

Market Opportunities in Nanostructured Coatings

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Nanomaterials Crossroads
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Summary

- ❑ **Types of nanostructured coatings**
- ❑ **What types of products and markets will make use of nanocoatings?**
 - **Where are they used now?**
 - **Where are the market opportunities, and for what?**
 - **What developments are likely to have good markets?**
- ❑ **What are the drivers and barriers?**
- ❑ **How can we make money at it?**

Primary coatings markets

□ Tooling

- willing to try new wear coatings – low risk

□ Aerospace

- push the envelope, but conservative
- advanced coatings essential for making some components work (e.g. hot section turbine blades)

□ Automotive

- fuel injectors, valve stems
- highly cost driven

□ Optical and electronic

- innovative, short product cycles

In some markets a coating can also be a structural or functional material – e.g. fuel cells, gas separators

Functional coatings

- ❑ **Surface that differs from the underlying material**
 - **Wear, erosion, abrasion**
 - **Corrosion (Zn)**
 - **Friction (MoS_2)**
 - **Optical (glasses, CD)**
 - **Electronic, magnetic**
 - **Decorative (Cr)**
 - **Specialized military**
 - ◆ **low observable (aircraft)**
 - ◆ **anechoic (subs)**



(U.S. Air Force)

What do people look for in advanced coatings?

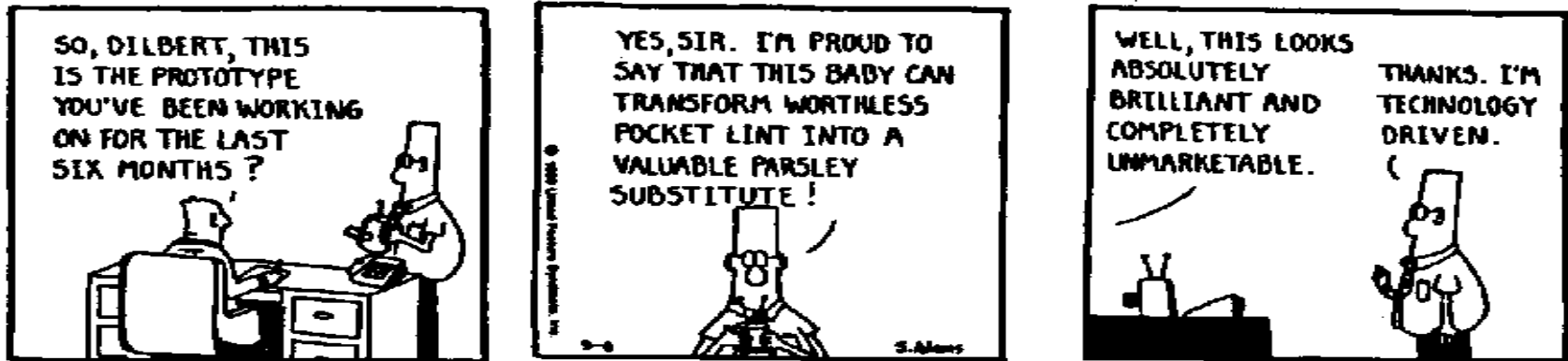
□ Better performance

- **harder**
- **stronger**
- **tougher**
- **more corrosion-resistant**
- **sometimes a unique combination of properties**
 - ◆ **hard and tough, impermeable and transparent**

