mie, 1908).

2.2. The nanogold surface plasmon light scattering

Upon illumination by a white light beam, the gold particle suspensions scatter colored light (Stephen and Mostafa, 2004). The suspensions of light-scattering nanogold particles show appearance similar to fluorescent solutions (Yguerabide, 1998). The light scattering is sensitive to the size, the shape and the composite of the nanoparticles. Nanoparticles of 58 nm diameter scatter green light while those of 78 nm diameter scatter yellow light and gold nanorods scatter red light under illumination of a beam of white light (Sönnichsen et al., 2002).

3. Nanogold preparation methods

3.1. Physical methods

Laser ablation method is used to produce gold nanoparticles by using the pulsed laser irradiation of gold target in water in the absence of any additives, at (532 nm, 10 ns, 10 Hz), or (266 nm) wavelengths (Ko et al., 2006). Inert gas condensation can be used for the preparation of gold nanoparticles (Lee et al., 2005). In this method, the gold nanoparticles as soon as they are formed rapidly collide with inert gas in a low-pressure environment and thus smaller and controlled nanoparticles are formed. The advantage of these methods is the narrow particle size distribution of the produced gold nanoparticles, while its limitation is the need for expensive equipment. Other physical methods such as thermolysis of gold(I) complex at 180 °C for 5 h under nitrogen atmosphere (Yamamoto and Nakamoto, 2003), radiolysis of gold salts in aqueous solution using γ -irradiation-induced reduction in the field of a ^{60}Co γ -ray source (Henglein and Meisel, 1998; Dawson and Kamat, 2000), photochemistry, e.g. in the HAuCl_4 solution containing certain amounts of protective agent and acetone, the colloidal gold particles with an average

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