



“Applications of TiO_2 , $CoFe_2O_4$ and ZrO_2 based nanomaterials on textiles, experimental results”

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Technores s.r.l. activities:

- Project funding (EU, national and regional funds etc.)
- Advanced engineering (Design Of Experiments, tests)
- Research
- Legal engineering



www.nano-rss.it

- Pharmaceutical
- Biomedical
- **Textile**
- Glass
- Ceramic
- Water treatment
- etc.

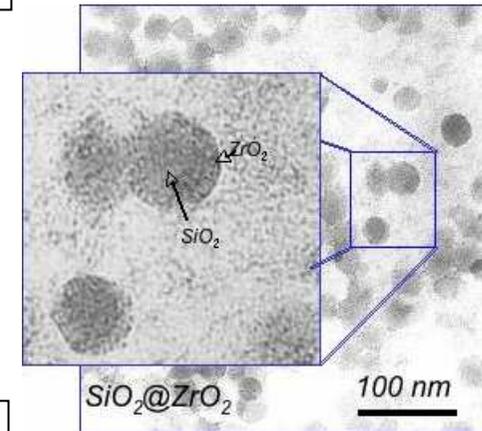


Starting nanomaterials (liquid/powders stabilised suspensions):



The main research field of Cericol (centro ricerche colorobbia) is focused on the development of nanomaterials for many different applications. The cooperation between Technores s.r.l. and Cericol made it possible to select a first series of nanosolutions to be developed for textile applications. They are:

Metals	→	Au ⁰	Ag ⁰	Pt ⁰	Rh ⁰
Mixed Metals	→	Pt ⁰ -Au ⁰	Rh ⁰ -Au ⁰	Ag ⁰ -Au ⁰	
Coatings	→	TiO ₂ @Ag ⁰	TiO ₂ @Me		
Oxides	→	TiO ₂	Fe ₂ O ₃	CeO ₂	
		SiO ₂	ZnO	Fe ₃ O ₄	ZrO ₂
Complex oxides	→	Spinel $M^{II}M^{III}_2O_4$	Titanates (Ti,Sb,Cr)O ₂		
Semiconductors	→	Cd(S,Se)			
Ceramers	→	Si-Al			



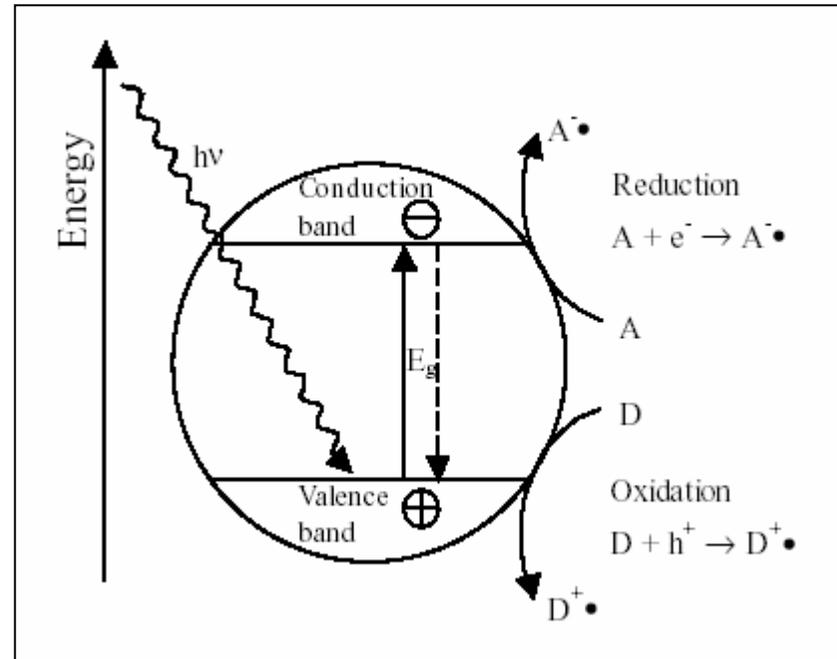
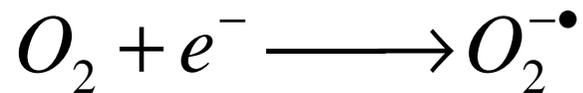
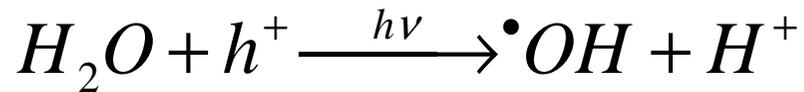
Me = transition metals



FIRST LINES OF R&D:

- TiO_2 → UV resistance and photocatalytic antibacterial effect
- CoFe_2O_4 → magnetic properties and Hyperthermia
- ZrO_2 → textile hand, surface abrasion resistance etc.

