Bayer MaterialScience

Nanocomposites for Automotive Applications

Dr. Péter Krüger, Bayer MaterialScience AG

Bayer Working Group Nanotechnology

SPE ACCE

Troy, 2007 September

Bayer – Science for a Better Life

Working Group Nanotechnology → **Nanotech Network within the Bayer Group**:

Virtual platform **for Bayer scientists engaged in nanotechnology Panel of experts**

- **Exploit synergistic effects between subgroups and business units**
- **Evaluation of safety issues (HSEQ)**
- **External representation of Bayer: Networks, competence center, associations etc.**

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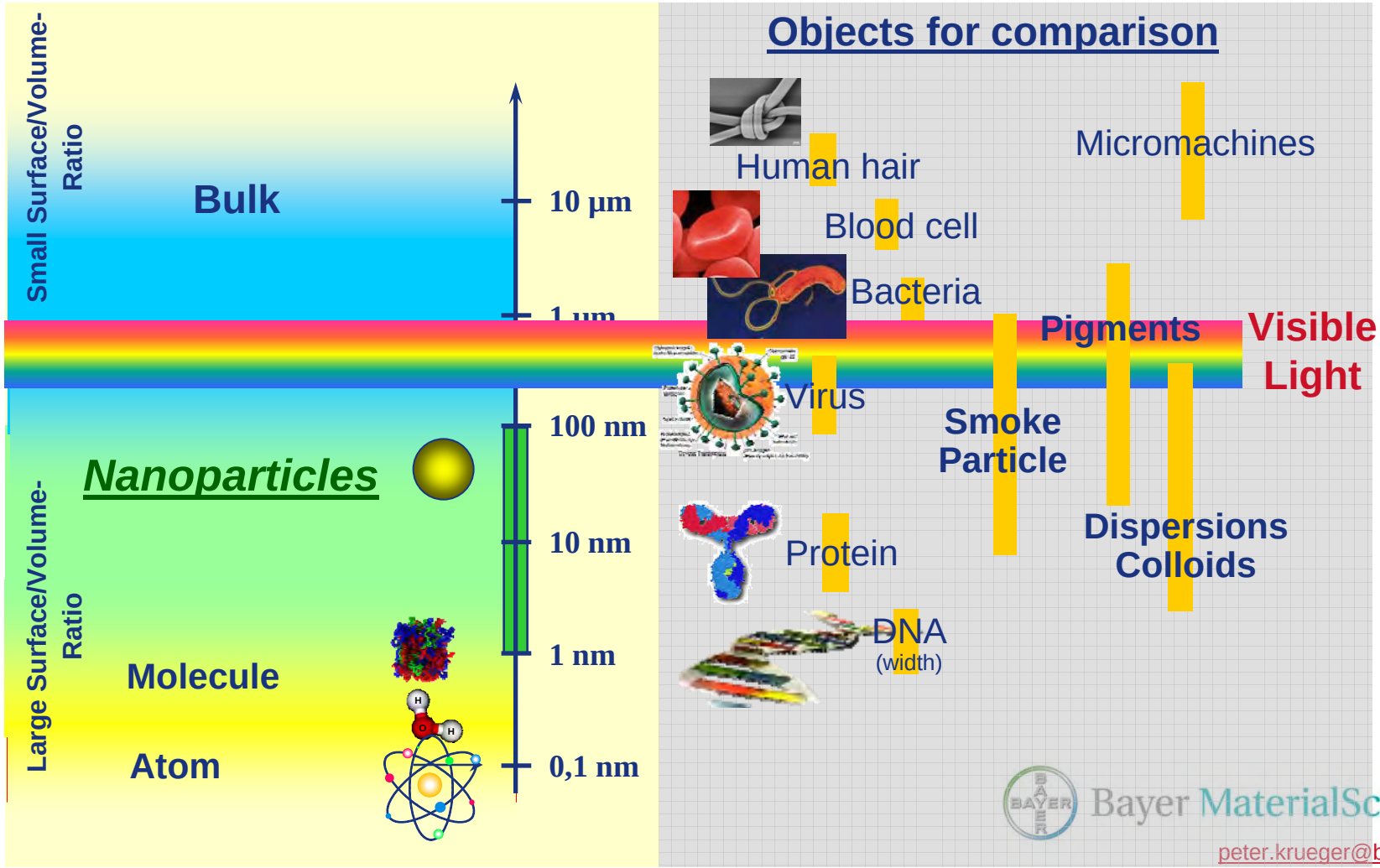
Key Facts on Nanotechnology