□ Lower cost

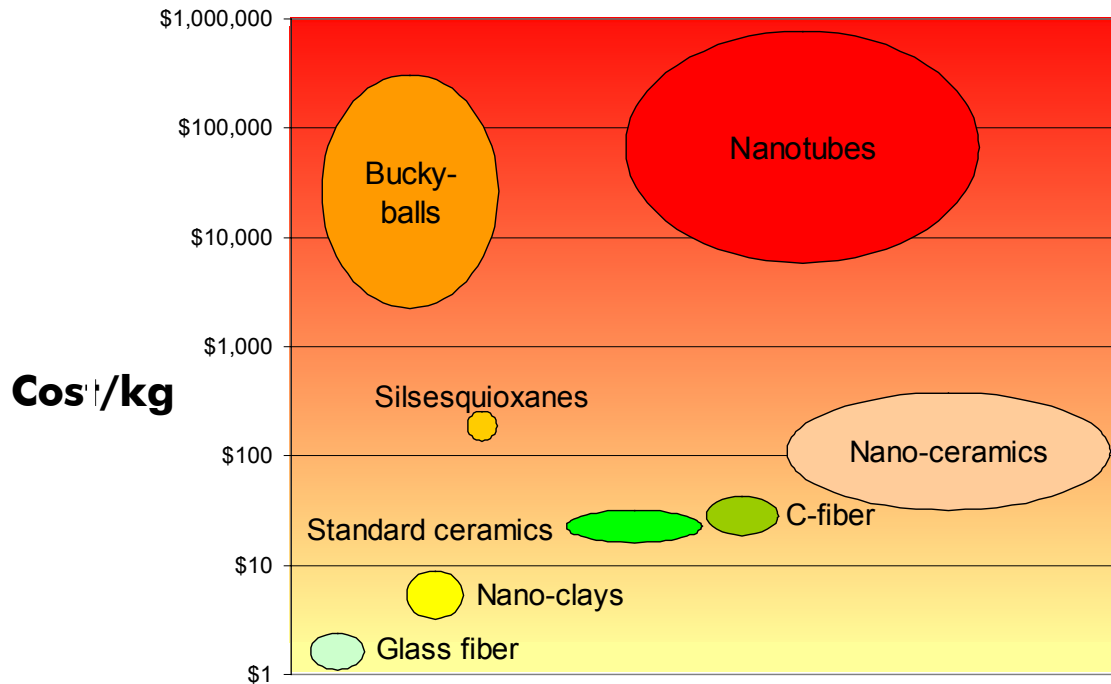
- **in all industries cost is important**
 - ◆ **in automotive, cost is paramount!**

Who cares?



- ❑ **Materials engineers are technology-driven**
- ❑ **Mechanical engineers are performance- and cost-driven**
 - **To get materials technologies to market they must offer a real performance advantage that people are willing to *pay for***
 - **Nanomaterials and nanocoatings can *improve* properties**
 - ◆ **Engineers don't want it because it is nano, but because it does what they need**
 - ◆ **Best is when it does something you cannot do any other way**

Cost of nanomaterials



- **Materials too expensive for bulk materials might be viable in coatings because of smaller volume**
 - **However, never assume cost is no object!**
 - **Most cost-effective approach is to grow a nanocoating, not put nano-material into a coating**

Methods of putting down coatings



- ❑ **Much less material needed**

- **Get the advantages of nanomaterials without making the whole part of expensive material**
 - ◆ **Nanoparticle cost not as critical**



Vacuum deposition
Eyeglasses, drills, watchbands



Thermal spray
Aircraft, industrial rolls



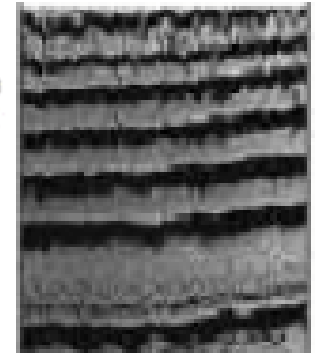
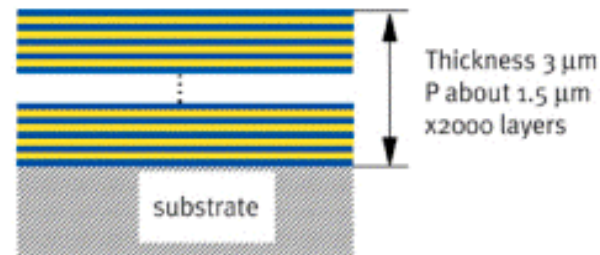
Electroplating
Chrome plate, Ni

Where are nanocoatings used today?