TiO₂:



- Nanoparticle /Solution development (glycol, water, concentration etc.)
- Fabric preparation process if needed (plasma, etc.)
- Application process cycle
- Stabilization process (if needed)
- Finishing process (if needed)
- Testing procedures definition (irradiation procedures etc.)
- Testing and validation (microbiological testing etc.)
- Price analysis on first samples → first product line (PL, PA, Li, Co)



Results: Photocatalytic antibacterial effect



PA-Poliammide (sitip)

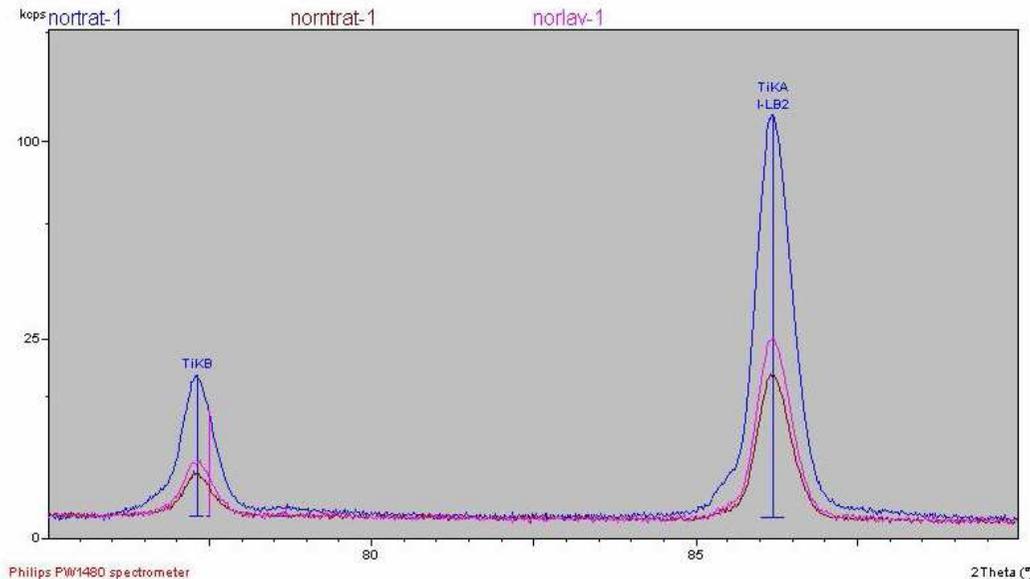
- Nano TiO₂ water stabilized and neutralized solution
- Pressure-Thermal applications cycle
- XRF analysis
- Defined activation procedures (6-8 h UV / sun irradiation)
- Defined contamination procedures
- AATCC 100:2004 testing

PL-Polyester (Asterix)

- Nano TiO₂ water stabilized and neutralized solution
- Pressure-Thermal applications cycle
- XRF analyses
- Defined activation procedures (6-8 h UV / sun irradiation)
- Defined contamination procedures
- AATCC 100:2004 testing



Results: Photocatalytic antibacterial effect PA-Poliammide (sitip-)-nortrat /nortrat:



XRF analysis by: Cericol- Empoli (FI)

Results:

- Complete Photocatalytic antibacteric effect
- First product line almost ready at a reasonable price

Problems:

- TiO₂ micropowder deposition
- Washing resistance

Untreated SITIP (norntat)

Parametro	U.M.	Risultato
E.Coli	% di abbattimento	14,3%
Staphylococcus Aureus	% di abbattimento	81%
Bacillus Subtilis	% di abbattimento	0%
Pseudomonas Aeruginosa	% di abbattimento	0%

Nano TiO₂ treated SITIP (nortrat)