Nanotech: purposeful tool or process to engineer matter on a scale between 1 and 100 nm, to achieve modified or new properties



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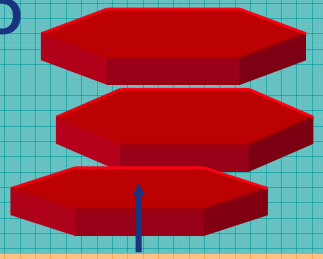
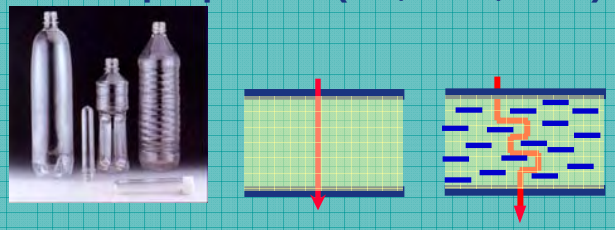
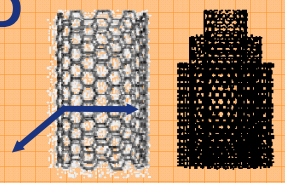
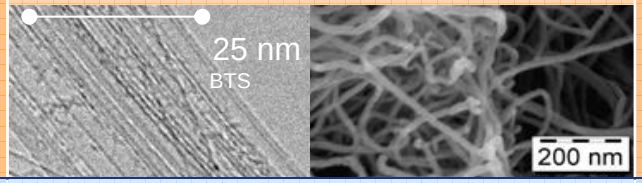
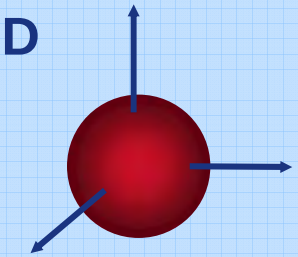
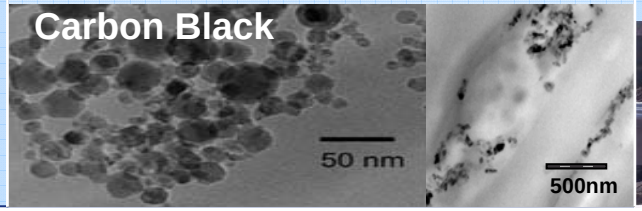
Dimensions of Nanoparticles

Dimensions	Examples	Benefits
1D 	Natural and synthetic nanoclays 	Barrier properties (O2, CO2, H2O) 
2D 	Carbon Nanotubes (SW & MW) 	Mechanical reinforcement, ESD 
3D 	SiO2, TiO2, ZnO2 CeO2, Carbon Black 	Mechanical reinforcement Scratch resistance, Flame Retardance 

