



TARGETED DELIVERY OF ACTIVES: Cationic Nanoparticles for use in Hair and Skin Products

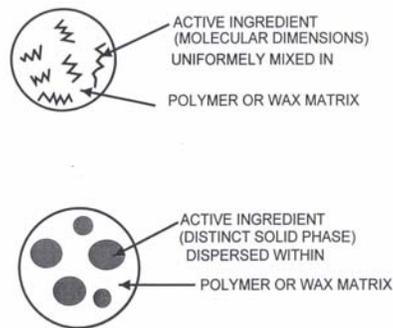
INTRODUCTION

The inclusion of, for example, sunscreens in hair care products is of great interest because of the potential to reduce damage such as drying and loss of elasticity and also to reduce the fading of color-treated or bleached hair. For a variety of reasons traditional methods of incorporation of UV filters have often proved difficult and, at best, unsatisfactory; the need for additional solubilizers, changes in residual feel, rinse out, incomplete wetting and poor affinity have all been noted and observed.

Furthermore, traditional hair conditioning formulations are sensitive to any processing conditions which might affect the size and distribution of the dispersed conditioning agent (1). In formulations containing silicone or hydrocarbon oil the performance is influenced by the nature of the emulsifying system and the extent to which any cationic substituents modify the physical and chemical characteristics of the oil phase. Thus, an important pre-requisite is that any additional component must not adversely affect the conditioner composition nor inhibit the conditioning behavior.

Particle Sciences' proprietary microencapsulation technology is an adaptation of a physical methodology; however, the average particle size is an order of magnitude smaller, typically from 0.1 to 1.0 micron (Figure 1). These nanoparticles are a homogeneous mixture of matrix and active dispersed in water. Because of their extremely small size, the nanoparticulates are easily incorporated into virtually any kind of delivery system; being encapsulated, the organic actives can then be delivered in systems formerly unacceptable or hostile to them. The particles can be designed for controlled release, or, as this example for sunscreen actives, no release (2).

Figure 1 Schematic of Particle Sciences Nanoparticles



The surface chemical properties of the particulates can also be modified to increase product performance. A useful measure of the nature and strength of the surface charge of nano-sized particles is the zeta potential (ZP) (3). The ZP can be conveniently be determined by electrophoretic light scattering (ELS) and by phase analysis light scattering (PALS). ELS is suitable for aqueous-based systems and provides a measure of the charge distribution (4). PALS, a more recent development (5), provides only an average value but is the only technique applicable to non-aqueous systems, in particular suspensions of particulates in volatile solvents and high viscosity oils.

The chemistry of hair is extremely complex (6), nevertheless the overall net surface charge appears to be negative (7,8); damaged hair is particularly so because of the various assaults from relaxers, permanent-waving products and oxidative hair colorants, as well as UV radiation. Thus a positively charged (cationic) moiety will be attracted and potentially adsorb to the hair surface. This is the basis of the mechanics of conditioning agents.

With this in mind, to facilitate compatibility with hair conditioner formulations and to enhance affinity of the nanoparticles for hair, a number of encapsulated sunscreen systems were prepared having different cationic charge densities (charge per unit area) (Table 1). The substantivity of each system, for hair, was then measured and compared, using the technique of streaming potential (SP) (see below). This technique also allows the washing process of hair to be mimicked (9).

Three different cationic particulate systems were prepared using three different matrix/stabilizer compositions but essentially the same manufacturing procedure. Each organoparticulate comprised approximately 50% solids that contained two widely used

sunscreen actives (Octyl methoxycinnamate and Benzophenone3) in the ratio of 2:1 at 50% loading.

Cationic Nanoparticles

System 1: A matrix based on polyester/beeswax, similar to that used in commercial sunCaps™ 664, but modified to make the surface cationic by physisorption of Katemul IGU-70 (isostearamidopropyl dimethylamine gluconate – a shampoo ingredient used to impart substantive hair conditioning, body and softness).

System 2 : A matrix comprising a highly siliconized version of a polydimethyl siliconyl beeswax, cationically stabilized with Adogen 432 CG (dimethyl dialkyl ammonium chloride – a standard commercial Quat used to formulate hair crème rinse concentrates).

System 3 : A matrix based on a proprietary cationic silicone polymer. Here the cationic charge is a fundamental part of the polymer backbone.

