Technical note T01

Colloid production with ultrafast laser

Pulsed laser fragmentation in liquid

i-colloid is produced with a top-down method utilizing the high power of ultrafast pulsed laser to fragment a bulk target such as gold directly in a solvent desired for the end application. With a pulse duration of a few hundred femtoseconds, the focused laser beam produces intense transient heat and pressure within the target material at the focal spot. Material heating and breakdown (boiling) occur within a few nanoseconds after illumination by a laser pulse, expelling nanoparticles mixed with a low density ionized vapor (plasma). The process is illustrated in Figure 1.

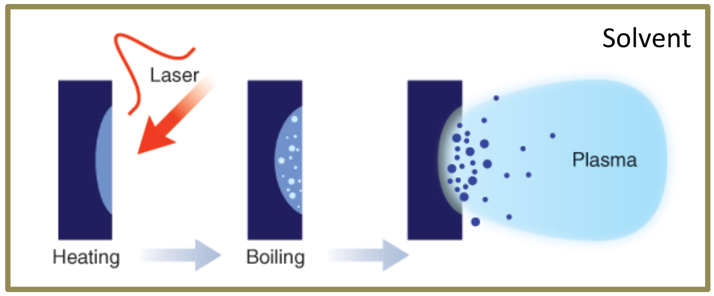

Fig. 1. When using ultrafast laser pulses with pulse duration of less than 1 picosecond to ablate a solid in a solvent, the target material is fragmented within a few nanoseconds, leaving a colloidal suspension of nanoparticles.

Colloid stabilization

i-colloid is stabilized by a low surface coverage of hydroxyl group (OH-) without using additional surfactant. Due to the presence of laser plasma, the noble metal nanoparticle surfaces are slightly oxidized at a coverage of about 1 at.%. Hydroxyl groups in the solvent attach to the surface oxidation sites, electrically charging the nanoparticle surfaces and stabilizing the colloids. Figure 2 illustrates two stabilization mechanisms, where the left shows hydroxyl stabilization and the right shows the standard citrate stabilization.

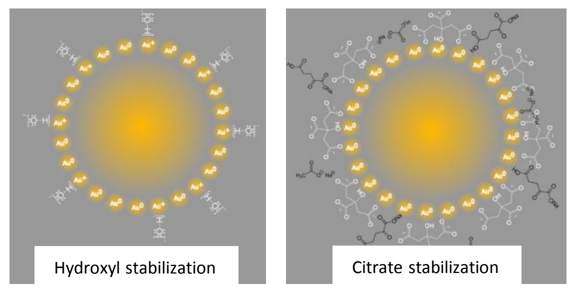

Fig. 2. Comparison of two stabilization mechanisms. Left: the i-colloid is stabilized with a small surface coverage (~1%) of hydroxyl groups, leaving predominant bare gold surfaces. Right: In standard chemical synthesis, gold nanoparticle surfaces are covered by a layer of citrate ions.

Narrow size distribution

Typical laser fragmentation process produces a wide particle size distribution. We have developed a strict process controlling the related laser and liquid parameters and achieved narrow size distributions that are suitable for various biological applications, as illustrated in Figure 3.

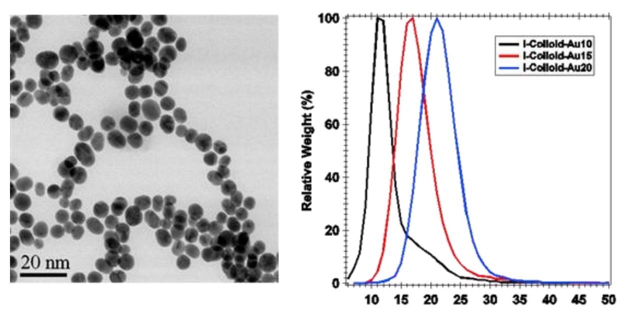

Fig. 3. TEM image and typical size distribution of i-colloid Au series.

High purity

One advantage of i-colloid is its high purity with a total ionic concentration in the range of micromolar, compared with the milimolar ionic concentration in standard chemical synthesis. Figure 4 shows different electrical double layer thickness, calculated for several bulk ionic concentrations, demonstrating the long decay distance at low ionic concentration. Such high purity is critical in maintaining colloid stability and precise control of biomolecuel loading during bioconjugation of the nanoparticles (see Technical note T02).

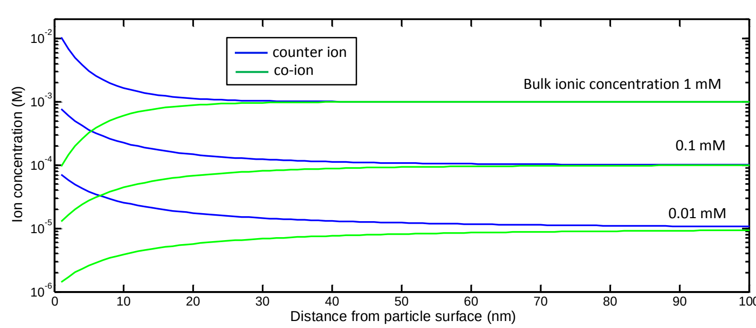

Fig. 4. Ionic concentration distribution of electrical double layer of nanoparticles, calculated for different bulk ionic concentrations.

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