Cutting tools

□ Nanolayered coatings for cutting tools

- Superhard, tough
- Less wear
- Less setup time
- Manufacturers

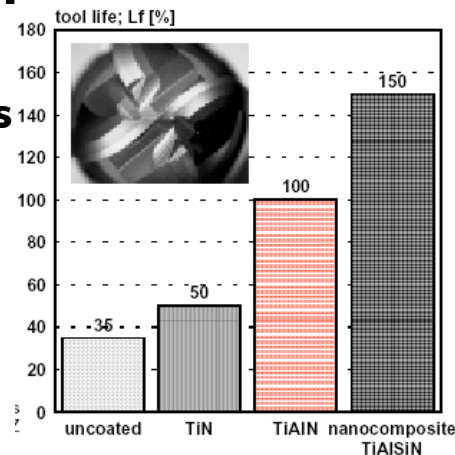
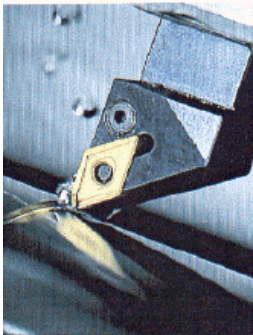


◆ Balzers Futura Nano TiAlN

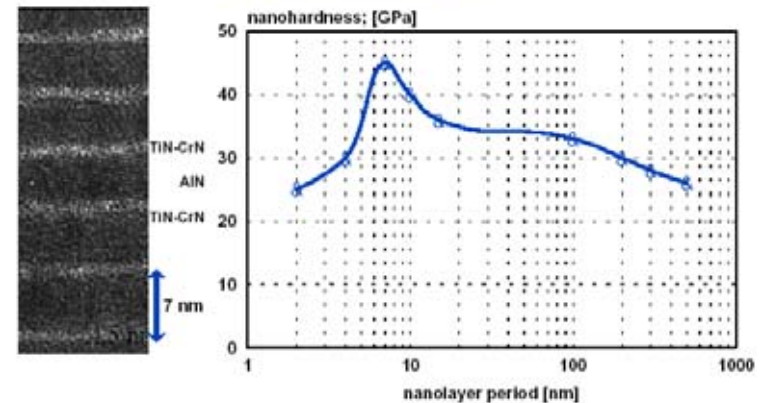
◆ Sumitomo ZX TiN/AlN

◆ Bekaert Dylyn

◆ Various others

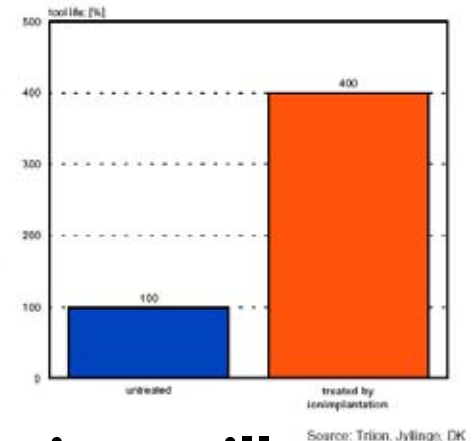


Superlattice Nanolayer



A word of caution on cutting tools

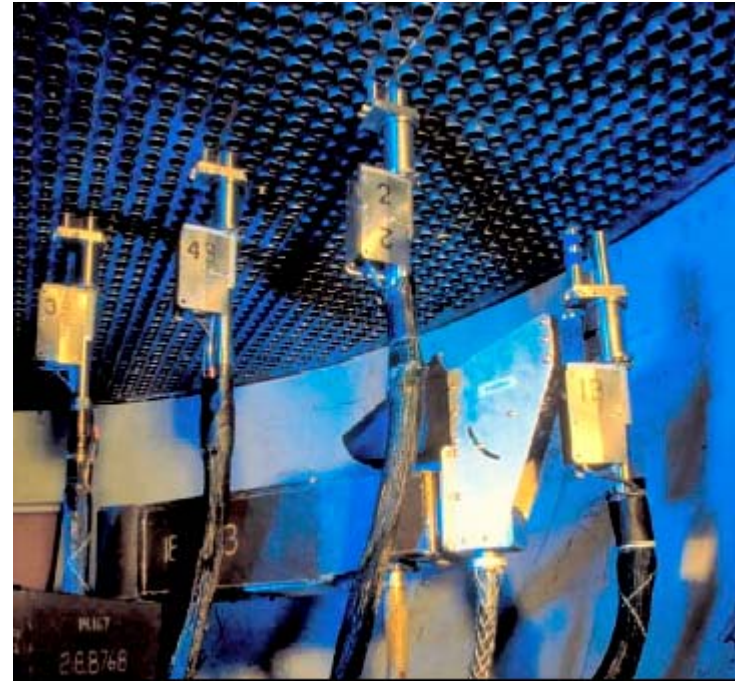
- ❑ **Superhard sounds good, but does not mean much to the market**
- ❑ **Wear life increases of 2-4x may not be worth much either**
 - **the tool market rarely pays more than 20% extra for anything**
 - **cf Ion Implantation**
 - ◆ pushed for many years
 - ◆ good improvements some applications
 - ◆ never made a real dent in the market



