TECH NOTE:

ZETA/pH CURVES AND ISOELECTRIC POINT DATA FOR STANDARD NANOCOMPOSIX SILVER CITRATE AND PVP NANOPARTICLE DISPERSIONS

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Introduction

All colloidal dispersions are stabilized by electrostatic repulsion, steric hindrance, or a combination of the two. In the absence of sufficient stabilization, every nanoparticle formulation will eventually aggregate. Electrostatic stabilization can be estimated by measuring the zeta potential, which is the charge at the surface of the electrical double layer (Figure 1). Nanoparticle suspensions with a zeta potential greater than +25 mV or less than -25 mV typically have high colloidal stability [1].

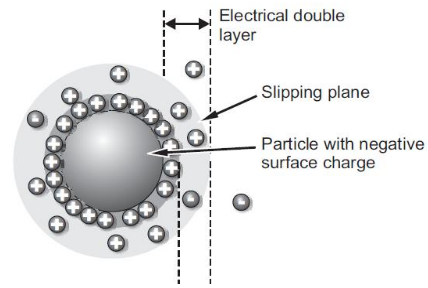

Figure 1: Electrical Double Layer

Zeta potential measurements of 10 nm, 50 nm and 100 nm citrate and PVP capped particles were taken to determine the surface charge of standard nanoComposix silver formulations in acidic and basic conditions.

Data Summary:
Each size and capping agent combination has a zeta potential that varies over the pH range 2-10 (Figure 2); however there are many trends that can be deciphered from examining the summary plot:

- There are two distinct "bands" of zeta potentials, with the PVP-capped nanoparticles exhibiting lower magnitude zeta potentials than the citrate capped nanoparticles.
- Particles of the same size have similarly shaped zeta potential/pH curves, despite having different particle surfaces. It can be discerned from Figure 2 that zeta potential values for 50

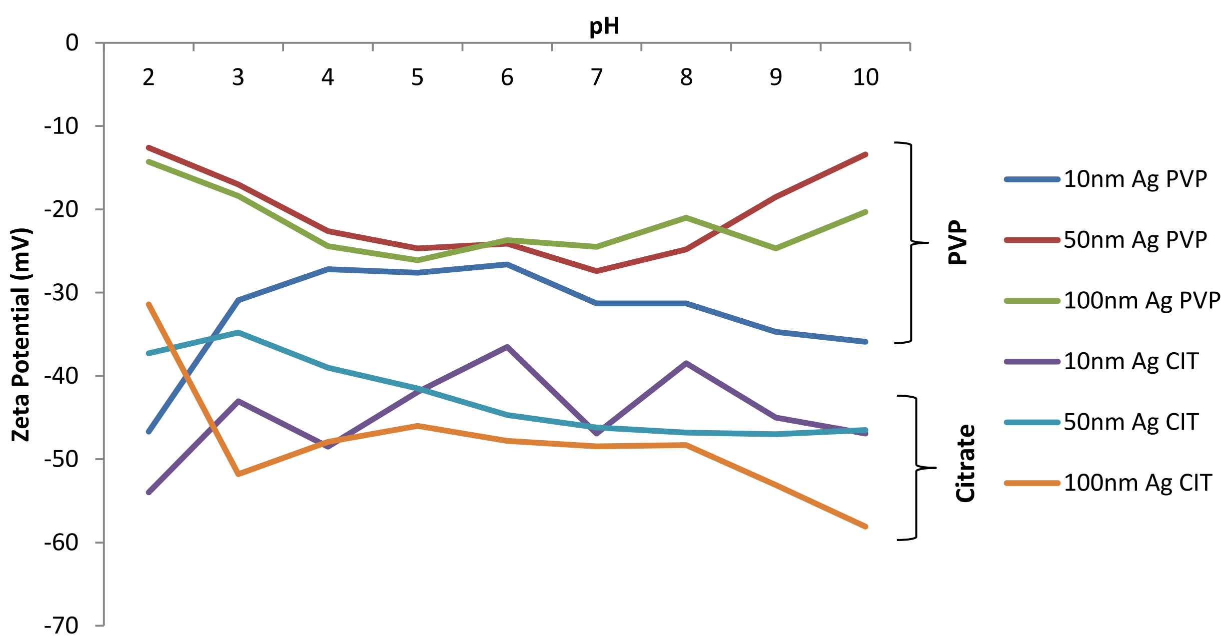

Figure 2: Summary of Zeta Potentials

and 100 nm Ag particles exhibit a high degree of consistency in the pH range 3-9, while the 10 nm particles of both capping agents exhibit more variability. The 10 nm Ag particles are less stable with respect to pH manipulation than are the much larger 50 and 100 nm particles.

