Synthesis of Gold Nanorods for Multifaceted Applications

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Introduction

The unique size- and shape-dependent optical and thermal properties of gold nanoparticles (AuNPs), as well as versatility of their functionalization and targeting, make them valuable tools in a variety of scientific and technological fields for a wide range of applications, including diagnostics, drug delivery, imaging, sensors development, and synthesis of organic compounds [1–3].

Among AuNPs, gold nanorods (AuNRs) are in high demand due to the tunability and sensitivity of their longitudinal surface plasmon resonance [4,5]. The anisotropic AuNRs structure displays two surface plasmon bands, corresponding to surface electron oscillation on transverse and longitudinal sides [6]. Typically, a two-step synthesis process using surfactants and seed particles, where gold seeds are prepared and then added to the growth solution, is used. Researchers continue to explore new applications for these nanomaterials, making them an active area of research and development [7].

The main aim of this study was to synthesize AuNRs of different lengths using the seed-mediated method. The obtained AuNRs were characterized using diffrent techniques. The width and length of AuNRs was defined using SEM, the hydrodynamic size was defined by DLS technique, and absorbance spectra were recorded. The evaluation of morphology and properties of AuNRs provided a deeper understanding of the synthesis and possible applications of nanoparticles.

Synthesis of AuNRs

The seed solution of shorter gold nanorods was prepared using the seed-mediated synthesis method. 1 mL 0.2 M CTAB solution was mixed with 1 mL 5 mM $HAuCl_4$ and placed in a thermostat at 35 °C for 5 min. Cold 800 μL 0.01 M $NaBH_4$ solution was poured into a warm mixture and the final solution was left at 35 °C for 1 hour. The growth solution was produced by combining 5 mL of 0.2 M CTAB and 5 mL 1 mM $HAuCl_4$ solutions. Then 160 μL 5 mM $AgNO_3$ solution was added to the warm mixture. After slowly pouring 55 μL 0.1 M ascorbic acid into the mixing solution, the liquid became transparent. The final solution was left in a thermostat at 35°C for 5 min. Finally, 12 μL of the seed solution was slowly added to the growth solution and incubated at 35 °C for 24 h. After incubation, the gold nanorods solution was centrifuged at 7000 rpm for 20 minutes. Then it was washed with 10 mL 0.1 M CTAB solution twice. Afterwards, 5 mL 0.1 M CTAB was added to the final product.

The seed solution of longer gold nanorods was also prepared using the seed-mediated synthesis method. 2.4 mL 0.01 M $HAuCl_4$, 960 μL, 0.02 M $AgNO_3$, and 270 μL 1 M HCl were mixed. Then 720 μL 0.33 M hydroquinone was slowly dropped into the solution and the mixture was left in a thermostat at 35° C for 5 min. After incubation, 3 mL 0.5 mM $NaBH_4$ solution was added. The longer gold nanorods solution was centrifuged at 6000 rpm for 20 min and washed 3 times with a 0.1 M CTAB.

Results

SEM analysis

Figure 1 shows the appearance of the AuNRs. The dimensions of the shorter nanorods were 35.7 ± 3.8 nm in length and 12.2 ± 1.0 nm in width. The longer nanorods had a length of 94.4 ± 12.1 nm and a width of 15.4 ± 2.4 nm.

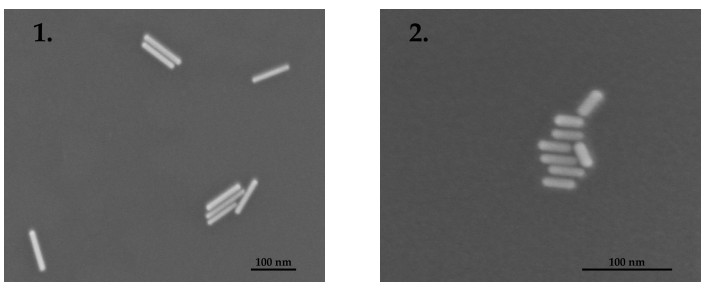

Figure 1. SEM images of (1) longer and (2) shorter AuNRs.

UV-Vis and DLS analysis

For both types of AuNRs, two peaks are visible. The absorption maximum occurs at wavelengths of 524 and 718 nm for short and 529 and 1270 nm for long AuNRs.

According to the results of the DLS analysis, the hydrodynamic sizes of AuNRs are 1.3 and 37.8 nm, 4.8 and 32.7 nm for short and long AuNRs, respectively.

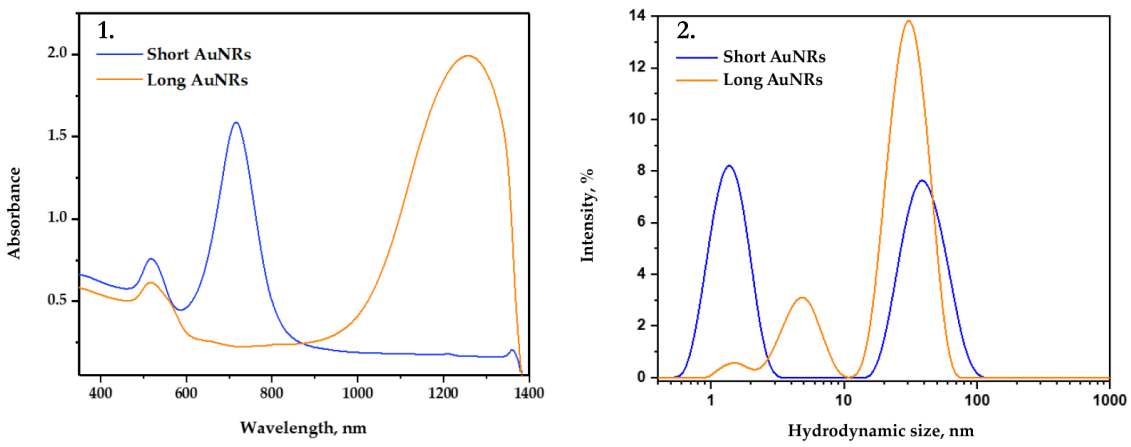

Figure 2. UV-Vis absorbance spectra (1) and size distribution by DLS (2) of short and long AuNRs.

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