chemistry proceedings

MDPI

Proceeding Paper

Synthesis of Gold Nanorods for Multifaceted Applications †

Marina Sidorova * and Anton Popov *

Nanotechnas—Center of Nanotechnology and Materials Science, Faculty of Chemistry and Geosciences, Vilnius University, Vilnius, Lithuania; marinasidorova@chgf.stud.vu.lt (M.S.); anton.popov@chgf.vu.lt (A.P.)

† Presented at the 27th International Electronic Conference on Synthetic Organic Chemistry (ECSOC-27), 15–30 November 2023; Available online: https://ecsoc-27.sciforum.net/.

Abstract: Different length gold nanorods (AuNRs) were synthesized using a seed-mediated method. The obtained AuNRs were characterized using scanning electron microscopy (SEM), dynamic light scattering (DLS) technique, and UV-Vis spectroscopy. These techniques allowed a detailed study of the structural and optical properties of the AuNRs and provided valuable insight into the synthesis. The characterization results were crucial to guide the synthesis and to further understand the potential applications of AuNRs.

Keywords: nanoparticles; nanostructures; synthesis; gold nanorods

Citation: Sidorova, M.; Popov, A. Synthesis of Gold Nanorods for Multifaceted Applications. **2023**, *14*, x. https://doi.org/10.3390/xxxxx

Academic Editor(s): Name

Published: 15 November 2023

1. 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 different methods. 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.

2. Results and Discussion

2.1. SEM Analysis

AuNRs were synthesized via seed-mediated method. In order to perform the imaging procedure, both samples of shorter and longer nanorods were diluted 10 times. The SEM images are presented in Figure 1.

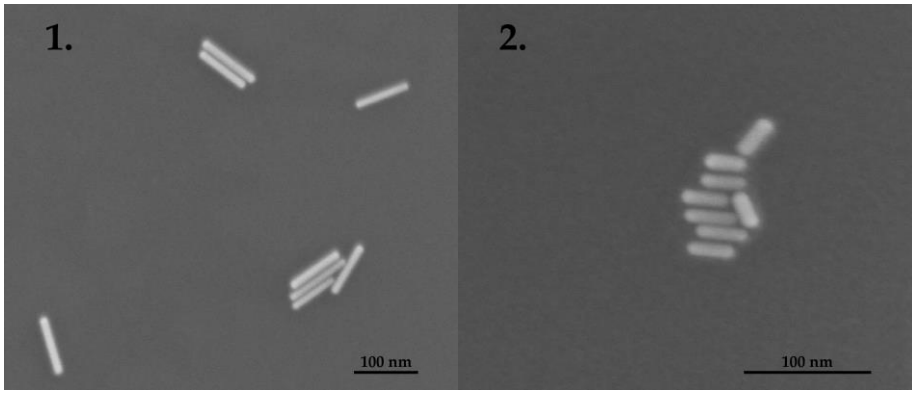

Figure 1. SEM images of (**1**) longer and (**2**) shorter AuNRs.

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. These observations indicate that the length of AuNRs is different by a factor of three, while the width of both types of AuNRs is relatively the same.

2.2. UV-Vis Analysis

Before recording the absorption spectra of AuNRs, samples were diluted 10 times. Figure 2 shows the UV-Vis absorption spectra of short and long AuNRs.

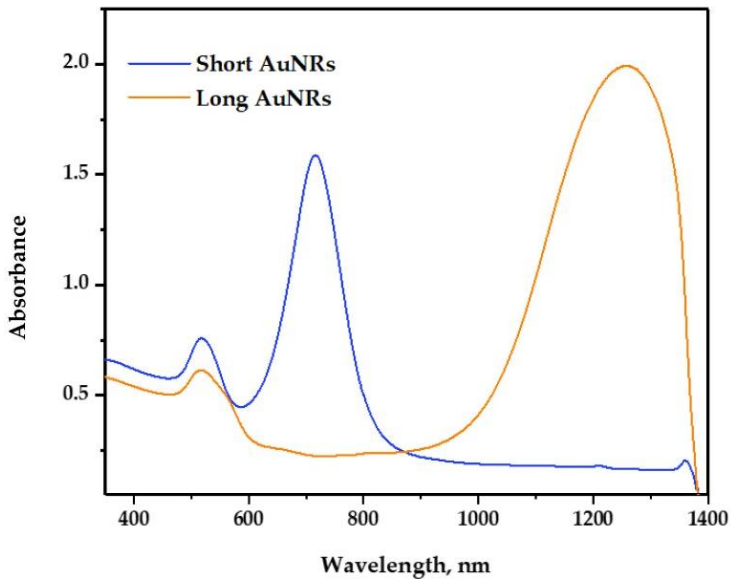

Figure 2. Absorbance spectra of short and long AuNRs.

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. Gold nanorods have two surface plasmon resonance modes: transverse and longitudinal. The transverse surface plasmon resonance, due to an electronic oscillation across the width of the rod, is basically of the same type as the plasmon resonance of simple gold nanospheres. It peaks at approximately 520 nm and is comparatively weak. However, the longitudinal mode yields a much larger extinction coefficient and is due to the oscillation of electrons in the longitudinal direction of the rod. It occurs at longer wavelengths than the transverse resonance [8].

2.3. DLS Analysis

DLS analysis was done in order to define the hydrodynamic size of AuNRs. DLS results are presented in Figure 3.