Citrate Capped Particles

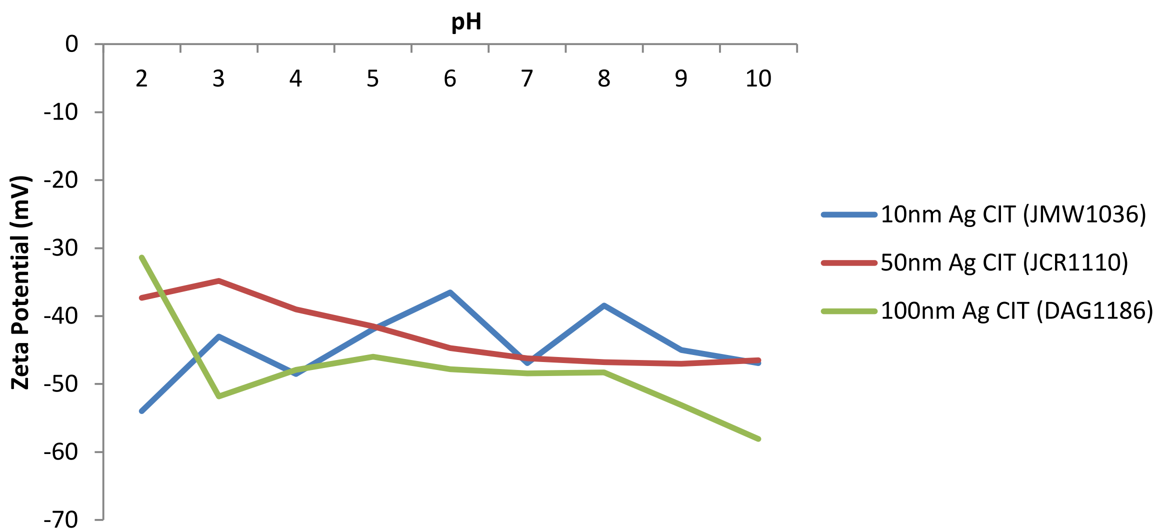

Figure 4: Zeta Potentials of citrate capped silver nanoparticles

- Relative to PVP capped silver nanoparticles, the citrate capped particles exhibit higher magnitude zeta potentials (Figure 4).
- Over the ambient pH range of 5-8, the 10 nm citrate capped nanoparticles exhibit the least amount of stability, as indicated by the lower magnitude zeta values. Conversely, 100 nm citrate capped silver particles demonstrate the most stability over this range. All sodium citrate dispersions show excellent stability in highly basic pH conditions.

pH	10 nm Ag CIT	50 nm Ag CIT	100 nm Ag CIT
2	-54	-37.3	-31.4
3	-43.03	-34.8	-51.8
4	-48.5	-39	-47.9
5	-41.93	-41.5	-46
6	-36.5	-44.7	-47.8
7	-46.9	-46.2	-48.45
8	-38.47	-46.8	-48.3
9	-45	-47	-53.08
10	-46.9	-46.5	-58.1