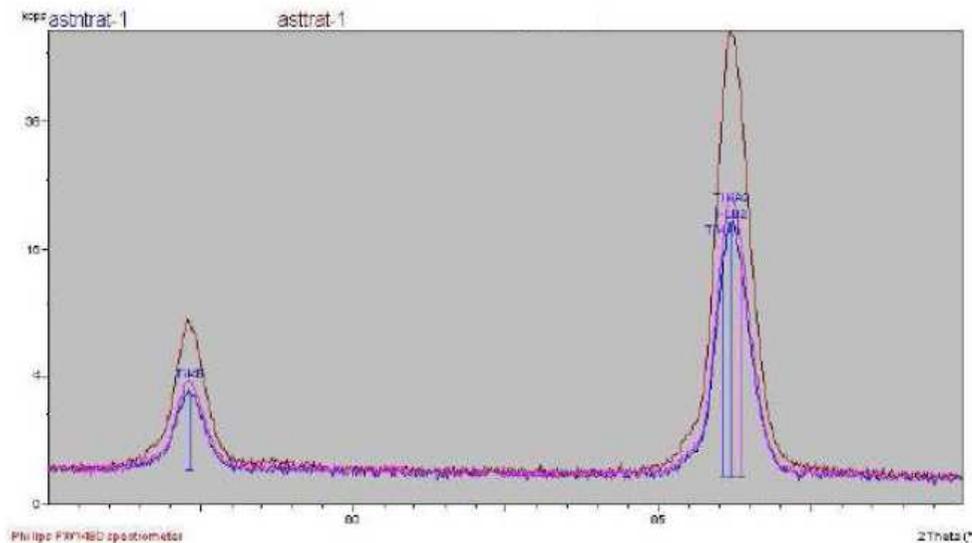
Parametro	U.M.	Risultato
E.Coli	% di abbattimento	>99,99%
Staphylococcus Aureus	% di abbattimento	>99,99%
Bacillus Subtilis	% di abbattimento	>99,99%
Pseudomonas Aeruginosa	% di abbattimento	>99,99%

Microbiological analysis by: Biochemie LAB – Calenzano (FI)



Results: Photocatalytic antibacterial effect

PL-Polyester (Asterix-)-asttrat /astntrat:



XRF analysis by: Cericol- Empoli (FI)

Results:

- Complete Photocatalytic antibacteric effect
- First product line almost ready at a reasonable price

Problems:

- Washing resistance

Untreated Asterix (astntrat)

Parametro	U.M.	Risultato
E.Coli	% di abbattimento	40,9%
Staphylococcus Aureus	% di abbattimento	0%
Bacillus Subtilis	% di abbattimento	62,5%
Pseudomonas Aeruginosa	% di abbattimento	0%

Nano TiO₂ treated Asterix (asttrat)

Parametro	U.M.	Risultato
E.Coli	% di abbattimento	>99,99%
Staphylococcus Aureus	% di abbattimento	>99,99%
Bacillus Subtilis	% di abbattimento	>99,99%
Pseudomonas Aeruginosa	% di abbattimento	>99,99%

Microbiological analysis by: Biochemie LAB – Calenzano (FI)



