

Particle size measurement of attenuation grade titanium dioxide in dispersion and in sunscreen lotion

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Introduction

Particle size measurement and its interpretation of attenuation grade titanium dioxide and zinc oxide has become critical in light of the recent consumer concerns over the safety and efficacy of nanotechnologies. In addition, particle size is typically used as a way to characterize and differentiate different raw materials for sunscreen products. In the first part of this study, three size measurement techniques, Dynamic Light Scattering, Scanning Electron Microscopy and Acoustic Ultrasound Attenuation were used to measure the size of TiO₂ aggregates dispersed in an ester.

In a second part, the particle size of TiO₂ aggregates in a lotion was compared with their size in the dispersion the lotion is based on, in an attempt to determine if formulation can affect aggregation.

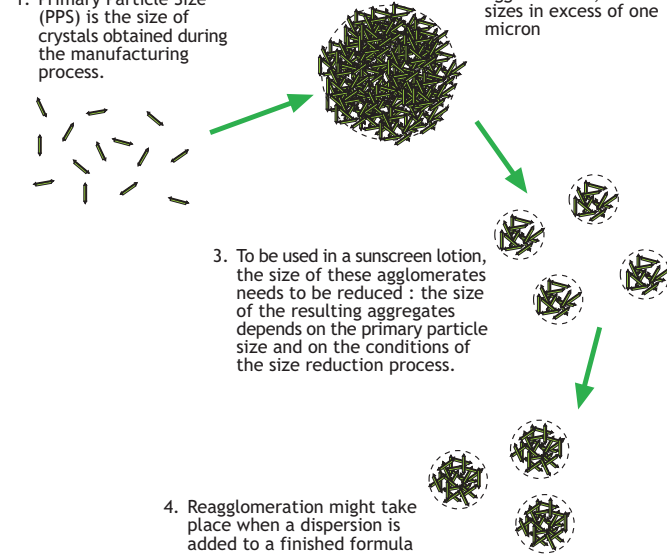
Particle Size - Definitions

1. Primary Particle Size (PPS) is the size of crystals obtained during the manufacturing process.

2. In powder form, TiO₂ crystals form agglomerates, with sizes in excess of one micron

3. To be used in a sunscreen lotion, the size of these agglomerates needs to be reduced: the size of the resulting aggregates depends on the primary particle size and on the conditions of the size reduction process.

4. Reagglomeration might take place when a dispersion is added to a finished formula



Statistics - Mean Calculation Methods

When all individual sizes of each particle of a distribution are known (i.e.: image analysis of an electron microscopy), a mean size can be calculated. Different calculations give different means, the two most common calculations being number (or length) and volume (or weight).

$$\text{Number Mean} = D[1,0] = \frac{\sum d_i}{n} \quad \text{Volume Mean} = D[4,3] = \frac{\sum d_i^4}{\sum d_i^3}$$

Volume mean is generally preferred for a dispersion as it better represents the variation in size reduction / agglomeration of the dispersion (ref: AAPS Journal 2004:6(3) article 20).

Global size measurement techniques, such as Dynamic Light Scattering (DLS) measure a physical characteristic of the dispersion with is used to calculate a mean and a dispersion. The mean/distribution can be weighted by a different value ("intensity" in the case of DLS).

Interconversion between intensity, volume or number-mean generates errors and lowers the precision of the measurement.

Particle Size Measurement of a Titanium Dioxide Dispersion Using Complementary Techniques

Comparison of the size measurement techniques

Three different particle size measurement techniques were used and their results compared.

Dynamic Light Scattering :

- Principle : uses scattered light to measure the rate of diffusion of particles (Brownian movement). Data is processed to calculate a mean particle size and size distribution.
- Pros : Statistical method / Easy to use
- Cons : Sample has to be diluted, which may affect its aggregation state

Cryo Scanning Electron Microscopy :

- Principle : an image of a frozen sample is taken with an scanning electron microscope. The image is analyzed to determine individually the size of the observed particles.
- Pros : Minimal sample preparation.
- Cons : It is not possible to measure a large number of particles; the result is only valid for the image(s) taken and the particles measured.