TABLE 1: Characterization of the Cationic Organoparticulates

System	Particle Size (PS) ^(a) (nm)	Zeta potential(ZP) ^(b) (mV)	ZP:PS ratio
Code#841	325	+48	0.15
Code#843	350	+17	0.05
Code#845	305	+60	0.20

(a) Weight average, D_w , measured by disc centrifuge photosedimentometry

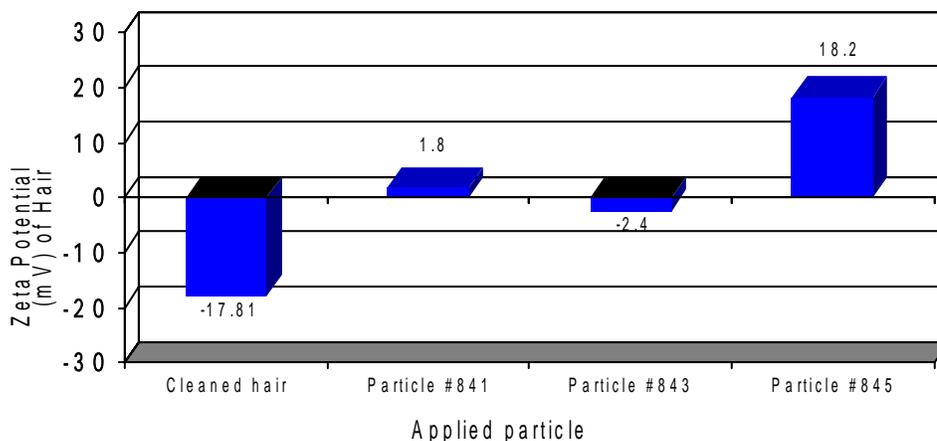
(b) Electrophoretic light scattering in 0.001M KCl at 25°C.

Based on the matrix chosen, the hydrophile-lipophile (HLB) balance of each system is clearly different (decreasing, i.e. becoming more lipophilic, in order from Code #841< Code#843< Code#845).

The ratio of ZP:PS contains both measurable hydrodynamic transport terms and has been suggested to approximate a “charge density” and has been shown to allow a simple interpretation in terms of titrating the total charge on a particle (10). This ratio is greatest for the cationic silicone polymer (Code#845) and least for the quat-stabilized organoparticulate (Code#843).

Deposition of the cationic organoparticles was followed using the technique of streaming potential, from which a ZP value can be computed. Each sample of hair was first rinsed with DI H2O followed by a washing with a standard anionic surfactant (SDS) and then rinsed with DI H2O until no change was observed in the SP/ZP signal. The hair was then allowed to equilibrate for 5 minutes in a diluted dispersion of the organoparticulate and again rinsed until no change was detected in the SP/ZP signal. These data are summarized in Figure 1.

FIGURE 1: Streaming Potential of Hair challenged with Cationic Organoparticulates



The ZP of the “cleaned” hair used in the study was found to be quite negative, and it is clearly seen that there is substantial particle deposition because, in each case, the ZP is significantly reduced from -18mV. The most effective system was Code#845. This is not surprising since it comprised a combination of the most hydrophobic matrix with the largest effective “charge density”.

This system (Code#845) was then tested by a large personal care company using human volunteers. Surprisingly, subsequent microscopic examination revealed that the majority of the particles had adsorbed at the root/follicle and not on the hair shaft. The degree of UV protection provided using this particular cationic organoparticulate system was, however, not cost effective for use in a low margin product.

Nevertheless, the results demonstrate the use of such nanoparticles for targeted delivery. These studies suggest that, for pharmaceutical applications, such a system might be very effective in delivering a biological active (such as a steroid, antifungal etc) to the scalp.

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Particle Sciences is located in Bethlehem, Pennsylvania. Our analytical staff has extensive experience in method development and validation with particular expertise in topical and mucosal products. Our physical characterization cGMP laboratories include HPLC, UV/IR, X-Ray, Particle Size, Zeta Potential, Turbidity, Viscosimetry, Rheology, Contact Angle, Surface Energy, and ICH compliant stability programs. Our formulations group has pioneered nanoparticle - drug encapsulation systems, resulting in many commercialized products.