- ❑ **Simple coatings still dominate market**
- ❑ **However, the tool market could get excited about something that gave truly unique capability**
 - **e.g. interrupted cutting dry machining for steels**

Nanophase electroplate

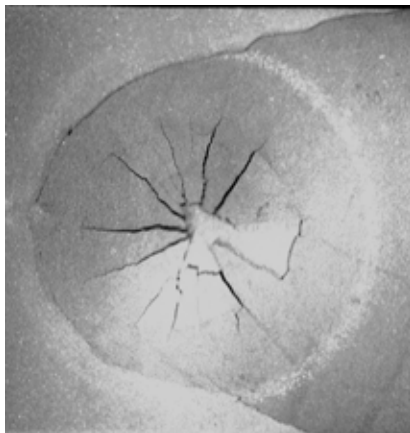
- ❑ **Babcock and Wilcox
Electrosleeve nanophase
Ni coating**
 - **Nanograin**
 - **Used for reclamation of
IDs of boiler tubes in
power stations**
 - **Framatone Technologies**
 - **Nanophase electroplating
technology development
by Integran**
 - ◆ **buildup**
 - ◆ **hard, wear resistant**
 - ◆ **corrosion**



Nanostructured thermal sprays

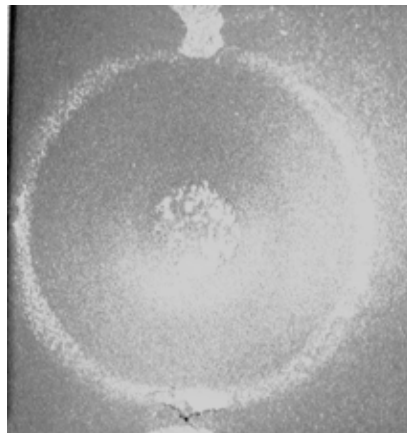
❑ Nano WC-Co not very useful

- WC tends to dissolve in Co
- Small carbides not good for wear
- Variable properties



❑ Successful thermal spray nanograin coatings

- Alumina/titania thermal sprays
- Constituents immiscible
 - ◆ Melt in gun and precipitate at substrate
 - ◆ **Hard/wear-resistant + ductile/crack resistant**
 - ◆ Developed for Navy
 - ◆ Powder from Inframmat



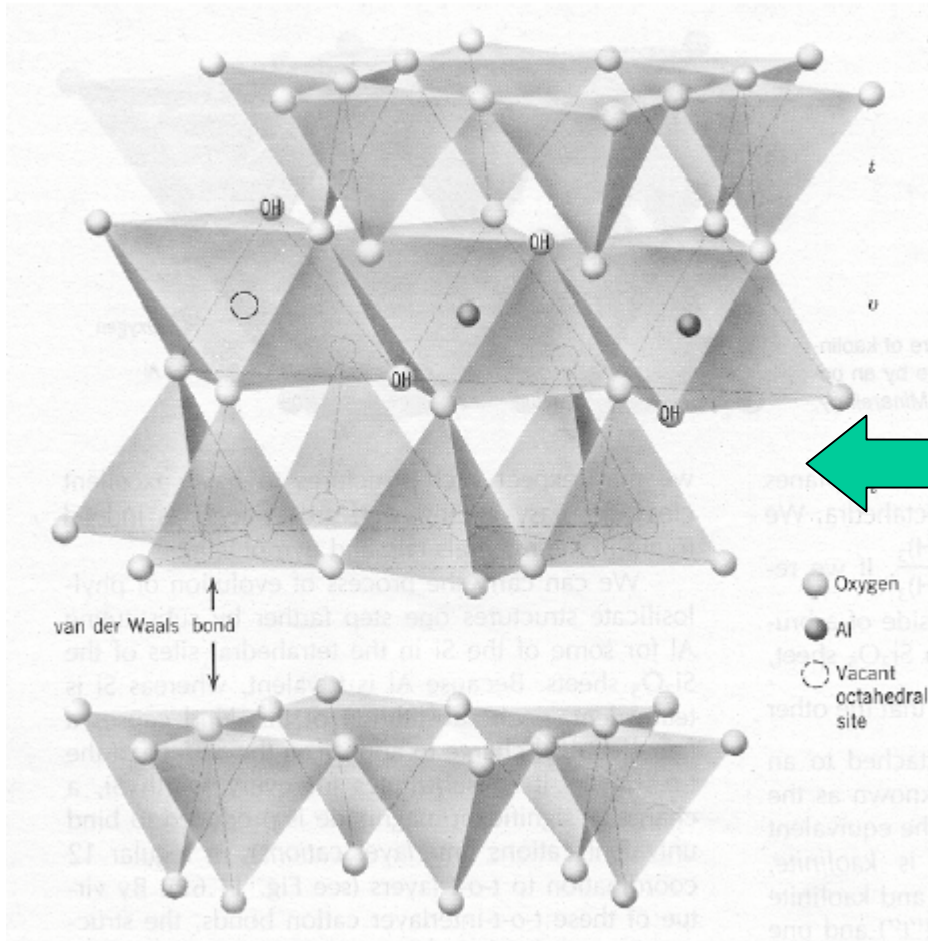
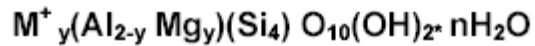
**Plasma spray alumina/titania
Standard
Nano
(Rigney, A&A Co)**