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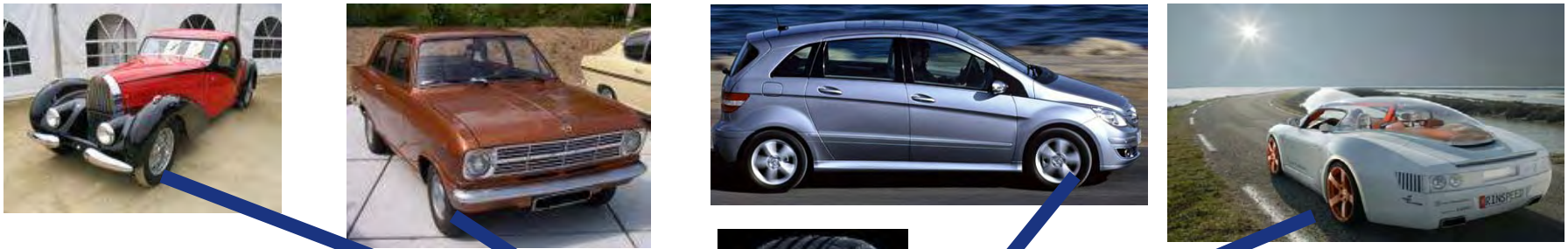
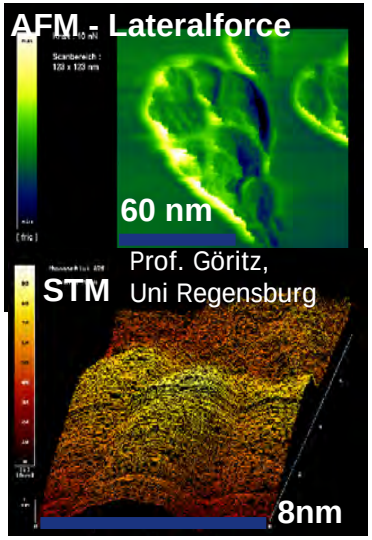
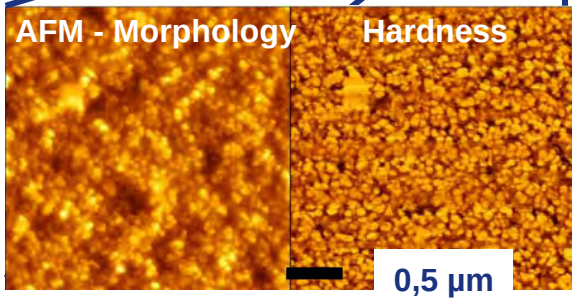
Established Nanotechnology