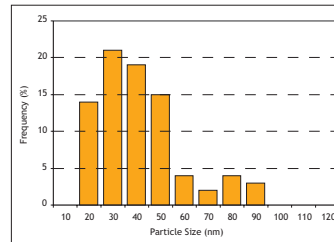
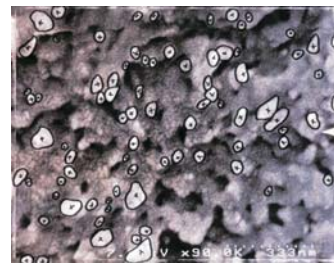
Acoustic Ultrasounds Attenuation :

- Principle : Particles also scatter sound. Acoustic attenuation of ultrasound pulses is measured for a set of frequencies and Particle Size Distribution is calculated by minimizing deviation between measured and calculated acoustic attenuation spectra.
- Pros : Minimal sample preparation (no dilution) / Statistical method.
- Cons : Relatively new technique.

These three methods were used to test a surface-treated attenuation-grade titanium dioxide dispersed in an ester :
Dispersion Name : TNP50T7
Primary Particle Size : 15nm
INCI Name : C12-15 Alkyl Benzoate (And) Titanium Dioxide (And) Alumina (And) Polyhydroxystearic Acid (And) Methicone

Cryo Scanning Electron Microscopy

A scanning electron micrograph of a frozen sample was taken. The sizes of the particles visible on the picture were measured individually with a ruler and used to calculate a number-mean, D(1,0), a volume-mean, D(4,3) and a number-distribution.



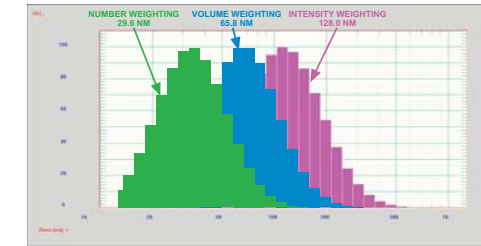
Number Mean - D(1,0) = 45.2 nm
 Volume Mean - D(4,3) = 68.0 nm

Note : due to the limited number (82) of particles measured this result is only indicative.

Dynamic Light Scattering

To evaluate repeatability and robustness, the measure was made 8 times, using 3 different dilutions. The following graph presents one of these measures, expressed as intensity-distribution, volume-distribution and number (length)-distribution.

Measure on Nicomp Model 370 - samples diluted in chloroform to 200-350 kHz.



The following table shows the averaged results for the 8 measurements. Precision is calculated as the Relative Standard Deviation of the measurements.

Mean Calculation	Particle Size	Precision
Intensity Weighting	127.9 nm	2 %
Volume Weighting	71.6 nm	16 %
Number Weighting	36.2 nm	25 %

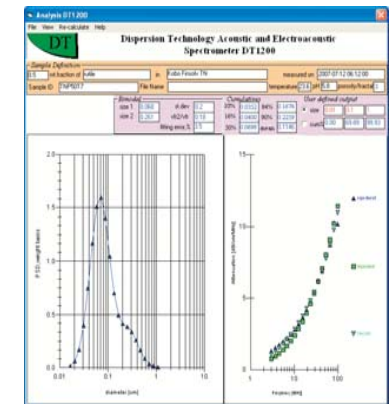
Particle Size Measurements - Correlation

Mean Calculation	Cryo-SEM	Dynamic Light Scattering	Acoustic Ultrasounds Attenuation
Intensity Weighting	-	127.9 nm	-
Volume Weighting	68.0 nm	71.6 nm	68 nm
Number Weighting	45.2 nm	36.2 nm	-

The results confirm that the volume mean sizes from the three methods are similar, all around 70 nm. The accuracy of the measurement appears to be very high. However, the conversion of the result for DLS in number mean is not in good correlation with the result obtained from an image analysis method.

Acoustic Ultrasounds Attenuation

Samples were measured three times, without dilution or stirring, to minimize possible reagglomerations.



The sample appears to be bimodal, with one major component.