Naval applications of Alumina/Titania

- ❑ **Main propulsion shafting for Minesweepers**
- ❑ **Through-hull submarine ball valves**
- ❑ **Gear shafts (80 Ton air conditioning units for surface ships)**



Composites - Filled polymers



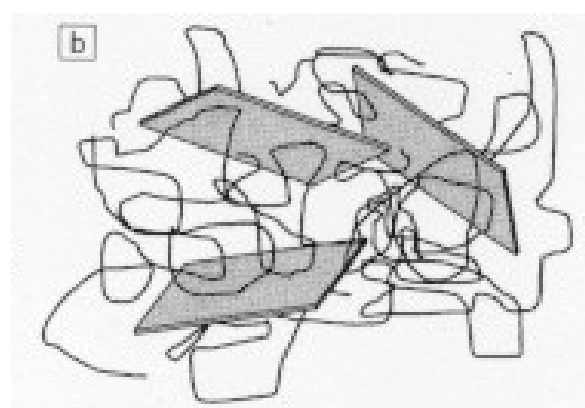
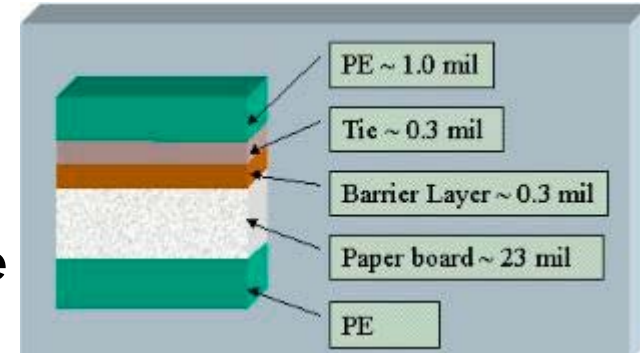
Composite fillers (for polymers, metals, etc.)

- Carbon black used for years in tires, etc.
- 1% Al_2O_3 filled gelatin scratch-resistant film (Kodak)
- Montmorillonite clay (Nanocor, Southern Clay Products)
 - ◆ particle thickness comparable to polymer molecule sizes
 - ◆ clean and treat to functionalize
 - ◆ large surface areas, low loading, less cost
 - ◆ clear - less light scattering

Smectite clays in polymer gas barriers

□ Gas barrier materials being marketed by Honeywell

- **Aegis NC Nylon nanocomposite**
 - ◆ juice cartons
- **Aegis OX Polyamide nanocomposite**
 - ◆ plastic bottles, etc.



