Introduction

• Metal nanoparticles with high near-IR absorbance are of interest in biomedical imaging and therapy – soft tissues are relatively transparent to a NIR range of 650-950 nm [1].
• Gold is an inert metal thus can safely be used for short times in the body.
• The surface plasmon resonance (SPR) of spherical gold particles undergoes a red shift to NIR when packed into dense asymmetrical nanoclusters.

Nanocluster Formation

\[ V_{\text{total}} = V_{\text{electrostatic}} + V_{\text{VDW}} + V_{\text{hydration}} \]

• Kinetic assembly of the nanoclusters may be controlled by manipulating the total interaction potential, \( V_{\text{total}} \) [1].
• The addition of the zwitterionic ligand – lysine – weakens the electrostatic repulsion of citrate-capped Au primary particles.
• However, it is difficult to control the balance between van der Waals (VDW) attraction and electrostatic repulsion.
• Addition of weakly adsorbing polymer reduces electrostatic repulsion via charge screening; also manipulates depletion-attraction potential and provides steric stabilization of resulting clusters.

• Solvent evaporation increases the volume fraction (\( \Phi \)) of Au particles and polymer in solution thereby increasing their interaction and resulting in the formation of nanoclusters.

Objective

• Form ~40 nm Au nanoclusters that show good NIR absorbance.
• Clusters must biodegrade, in cellular environment at pH 5, to 3-5 nm primary particles with low surface negative charge to eliminate protein adsorption and maintain efficient renal clearance.

Methods

Color of final primary gold particle solution

TEM image of an Au nanocluster formed with a 9/1 lysine/citrate molar ratio, 20/1 polymer/Au weight ratio, after 50% evaporation.

• Primary gold nanoparticles capped with citrate ligands were synthesized by an established procedure [1].
  • Briefly, HAuCl\(_4\) was added to DI H\(_2\)O at 97°C under stirring, after which sodium citrate and sodium borohydride were added in 1 min intervals. After 5 mins, solution was cooled and gold particles were removed by centrifugation at 4°C.
  • Primary particles were stirred with a lysine solution for 15 mins at RT; polymer solution was then added iteratively over time.
  • After solvent evaporation, nanoclusters were isolated through centrifugation.

Results and Discussion

Size and Optical Properties

UV-Vis

• Nanoclusters of ~45 nm successfully assembled under conditions of a 9/1 lysine/citrate molar ratio, 20/1 polymer/Au weight ratio, and 5 iterations of polymer solution added to the Au solution over 10 min.

Degradation

• Nanoclusters degraded to ~4 nm particles when placed in pH 5 HCl solution over 48 hrs.
  • Zeta potential (surface charge) dropped to -4.4 mV, decreasing chance of protein adsorption.

Future Work

• Conjugate antibody probe molecules to the clusters, enabling targeting of specific cellular molecules and enhancing the efficiency of the bioimaging technique [3].

References


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Conclusions

• Successful assembly of Au nanoclusters with strong NIR absorbance.
  • Kinetic assembly process controlled by manipulation of interaction potential between Au particles, through addition of polymer.
  • Resulted in dense ~40 nm clusters with close spacing between Au nanoparticles, giving strong NIR shift of surface plasmon resonance.
• Nanoclusters demonstrated biodegradation in a cellular pH 5 environment.
  • Low negative surface charge on degraded primary particles decreases protein adsorption.

24 hours 96 hours 168 hours

Spectra of cells treated with nanoclusters over time. Illustrates both the strong imaging contrast provided as well as degradation [2].

24 hours 96 hours 168 hours