Results: UV protection Cotton and linen

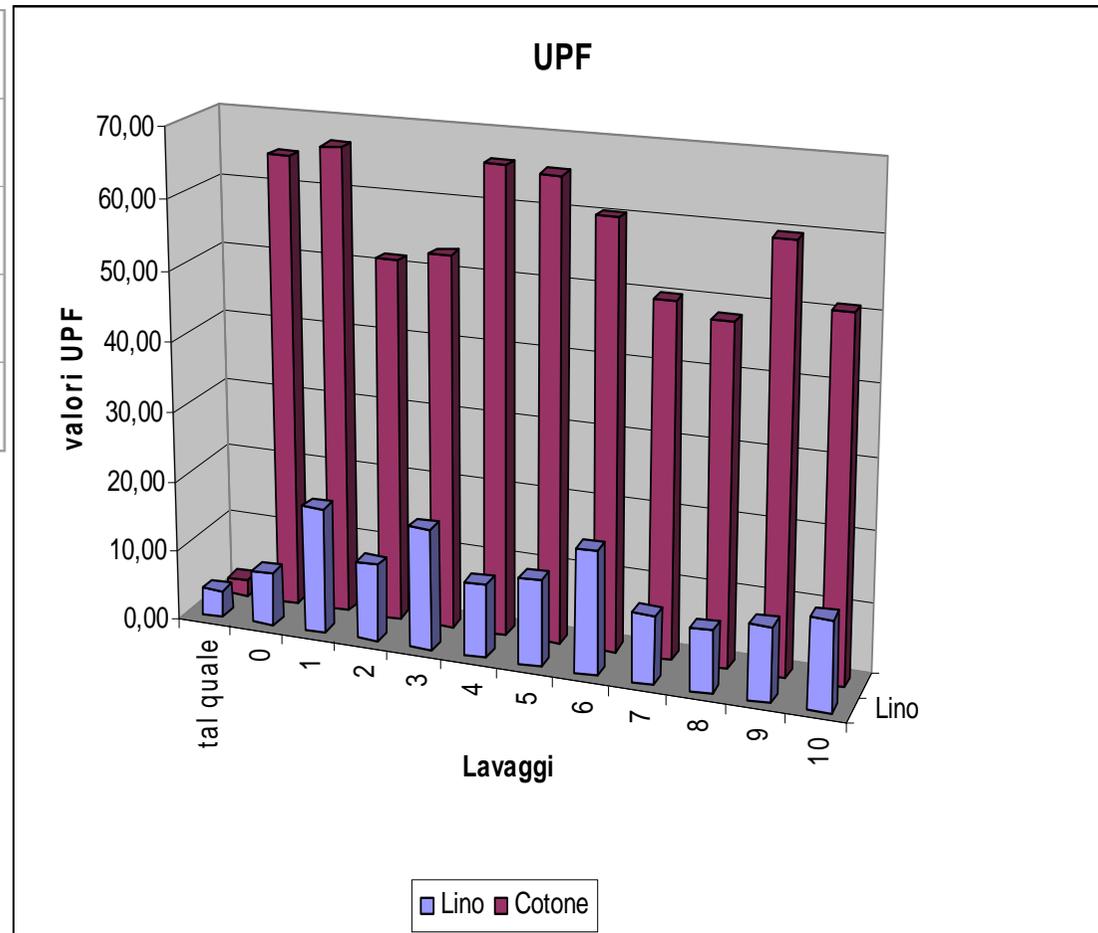
UPF	Categories
from 40 to 50+	Excellent UV protection
from 25 to 39	High UV protection
from 15 to 24	Good UV protection
10 or less	No protection

Results:

- UV protection
- Good washing resistance

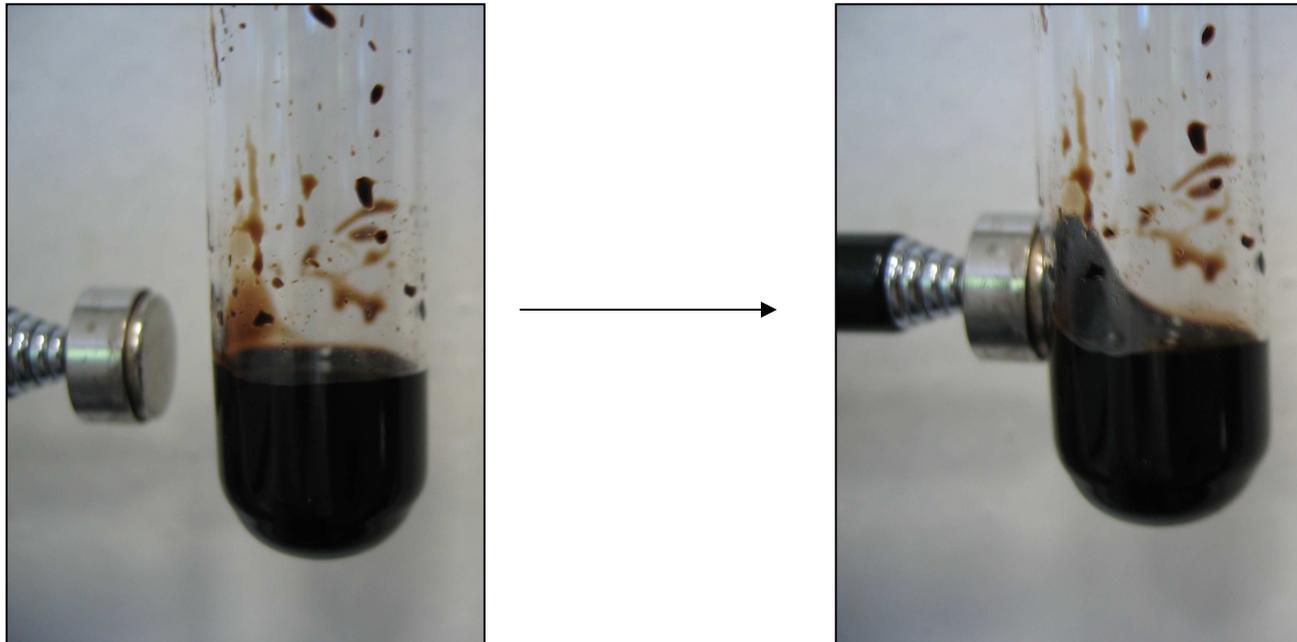
Problems:

- No market interest



UPF analysis by: Cericol - Empoli (FI)

CoFe₂O₄



Same approach (cotton and Polyester samples) but:

- Glycol based solutions
- High nano-solution economic value
- Black color
- More complex processes (Glycol smoke in thermal cycles etc.) – solved



Results: Magnetic properties

PL-Polyester (same results with cotton etc.):



Results:

- Complete homogeneous reaction to magnetic forces with almost unchanged hand
- As shown in the next slide, homogeneous Hyperthermia induced by controlled electromagnetic fields (fabric increase temperature between 8 and 10°C in 15-20s of irradiation with a 170 kHz / 21 kA/m field)

Problems:

- Black color
- High price (but with decreasing trend)

(*) Tessiltoschi/Technores patent pending

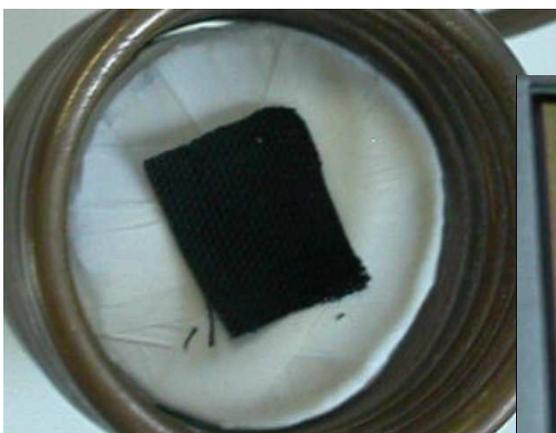


Polyester

Increase in Polyester Temperature
(starting from 20°)



Polyester T after 15-20s



Cotton

Increase in Cotton Temperature
(starting from 20°)



Cotton T after 15-20 s



Results:

- Conductivity tests have also shown interesting changings in fibers
- Tests are still ongoing in order to understand the fiber-nanosolution-conductivity relations

Problems:

- Non omogeneous conductivity increase
- Different fibers react in very different ways



Prototipo	Temperatura (°C)	umidità relativa(%)	R _s (MΩ)	R _t (MΩ)
K18-poliestere Con NANO cobalto ferrite	22.3	23	10.7	8.8
K18-poliestere non trattato	22.3	23	3600	590

Conductivity analysis by: [Tessiltoschi Industrie Tessili - Prato](#)

ZrO₂



- Solution application similar to the one of TiO₂ (water stabilized/neutralized solution)
- Economic value in the same range as for TiO₂
- Very interesting change in hand
- Some fibers appear to react increasing the surface abrasion resistance
- Market interest for forming productions especially for nets



- Simple cotton

- Cotton with ZrO₂

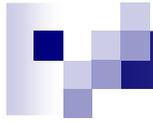


- More R&D activities needed testing the results



Conclusions and considerations:

- With Nanosuspensions is possible to **customize** many different textiles products, also combining more effects according to the performances required.
- UV protection and photocatalytic antibacterial effect are already available on many products and, in comparative testing, give much **better results** than simple Silver salts based products available on the market, moreover nano $\text{TiO}_2 @ \text{Ag}^0$ can be used instead of simple TiO_2 in order to combine Ag and nano TiO_2 properties
- **Magnetic and Hypertermic** textiles are still under development, depending on the different requirements of end-users (biomedical, advanced filters etc.)
- ZrO_2 products still **need more testing** and understanding
- The use of nanomaterials in textiles innovative products is a promising field of research and development since other applications can be investigated.
- Even though Innovative products may now have high prices, it is reasonable to expect a decrease in their **production costs** in the near future; that's why it is worth investigating.
- **Toxicology** of nanomaterials, like any other material has to be evaluated in order to guarantee the use of non toxic products.
- After many studies, also involving EU projects R&D teams, we think that for first industrial applications, where possible, liquid confined nanomaterials are a safe choice both for producers and users. **Nanopowders**, once tested in/by Technores/Cericol/Tessiltoschi combined with hot-melt technology, are still really difficult to handle and confine and need more time to be studied.
- **NANOMATERIALS** open a new world of material based research and possibilities in many different industrial fields, but they will need time in order to guarantee a sustainable diffusion.



Thank for your attention

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