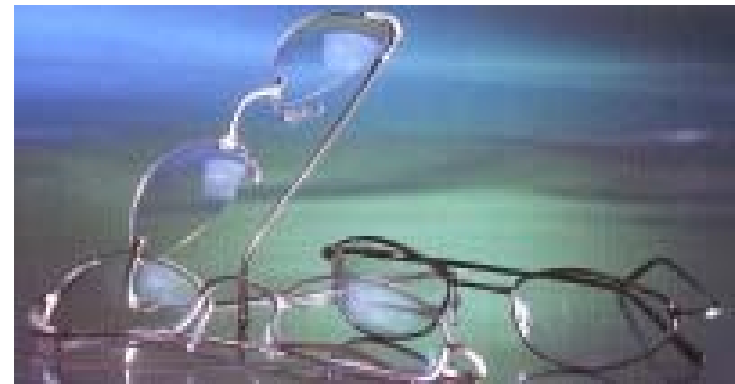
**Long paths
inhibit gas
flow**

Could you make good corrosion-resistant coatings out of this stuff?

Nanocoatings under development

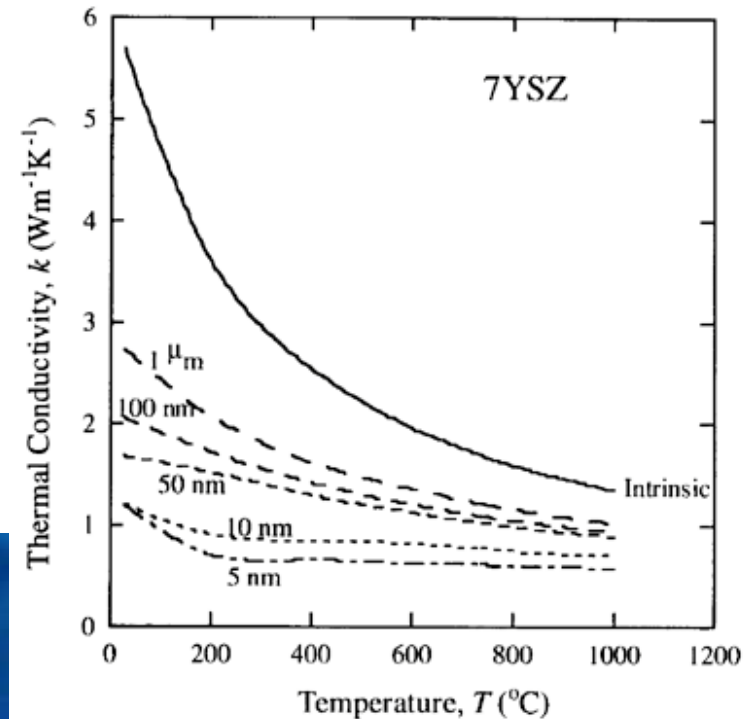
- ❑ **Polymer/nano-ceramic composite**
 - **Nylon or polycarbonate + nano-silica**
 - **Improved scratch-resistance**
 - **Various developers**
 - **Note: these do not have to be thermal spray**

- ❑ **Good potential for nano-fillers in polymer coatings**
 - **scratch-resistance**
 - **corrosion resistance**
- ❑ **Does something you cannot do another way**
 - **keeps it clear**



Another potential nanophase coating

- **Nanophase thermal barriers**
 - **Significantly lower thermal conductivity**
 - **Thinner, lower weight, better fatigue likely**
 - **Gas turbine engine blades and hot section walls**



Best potential applications for functional nanocoatings

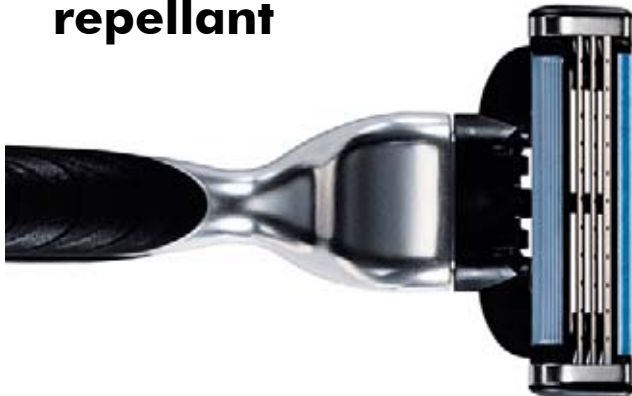
- **Look for the things you cannot do **any other way****
 - **scratch-resistant + gas and corrosion-resistant + **clear** coatings**
 - ◆ **may be able to engineer for exceptional corrosion resistance**
 - **hard + ductile coatings for wear resistance**
 - ◆ **high stress components**
 - **thermal barriers**
 - ◆ **turbine engines (aircraft and power)**



