Synthesis of Monodisperse Nano Zinc Oxide Particles by a Newer Chemical Route

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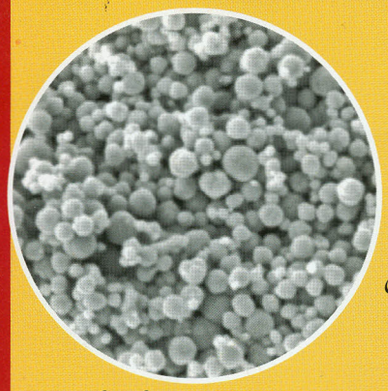
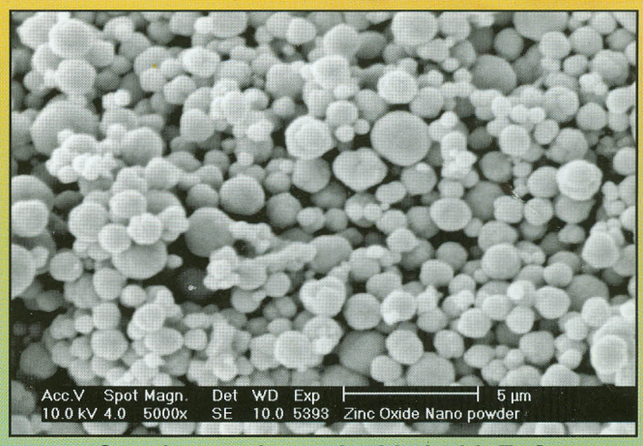


Introduction - Zinc-Oxide nanoparticles

Nanotechnology is hailed as a revolution of the 21st Century. ZnO, an n-type semiconductor with a band gap of 3.37 eV, is a very interesting multifunctional material for its promising application in solar cells, sensors, displays, gas sensors, varistors, piezoelectric devices, electro acoustic transducers, and photodiodes. In spite of the advantages of Zinc Oxide nanoparticles, their use is limited mainly due to the difficulties encountered in their synthesis by physical and chemical methods. Additional techniques include processing by sonochemical, cavitation, microemulsion routes and through high-energy ball milling. One of the most challenging problems in synthesis is the controlled generation of monodisperse nanoparticles with minimal size variance, ensuring the stability of the particles against agglomeration, sintering and compositional changes. The Zinc Oxide nanoparticles (Nano-ZnO) are known to exhibit the properties like UV-absorbing and antimicrobial activities. Hence its application in cotton fabrics, paper and sun creams would confer novel functionalities to the product.

A novel chemical Process

A novel chemical process was developed at CIRCOT for the preparation of Zinc Oxide nanoparticles (Nano-ZnO) by using zinc nitrate and sodium hydroxide as precursors. Soluble starch is used as the stabilizing agent. The concentration of soluble starch is a major factor that decides the size of the nanoparticles. The average size of Nano-ZnO is estimated to be 38 ± 3 nm by using a transmission electron microscope.



Starch granules embedded with ZnO

Stability of Nano-ZnO

The effect of storage conditions and containers on the antibacterial activity of Nano-ZnO was evaluated. Nano-ZnO powder was stored in glass / polythene and stored in UV / high RH / high temperature 45°C for 300 hours and analyzed for antibacterial activity. In all cases, the antibacterial activity (>99%) was maintained even after exposure to harsh conditions.

Scale-up Trial

A scale up trial was carried out for the preparation of 500 grams of Nano-ZnO in a single batch. Also, the effluent during preparation was analyzed for COD, BOD, pH & zinc content. Except zinc content, all other parameters were within the permissible limits

Characteristics	Effluent from Nano-ZnO preparation	Tolerance limits for industrial effluents discharged into	
		Inland surface water IS: 2490 - 1974	Public sewers IS: 3306 - 1974
BOD	5 ± 1	30	500
COD	164 ± 6	250	-
Zinc (mg/L)	130 ± 3	5.0	15.0
pH	7.8	5.5 - 9.0	5.5 - 9.0

Coating of textiles

Nanocoating of textiles is one of the many approaches to the generation of highly active surfaces to have UV-blocking, antimicrobial and self-cleaning properties. Nano-ZnO is impregnated onto cotton fabrics by a pad-dry-cure method using acrylic binder. Qualitative assessment revealed the excellent antibacterial activity against two representative bacteria, *Staphylococcus aureus* (Gram positive) and *Klebsiella pneumoniae* (Gram negative). Quantitative analysis of antibacterial activity of Nano-ZnO coated cotton fabrics with 1% Nano-ZnO coating showed very high antibacterial activity (reduction > 99.9%). For medical textiles the use of 1.0% Nano-ZnO coating can be recommended.

Efficient UV protection and antibacterial activity of coated textiles

Efficient UV blocking and antibacterial activity

Nano-ZnO coated cotton fabrics showed efficient blockings of both UV-A (315 – 400 nm) and UV-B (280 – 315 nm) radiations.

Cotton fabrics	Percent blocking		UPF
	UVA	UVB	
Control	19	32	1.54
Coated with Nano-ZnO	65	68	3.71

UV protection of Nano-ZnO coated cotton fabrics

The efficient protection even with smaller amounts of coat could be ascribed to the uniform spread of the nano particles on the fabric surface.

S. No.	Nano-ZnO coated fabrics	Antibacterial activity (%)	
		Klebsiella pneumoniae	*Staphylococcus aureus*
1	As such	>99.9	>99.9
2	After 10 washings	99.6	99.3
3	After 15 washings	99.3	99.1
4	After 20 washings	98.2	99.1
5	After 30 washings	91.0	90.1

Antibacterial activity of Nano-ZnO coated fabrics after washings

Coating of Paper

Due to the organic, fibrous, hydrophilic and highly porous nature, paper is easily subjected to microbial attack and ultraviolet degradation. In addition, the sizing agents like starch that is applied to the surface of paper hasten the degradation. To circumvent these problems, Nano-ZnO prepared at CIRCOT was used as a coating material. The brightness, whiteness, paper smoothness, print density, print uniformity, picking velocity and oil absorbency of Nano-ZnO coated paper showed significant improvement than that of bulk-ZnO coated paper. In addition, the Nano-ZnO coated paper imparted excellent anti-fungal (Mildew-resistance) and UV-protecting properties that are much essential to enhance the life of a paper.

INVESTMENT COST AND PROFIT

1	Capital investment	₹ 30.00 Lakhs
2	Nano-ZnO production/ year	480 Kgs
3	Cost of production of 1Kg Nano-ZnO	₹ 0.19 Lakh
4	Selling Price of 1Kg Nano-ZnO	₹ 0.22 lakh
5	Profit	16%
6	Return on investment	50%

Applications

- Nanocoating the surfaces of textiles, clothing, and textiles for footwear to have UV blocking, antimicrobial and self-cleaning properties.
- As nanofillers in nanocomposite films which are suitable for food packaging industry.
- Coating of paper with Nano-ZnO to impart antifungal and UV protection to enhance the life of paper.
- In cosmetics for UV protection.
- In medical textiles.

Now, You Stand to Benefit

This technology is available for commercialization/licensing to budding entrepreneurs and companies who are interested to impart novel functionalities on textiles, cosmetics, paper and medical textiles

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