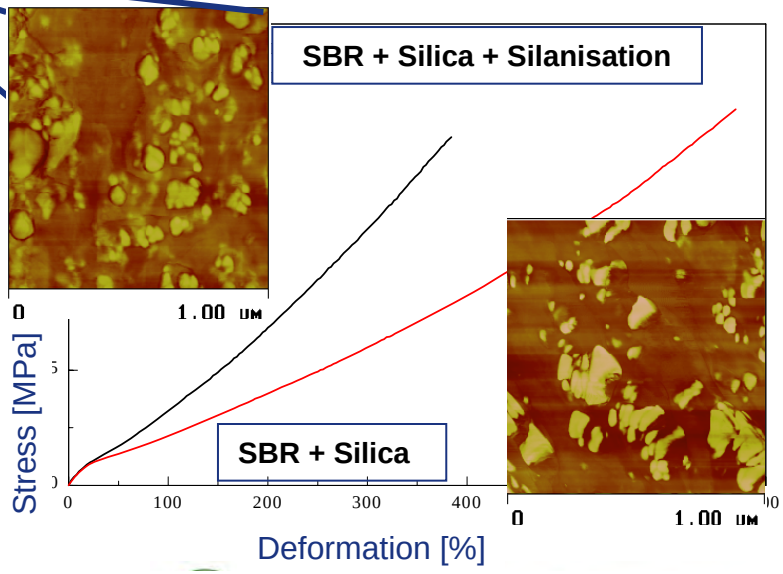


Carbon Black Technology

Silica Technology



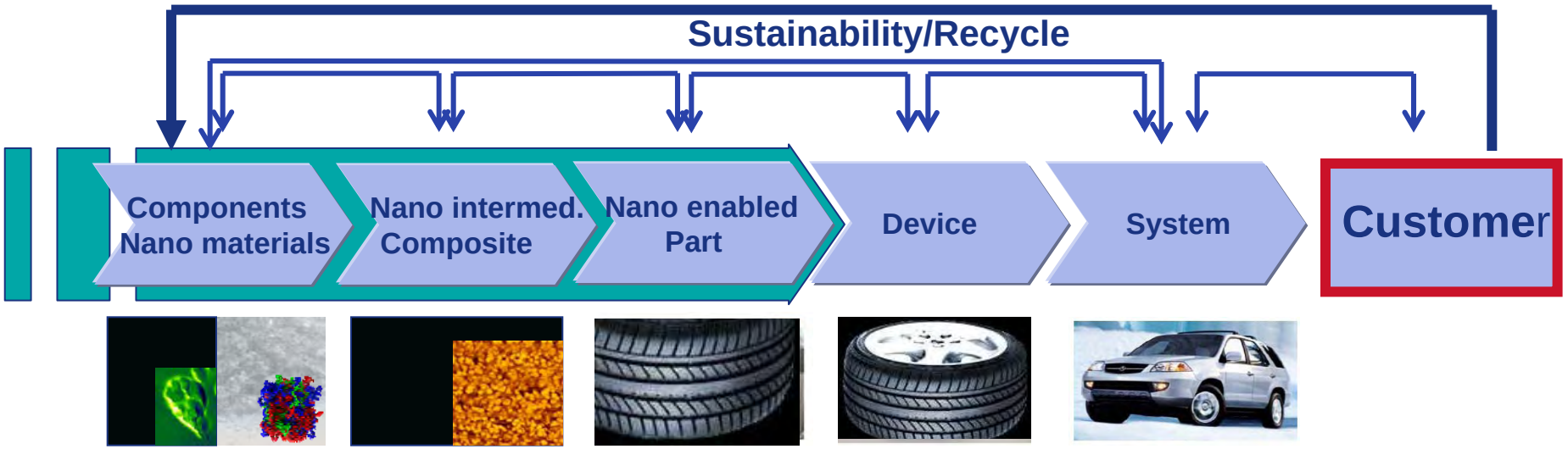




Nanotech is an Enabling Technology along the Value Chain since more than one Century

Key Facts on Nanotechnology
Three Truths*:

1. Nanotech is not new (Established nanotechnology)
2. Nanotech is not in all cases highly profitable
3. There are no nanotech markets, products and companies, **there is only a nanotech value chain (products enabled by nanotech)**



*Quelle: Lux Research

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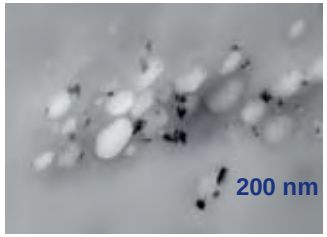
Nanotechnology Areas

Nanocomposites

Fire retardant plastics:
Bayblend FR incorporating nanoparticle



Thin Layer and Surfaces

Surface Modification:
Scratch Resistance,
UV-Protection,
Easy-to-Clean
Adhesives:
Bonding Strength
Thermal Stability
Processing

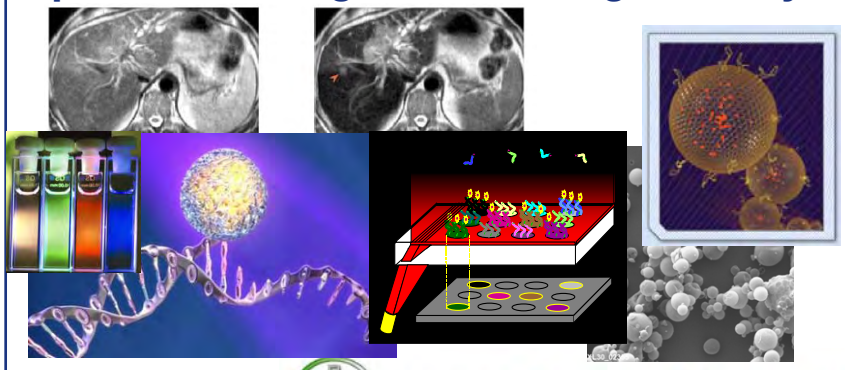
Nanoparticle / - additives

Carbon nanotubes – baytubes®,

Quantendots – Baydots®,

Nanobiotechnology

Liposomes, Diagnostics, Drug Delivery



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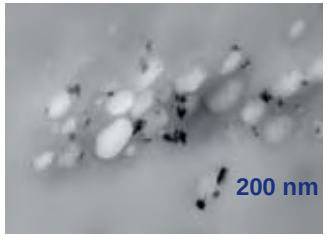