Corrosion is a multi-billion dollar issue throughout the economy

Consumer coatings

- ❑ **Decorative coatings**
 - **Look around – how many coatings do you see?**
 - **Paints**
 - **Inks**
- ❑ **Temporary coatings**
 - **Cosmetics**
 - **Razor blade lubricants**
 - **Sunscreen, insect repellent**



Paints and inks

□ Flex products

- **Nanosized multilayer interference filter optical flakes in polymer, paint, ink**
- **Deposit on plastic film, then dissolve film and break up into flakes**
 - ◆ **Anti-forgery for bills**
 - ◆ **Cool automotive paints**



Where are consumer nanocoatings used today?

□ **Cosmetics, sunscreen, etc.**

➤ **“Temporary coatings”**

◆ **Incorporate oxides**

- nano TiO_2 , ZnO , Al_2O_3

◆ **Liquid-carrying globules**

- nano-vesicles

➤ **A great deal of talk, few identifiable products**

◆ **Sunscreens in use (including “nanopants”)**

◆ **Limited, but growing, usage in cosmetics**

- lipsticks, creams, hair products

➤ **Why nanoparticles?**

◆ **Light scattering**

- particles $< 100\text{nm}$ are invisible

◆ **Dispersion and charge control**

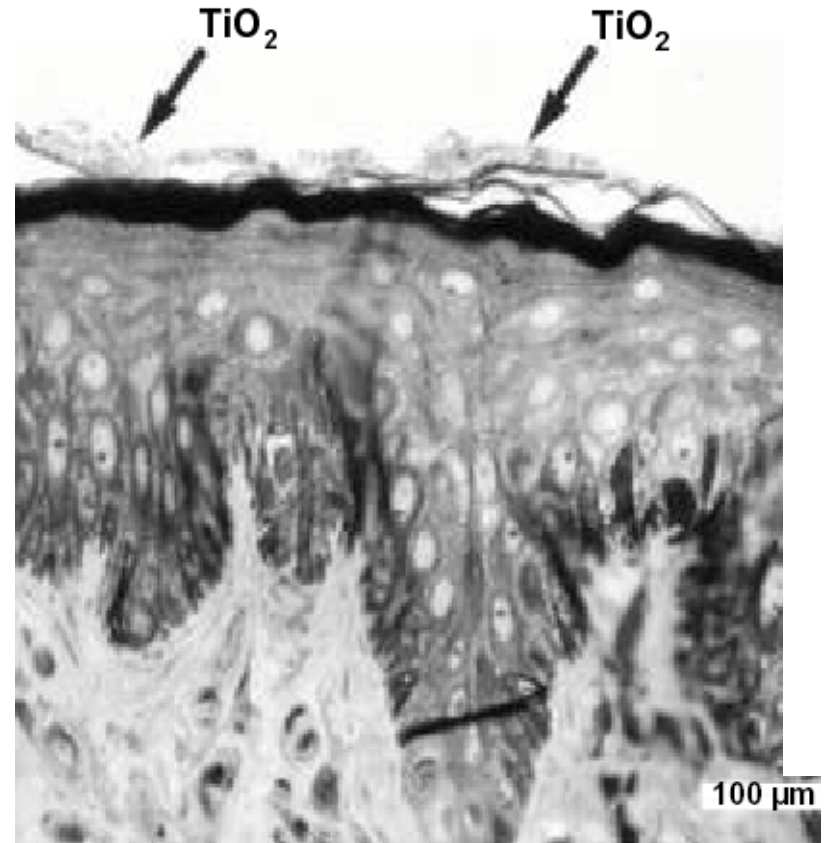
Nanoparticles in sunscreens

□ Nanopowders

- for sunscreen, wide spectrum reflectance
- no light scattering (clear, not white)
- high surface coverage (large surface area)
- good dispersion
- safe
 - ◆ well below $2.5\mu\text{m}$ particle size
 - ◆ does not penetrate skin

