Aggregation of Gold Nanoparticles Induced by Amino Acids: Enhancement of Colorimetric Response by Cu²⁺

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Abstract

Gold nanoparticles have an optical property that depends on the interparticle distance, and thus their aggregation can cause a noteworthy color change of the dispersion. This study investigated *the aggregation of gold nanoparticles caused by various amino acids* in order to develop a strategy for *colorimetric detection of a biological reaction*. We examined the colorimetric response of gold nanoparticles with varying concentrations of cysteine, cystine, arginine, aspartic acid, serine, and methionine solutions. The results demonstrated *gradual color changes* with increasing concentrations of **cysteine** but did not exhibit a noticeable change for other amino acids. We explored *the effect of the nanoparticle size on the cysteine-induced aggregation* and a smaller gold nanoparticle showed a lower detection limit than a larger one. Additionally, *the sensitivity of the colorimetric response was significantly increased by adding Cu²⁺* to the examined dispersions due to the chelate formation between the metal ion and surface-immobilized cysteines. The overall results demonstrate that the highly sensitive aggregation of gold nanoparticles caused by cysteine in the presence of Cu²⁺ ion has the potential to be used for *selective chemical and biological sensing for specific analytes*.

Colorimetric Detection of Cysteine

- The *disulfide linkage* between thiols groups of **cysteine** residues is an essential component of the secondary and tertiary structures of proteins, which define *the biological function of the proteins*.
- The *neurotoxicity* of excess cysteines has been proven, and cysteine deficiency can *impair immune system* and cause *metabolic disorder* → *a simple but rapid detection method for cysteine is required*.
- The *colorimetric response of gold nanoparticles caused by cysteine* can be used to *detect cysteine itself* and also indirectly *monitor other biological activities*.

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Colorimetric Responses of Gold Nanoparticles to Various Amino Acids

Sensitive Color Change
- Covalent Bond
cysteine

Moderate Color Change
- Ionic
aspartic acid

No Color Change
- Neutral
cysteine

Aggregation of Gold Nanoparticles by Cysteine

Zwitterionic Attraction

without Cu²⁺

Chelate Formation

with Cu²⁺

Size Controlled Synthesis of Gold Nanoparticle

SEM images of gold nanoparticles prepared with various mole ratios of citrate/gold salt concentrations (a) 0.5, (b) 3.0, (c) 5.0, (d) 12.0, and (e) 16.0.

Stability of Gold Nanoparticles

Gold nanoparticles prepared with citrate/Au³⁺ = 0.5, 3.0, and 5.0 did not show a distinct aggregation during one month period.

Colorimetric Responses of Gold Nanoparticles

Cysteine concentrations: (a) 0, (b) 0.1, (c) 0.2, (d) 0.4, (e) 1, (f) 10, (g) 100, (h) 200, (i) 500, (j) 1,000, (k) 10,000, (l) 20,000 μM.

The gold nanoparticles at 3 X 10¹¹ particles/mL exhibited the most distinct color change.

Colorimetric Response Improved by Cu²⁺

The addition of Cu²⁺ significantly improved the sensitivity of colorimetric response of gold nanoparticles to cysteine.

Conclusions

- Gold nanoparticles** demonstrated the potential to be used to selectively and semi-quantitatively *detect cysteine through their colorimetric response*.
- A *smaller gold nanoparticle* (26.5 nm) exhibited *a higher sensitivity* of the colorimetric response to cysteine than a larger one (46.5 nm).
- The addition of **Cu²⁺** greatly *facilitated the cysteine-induced aggregation of gold nanoparticles*, resulting in the distinct color change with a lower concentration of cysteine.

Future Works

- The **pH effect** on the cysteine-induced aggregation of gold nanoparticles will be investigated.
- The **size dependency** of the colorimetric response of gold nanoparticles to cysteine will be explored more systematically.
- The *colorimetric response of gold nanoparticles caused by cysteine* will be applied *to develop a biological sensor to monitor a virus*.

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