Volume Mean of the main component = 68 nm

Comparison of Particle Sizes of a Dispersion and a Finished Formula

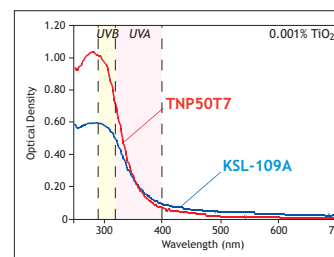
Formula KSL-109A : W/O High SPF Suncare Lotion				
Part	%	Ingredients	INCI name	Supplier
1	32.26	Deionized Water	Deionized Water	Morton Salt
	0.53	Sodium Chloride	Sodium Chloride	Sutton Labs
	0.19	Allantoin	Allantoin	
2	0.14	Methylparaben	Methylparaben	Nipa
	45.75	TNP50T7	C12-15 Alkyl Benzoate (And) Titanium Dioxide (And) Alumina (And) Polyhydroxystearic Acid (And) Methicone	Kobo Products
	2.83	Abil Wax 9801	Cetyl Dimethicone	Goldschmidt
	2.83	Floresters	Jojoba Esters	Floratch
	0.94	Shea Butter	Shea Butter	Cognis Corp
	2.35	Arlacel P135	PEG-30 Dipolyhydroxystearate	Uniqema
	2.35	Abil WE 09	Polyglyceryl-4 Isostearate (And) Cetyl Dimethicone Copolyol (And) Hexyl Laurate	Degussa
	0.06	Propylparaben	Propylparaben	Nipa
	0.19	Rosemary Oleoresin	Rosemary Extract	Hilltech
	0.19	HQ 3401	HQ 3401	
	1.90	Hallbrite BHB	Butyloctyl Salicylate	C.P. Hall Company
	0.28	Ascorbyl Palmitate	Ascorbyl Palmitate	Acatris
	0.94	Argan Oil	Argan Oil	Centerchem
3	0.28	SK-45	Mica (And) Polymethylmethacrylate	Kobo Products
	0.05	KTZ Bronze D'Or	Mica (And) Iron Oxide	Kobo Products
	0.47	Mica Powder Y-1800	Mica	Kobo Products
	2.83	Acculyn 44	Urethane/C1-12 Alkyl PEG-Copolymer	Rhame & Haas
	2.83	Iricatmin	Water (And) Triticum Vulgare (wheat) Extract (And) Saccharomyces Cerevisiae Extract (And) Sodium Hyaluronate	Centerchem
100				

Description
 This sunscreen is waterproof W/O emulsion and has a very high SPF. Mica and KTZ Pearls are added to improve feel and reduce bluing.

Active Ingredients
 Titanium Dioxide
 17.50%

Notes
 SPF testing: In-vivo on 3 subjects;
 UVA testing: In-vitro Boots star rating

Absorbance curves

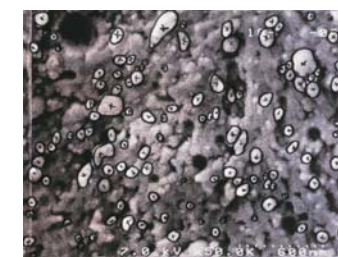


Samples diluted in Chloroform (0.001% TiO₂) Spectrophotometer Hitachi U3310 with Integrating Sphere

Sample	Max. Abs.	O.D. @310 nm
TNP50T7 (dispersion)	283 nm	0.8785
KSL-109A (Lotion)	300 nm	0.5525

The KSL-109A lotion shows a lower absorbance in the UVB range than the dispersion it is based on. Its maximum absorbance is also higher than that of the dispersion. These results show that the aggregates present in the dispersion may have partially agglomerated during the formulation process.

Cryo SEM



Sample	Number Mean	Volume Mean
TNP50T7 (dispersion)	45.2 nm	68.0 nm
KSL-109A (Lotion)	76.3 nm	125.1 nm

Measurement of the average particle size of the aggregates in the lotion show clearly an agglomeration compared to the size of the aggregates present in the dispersion, even though the lotion has a very high measured SPF.

Conclusion

In the course of this study, we have compared three techniques which are commonly used to measure the size of attenuation grade TiO₂ and ZnO. We have shown, by testing a TiO₂ dispersion, that these three techniques gave very similar results when the same calculation method for mean size is used. We have also shown that formulating the same dispersion in a W/O lotion has caused some degree of reagglomeration. However, a very high in-vivo SPF can still be achieved.

A similar study is being conducted on different types of attenuation grade TiO₂ and ZnO (primary particle sizes, surface treatments), to investigate the reagglomeration that might take place during formulation.