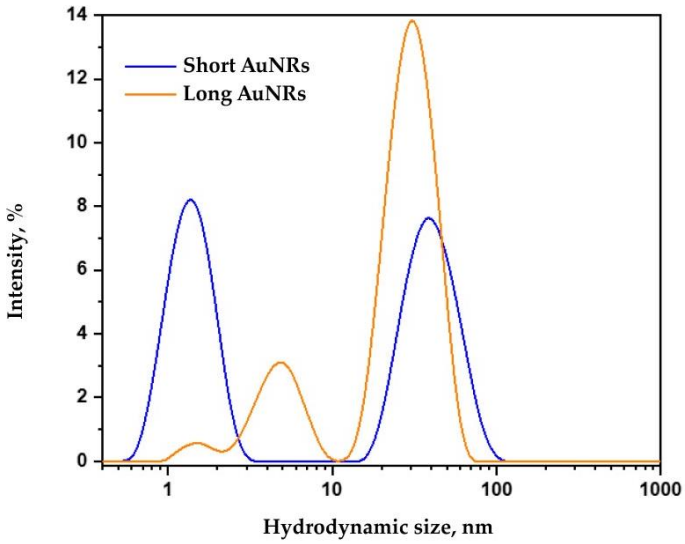

Figure 3. Short and long AuNRs size distribution by DLS.

According to the results of the DLS analysis, the hydrodynamic sizes of AuNRs is 1.3 and 37.8 nm, 4.8 and 32.7 nm for short and long AuNRs, respectively. The measured values do not reflect the true hydrodynamic size of AuNRs. These peaks are believed to be due to rotational diffusion in the AuNRs samples and are independent of either the length or the width. These peaks indicate that the AuNS exhibit a rotational diffusion coefficient characteristic of the corresponding spherical nanoparticles [9].

3. Materials and Methods

3.1. Seed Solution Preparation

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 h. 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 min. 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.

3.2. Materials Characterization

Morphology of the gold nanorods were defined using data, obtained by scanning electron microscopy (SU-70; Hitachi, Tokyo, Japan). The absorbance spectra of AuNRs were ascertained using a UV-Vis spectrometer (UV-1900i, Shimadzu, Japan). Measurements were performed in the wavelength range from 350 to 1400 nm. The hydrodynamic sizes were measured with the Zetasizer Nano ZS (Malvern, Herrenberg, Germany).

4. Conclusions

Shorter and longer nanorods were synthesized using different methods. The length was 35.7 ± 3.8 nm and 94.4 ± 12.1 for shorter and longer nanorods, respectively. The width of shorter nanorods was 12.2 ± 1.0 nm and longer nanorods were 15.4 ± 2.4 nm, respectively. The following results suggest that produced AuNRs are suitable for further application and investigation.

Author Contributions: Conceptualization, M.S. and A.P.; methodology, M.S. and A.P.; validation, M.S. and A.P.; formal analysis, M.S. and A.P.; investigation, M.S.; resources, A.P.; data curation, M.S. and A.P.; writing—original draft preparation, M.S. and A.P.; writing—review and editing, M.S. and A.P.; visualization, M.S. and A.P.; supervision, A.P.; funding acquisition, A.P. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data supporting the findings of this study are available within the paper and from the corresponding authors upon request.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Arvizo R.; Bhattacharya, R.; Mukherjee, P. Gold nanoparticles: Opportunities and challenges in Nanomedicine. *Expert Opin Drug Deliv.* **2010**, *7*, 753–763.
2. Siddique S; Chow, J.C.L. Gold nanoparticles for drug delivery and cancer therapy. *Appl. Sci.* **2020**, *10*, 3824.
3. Ferrari E. Gold nanoparticle-based Plasmonic Biosensors. *Biosensors* **2023**, *13*, 411.
4. Amendola V; Pilot, R.; Frasconi, M.; Maragò, O.M.; Iatì, M.A. Surface plasmon resonance in gold nanoparticles: A review. *J. Phys. Condens. Matter.* **2017**, *29*, 203002.
5. Cao, J.; Sun, T.; Grattan, K.T.V. Gold nanorod-based localized surface plasmon resonance biosensors: A review. *Sens. Actuators B Chem.* **2014**, *195*, 332–351.
6. Wu, H.Y. Chu, H.C.; Kuo, T.J.; Kuo, C.L.; Huang, M.H. Seed-mediated synthesis of high aspect ratio gold nanorods with nitric acid. *Chem. Mater.* **2005**, *17*, 6447–6451.
7. Kesharwani P; Ma, R.; Sang, L.; Fatima, M.; Sheikh, A.; Abourehab, M.A.S.; Gupta, N.; Chen, Z.-S. Gold nanoparticles and gold nanorods in the landscape of cancer therapy—Molecular cancer. *Mol. Cancer* **2023**, *98*, 22.
8. Kelly, K.L.; Coronado, E.; Zhao, L.L.; Schatz, G.C. The optical properties of metal nanoparticles: The influence of size, shape, and dielectric environment. *J. Phys. Chem.* **2003**, *B107*, 668–677.
9. Takahashi, K.; A Kramar, J.; Farkas, N.; Takahata, K.; Misumi, I.; Sugawara, K.; Gonda, S.; Ehara, K. Interlaboratory comparison of nanoparticle size measurements between NMIJ and NIST using two different types of dynamic light scattering instruments. *Metrologia* **2019**, *56*, 055002.