Table 1: Zeta Potentials of Sodium Citrate capped silver nanoparticles

PVP capped particles

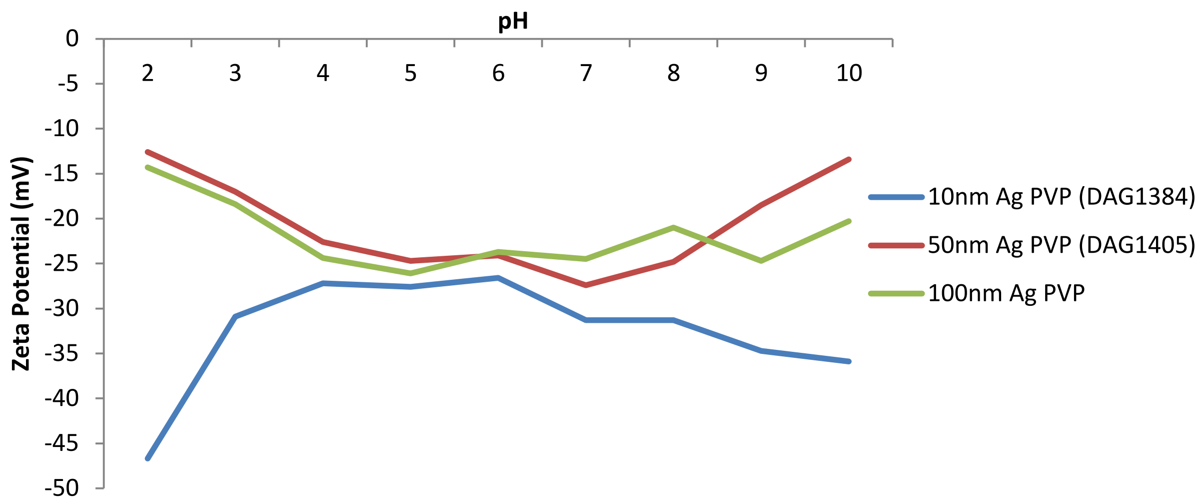

Figure 4: Zeta Potentials of PVP capped silver nanoparticles

- PVP-capped nanoparticles have lower magnitude zeta potentials than citrate capped particles. Nanoparticles coated with PVP remain dispersed in part by zeta potential and in part due to the steric hindrance created by the large PVP layer coating the surface of the particles. Table 3 shows the difference between TEM diameter and DLS diameter for the two different coatings. The PVP increases the hydrodynamic diameter to a much greater extent than the citrate (Table 3)[(2)].

- Over the ambient pH range of 5-8 the 10 nm PVP capped nanoparticles exhibit the greatest amount of stability, as indicated by the higher magnitude zeta values. Conversely, 100 nm Ag PVP

pH	10nm Ag PVP	50nm Ag PVP	100nm Ag PVP
2	-46.7	-12.6	-14.3
3	-30.9	-17	-18.4
4	-27.2	-22.6	-24.4
5	-27.6	-24.7	-26.1
6	-26.6	-24.1	-23.7
7	-31.3	-27.4	-24.5
8	-31.3	-24.8	-21
9	-34.7	-18.5	-24.7
10	-35.9	-13.4	-20.3

Table 2: Zeta Potentials of PVP capped silver nanoparticles

	TEM diameter	DLS diameter	% increase
50nm Ag CIT	49.1	54.9	11.8
75cm Ag CIT	76.6	80	4.4
100nm Ag CIT	99.4	99.8	0.4
50nm Ag PVP	51	68.7	34.7
75nm Ag PVP	73.5	86.7	18.0
100nm Ag PVP	98.5	117	18.8

Table 3[(2)]: TEM vs. DLS size data for PVP capped silver nanoparticles

particles demonstrate the least stability over this range.

Conclusion

Zeta Potential values of sodium citrate and PVP capped 10, 50 and 100 nm nanoparticles were taken, and their values compared. All dispersions exhibit excellent stability from the highly basic to moderately acidic pH range, as indicated by the magnitude of their zeta potentials. The lower magnitude zeta potentials of PVP capped particle dispersions, along with their larger hydrodynamic diameters, illustrate the two mechanisms of particle stabilization: electrostatic repulsion (zeta potential), and steric hindrance. In the absence of these two forces, all particle dispersions will eventually agglomerate due to inter-particle van der waals forces.

References:

(1) nanoComposix Guidelines for Zeta Potential Analysis of Nanoparticles.pdf
(2) nanoComposix Guidelines for DLS Measurements and Analysis.pdf