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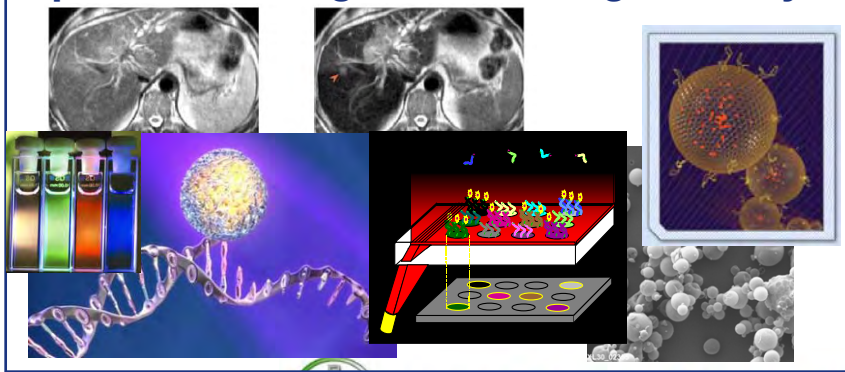
Liposomes, Diagnostics, Drug Delivery



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Use of Emerging Nanotechnology in Automobiles

Light Weight, Polymer Based Windows, Head Lamp Covers

Scratch and Chemical Resistance, IR- and UV-Protection, Easy to Clean

Improved Coatings on Metallic and Polymeric Substrates

Scratch and Chemical Resistance, Easy to Clean

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Nanocomposites for Coatings

Matrix polymer/Binder

Crosslinker / Hardener

Nanoparticle /Surface-mod.

Processing

Low viscous media

Jet disperser

High viscous media

Twin screew extruder

Nanocomposites

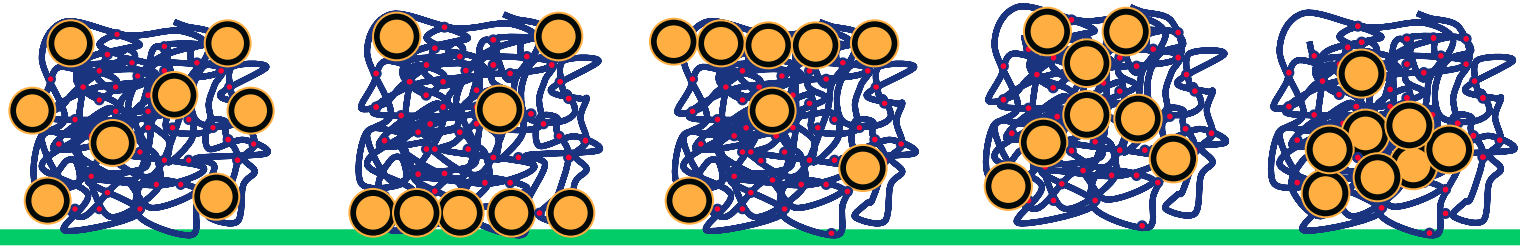
Homogenous

Enrichment

Enrichment

Network

Agglomerates



Substrate:
Metal, Polymer

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Emerging Nanotechnology is an Enabling Technology

Scratch Resistant Coatings

Desmodur XP ....

Hardener for CeramiClear PPG

Increased scratch, abrasion and solvent resistant coatings due to nanosized Silica in combination with a tailor made hardener

Binder
Nanoparticle
Surface-mod.
Hardener
Process

Coatings System

CeramiClear PPG

ALT UND NEU Glasklar spiegelt sich der Fotograf im kratzfreien Nanolack (unten). Dagegen erkennt man oben die Kratzer

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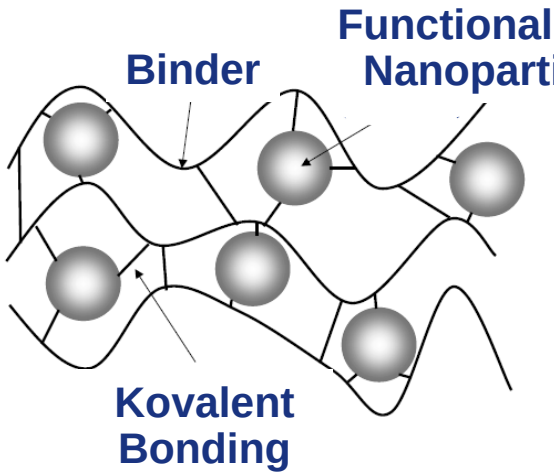
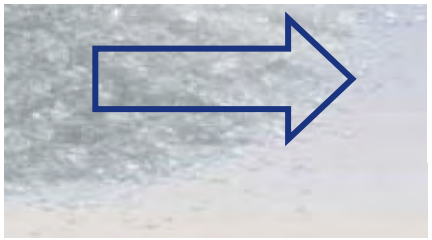
Nanotech as an Enabling Technology

