Optimization of Gold Nanoplate Synthesis for Theranostic Applications

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Statement of Purpose: Gold nanoplates offer tremendous potential for theranostic applications due to several beneficial properties such as non-toxicity and ease of functionalizing with proteins and oligonucleotides for a variety of biomedical applications (Pelaz, B., Langmuir 2012; 28: 8965-8970). The sharp edges of the nanoplates lead to an intense localized surface plasmon resonance (LSPR) field in the near infrared (nIR) region that can be utilized for imaging and plasmonic heating of biological tissue; while, their large flat surface area allows for good thermal contact with other surfaces. The nIR LSPR wavelength and bandwidth for a nanoplate sample is tunable by varying the geometric parameters of the plates (edge length, plate thickness, and "snipping" of vertices) as well as the degree of polydispersity within the sample. Carefully regulating fabrication conditions enables the control of these geometric parameters. Traditional gold nanoplates synthesis methods based-on gold salts and sulfur-based reducing agents are plagued by high polydispersity and colloidal contamination from small gold colloid seeds that do not mature into larger nanoplate structures (diameter = 2-10 nm), and psuedo-spheroid gold particles (diameter ≅ 30 nm) (Schwartzberg, A. M., J. Phys. Chem. C 2007; 111: 8892-8901). The goal of this research is to develop synthesis techniques that maximize the yield of nIR nanoplates, and increase LSPR tunability of the samples.

Methods: Gold nanoplates were synthesized from chloroauric acid and sodium thiosulfate in DI water using the DiaSynth technique, which involves combining an appropriate amount of each reagent within a cellulose acetate membrane (CAM) and dialyzing the reaction mixture against DI water for 1 hr. The amounts of reagents, reaction temperature, molecular weight cut-off of the CAM, and surface-to-volume ratio of the CAM to reaction mixture were varied experimentally. The raw nanoplate sample was then subjected to either sedimentation or gel electrophoresis. Sedimentation experiments were carried out by allowing the nanoplate sample to sit undisturbed for up to 72 hrs. The supernatant was removed and the pellet redispersed in DI water. Gel electrophoresis was performed after coating the nanoplates with PEG-SH (MW = 2kDa) by applying 100V to an agarose gel using TBE as the elution buffer. The separate particle bands were cut from the gels using a razor blade, the gel was digested with GELase (Epicentre) enzyme, and centrifuged to separate.

Results: The DiaSynth process has been shown to effectively eliminate small colloidal gold seeds from the product mixture through selective adsorption of the colloids onto the CAM. This process predominantly yields 30 nm pseudo-spheroid particles (weak LSPR near 530 nm) and nanoplates displaying an intense nIR absorption band between 650-1050 nm, Figure 1. Sedimentation experiments resulted in settling of nanoplates, primarily, to the bottom of the sample holder for easy isolation. The nanoplates had very little colloidal contamination as evidenced by the lack of absorbance at 530 nm (LSPR of colloidal gold). The LSPR wavelength of the nanoplates was highly tunable throughout the nIR region, Figure 1 inset.

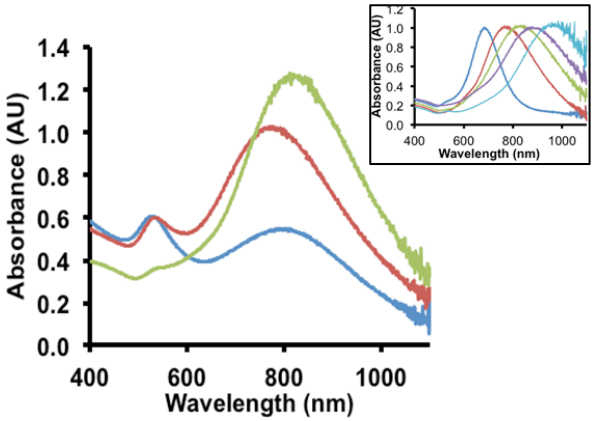

Figure 1. UV-visible spectra of gold nanoplates produced by traditional literature methods (blue), DiaSynth (red), and DiaSynth followed by sedimentation (green). Inset: Overlay of nIR spectra of nanoplates synthesized with various DiaSynth parameters.

Gel Electrophoresis was also found to be effective for separation of gold nanoplates from the majority of contaminants with good separation of bands, Figure 2. TEM of the particles from the green band show the sample is composed predominantly of triangular nanoplates.

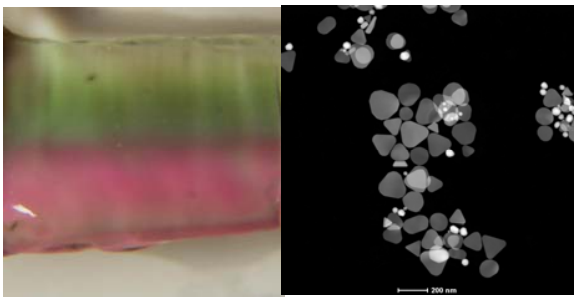

Figure 2. (Left) Image of agarose gel showing separation of nanoplates (green) from colloidal gold (red), and (Right) TEM image of nanoplates form the green band.

Conclusions: The combination of DiaSynth and either sedimentation or electrophoresis allows for the efficient synthesis of gold nanoplates of specific size and LSPR wavelength with good purity and reduced bandwidth for use in a range of biomedical applications. These particles are currently being employed in our lab in oligonucleotide-based drug delivery, plasmonic heating, radiosensitization, imaging and biodetection.