□ Producers include

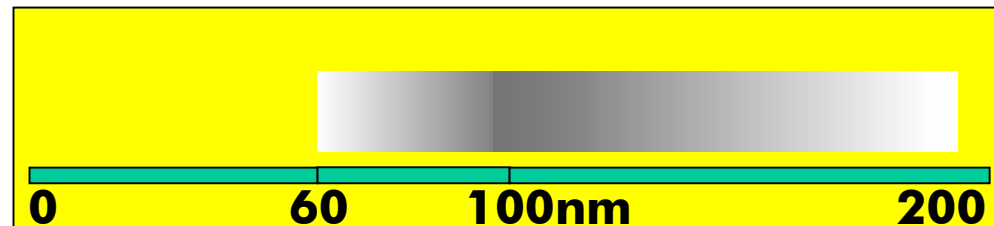
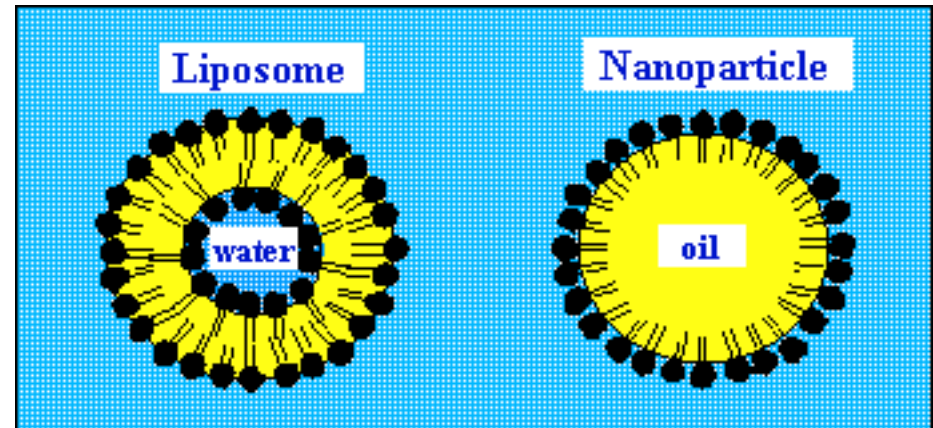
- BASF (TiO_2 on textiles)
- Sachtleben (Germany)



Sachtleben

Nanoparticles in cosmetics

- ❑ **Lipid nanoparticles carry oil, which can incorporate Tretinoin, Retinol, Vitamin E, UV-Filters, Fragrance**
 - <60nm transparent
 - **Good dispersion**
 - **Affinity to skin, releasing active agents**
 - **Do not feel greasy**
 - **Can make +ve charge to remain on hair**
- ❑ **L'Oreal, Mibelle AG (Switzerland)**
 - **Microsomes transport through skin**



Drivers and barriers - coatings

Drivers

- ❑ **Unique combinations of properties**
 - **hardness + toughness**
- ❑ **Transparency**
 - **Packaging**
 - **Clear coats**
 - **Cosmetics**
- ❑ **Unique capabilities**
 - **Gas, liquid impermeability**
 - ◆ **packaging**
 - ◆ **corrosion?**
 - **Very low thermal conductance**

Barriers

- ❑ **Cost sensitive**
 - **Strong barrier, even in aerospace/military**
- ❑ **Hard coatings must offer unique capability**
 - **Not just less wear**
 - **Things like lubricant-free interrupted cutting**

Market potential

- ❑ **Cosmetics probably offers best market potential**
 - **“Temporary coatings”**
 - **Titania particles**
 - **Lipid nanoparticles**
- ❑ **Functional coatings**
 - **Clear coats**
 - ◆ **various deposition methods**
 - ◆ **various markets, including eyeglasses**
 - **Barrier and corrosion coatings**

Where is the money to be made?

- ❑ **Companies in the nano-area with very good chemistry capabilities venturing with large cosmetics, paint makers**
- ❑ **Companies able to apply computational methods and/or combinatorial chemistry**
 - **Cost-effective product development**
 - **Minimal time-to-market**
- ❑ **Large-scale production capable technologies for clear-coats (licensing)**
- ❑ **Are there good solutions for corrosion?**

Serve market needs, not technology needs!

Conclusions

- ❑ **Cost is critical**
 - Even for aerospace coatings
- ❑ **Real market linkage - teaming between coatings development company and user**
 - Man shall not live by nano alone!
 - Only performance and cost sell
- ❑ **Functional coatings are great but the best short term opportunities are in consumer coatings**
 - Clear coats could be another big winner