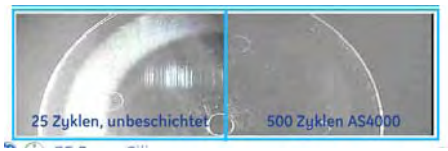
PC-Automotive Applications (Glazing, Headlamps)

Sol-Gel Hybrid Coatings and Polycarbonate substrates for scratch resistance in automotive glazing applications



PC-Substrat





Working Group Nanotechnology

makrolon the high-tech material

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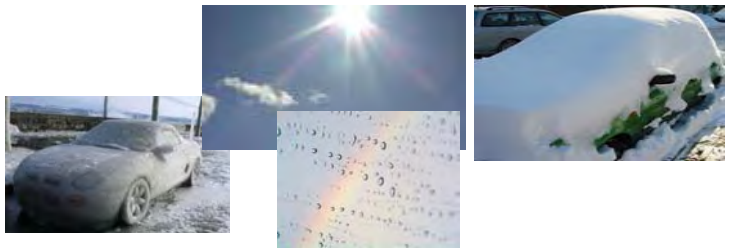
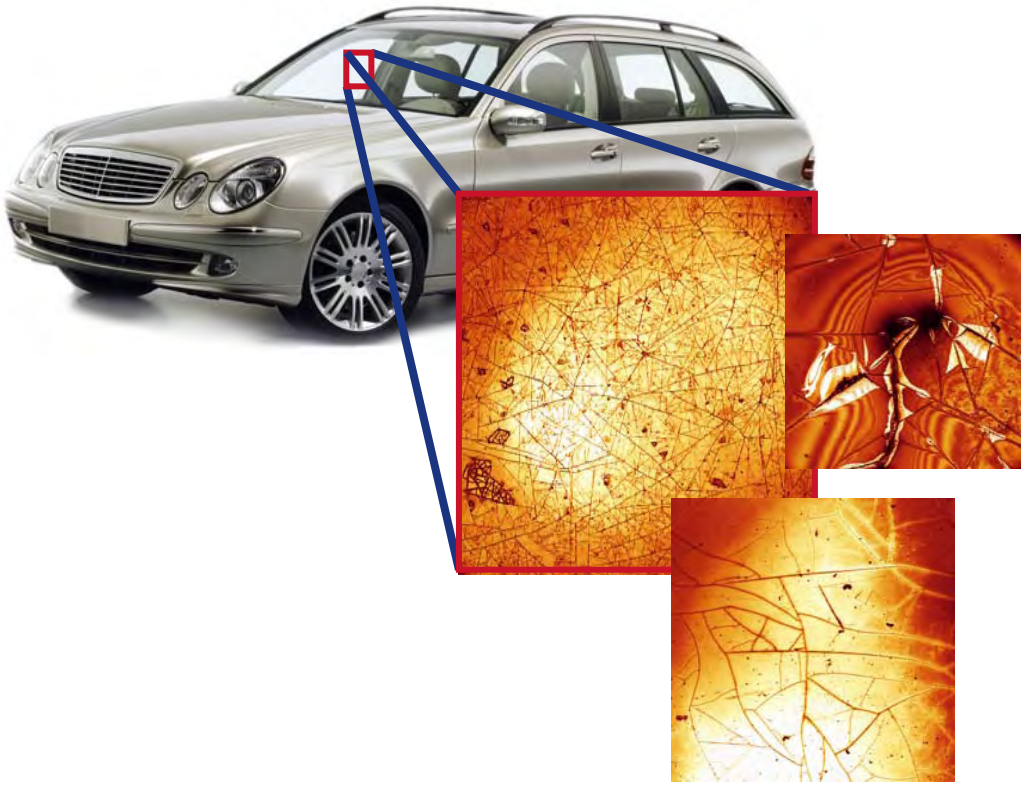
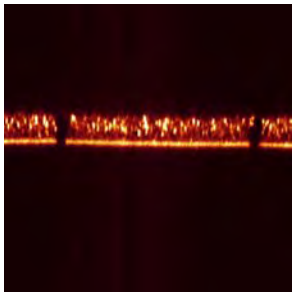
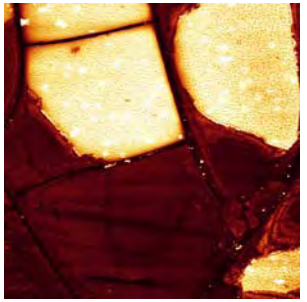
Challenge of Hard Coats on Polycarbonate Substrates: Durability of Coatings Properties after Weathering





Due to weathering very often high tendency to isotropic cracking (clod structure) within the coating layer leading to delamination of the coating at the final stage





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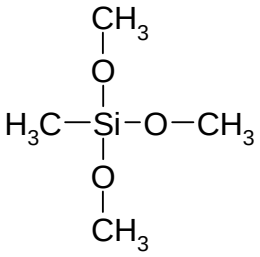
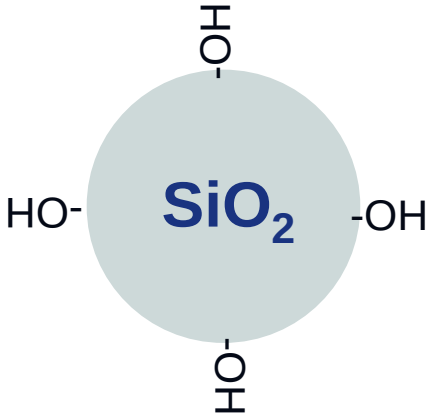
Hard Nano Based Coats
Resistance against Scratches and Chemicals

Type I

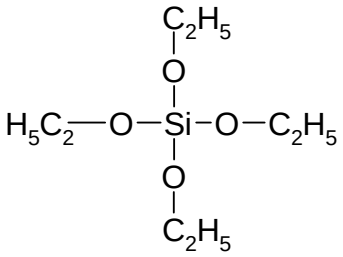


MTMOS

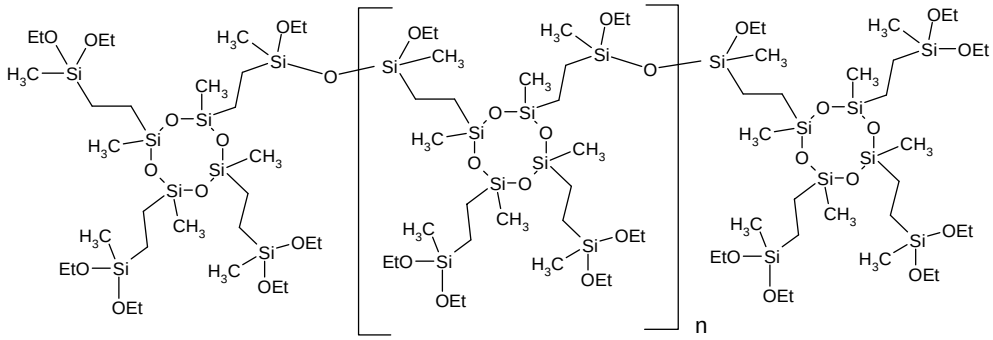


d = 10 - 30 nm

Type II



TEOS



BUT...

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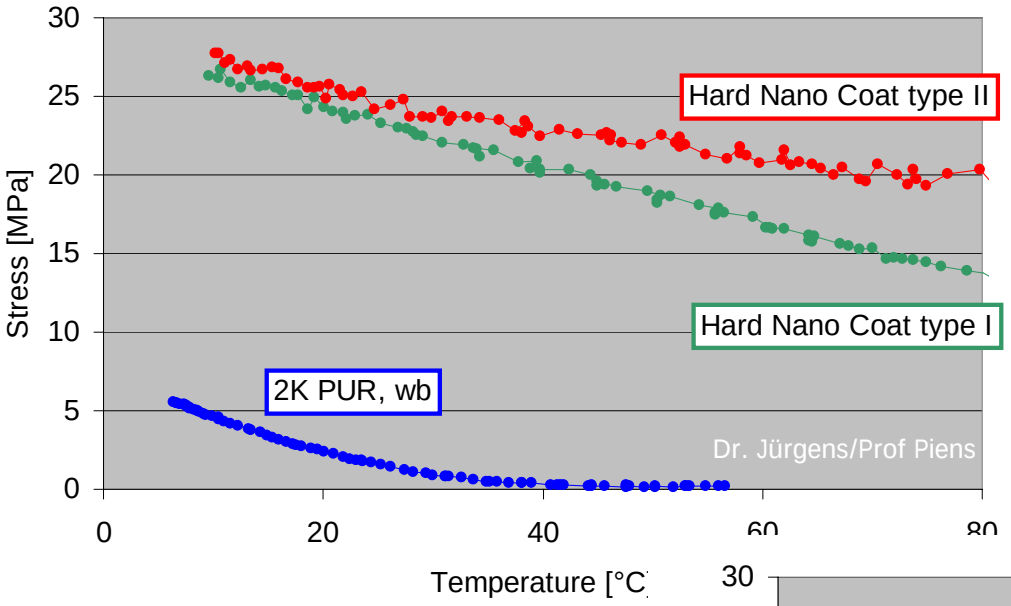
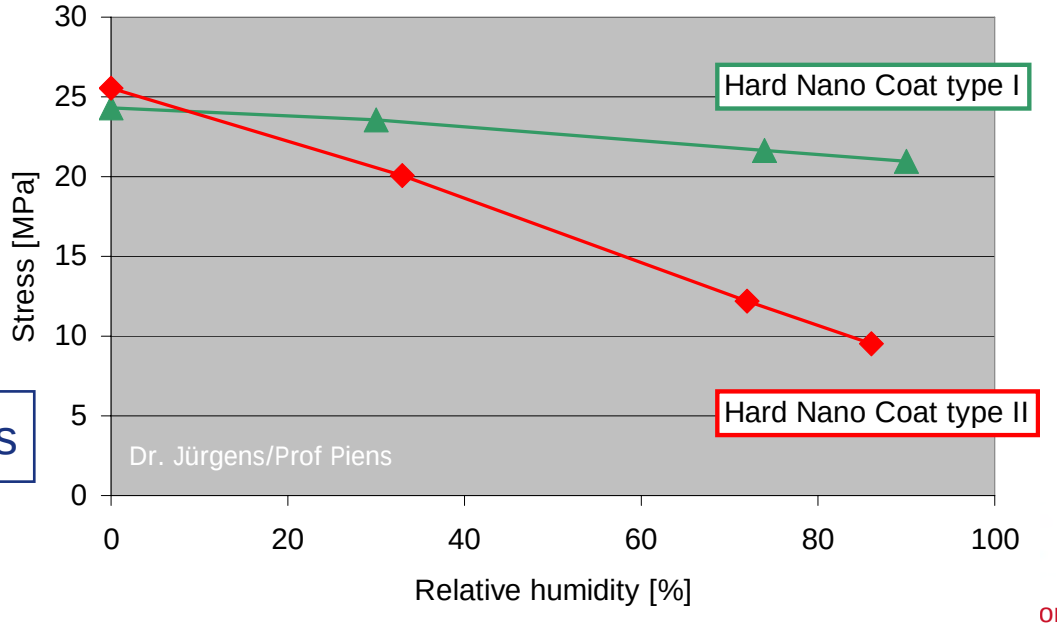
Thermal and Hygroscopic Stresses in Nanocomposites



Thermal Stress

Hygroscopic Stress



om

Adhesive Nanocomposits

Combination of Polychloroprene- and SiO-Dispersions

Technical improvements, New application fields, Health, safety, environment

SiO_2,
$\varnothing$ = 9 – 55 nm

Dispercoll® S	Concentration (%)	Density (g/cm³)	Spec. surface (m²/g)	Particle size (nm)
Dispercoll S 5005	50	1.39	50	55
Dispercoll S 4510	45	1.34	100	30
Dispercoll S 4020	40	1.30	200	15
Dispercoll S 3030	30	1.21	300	9

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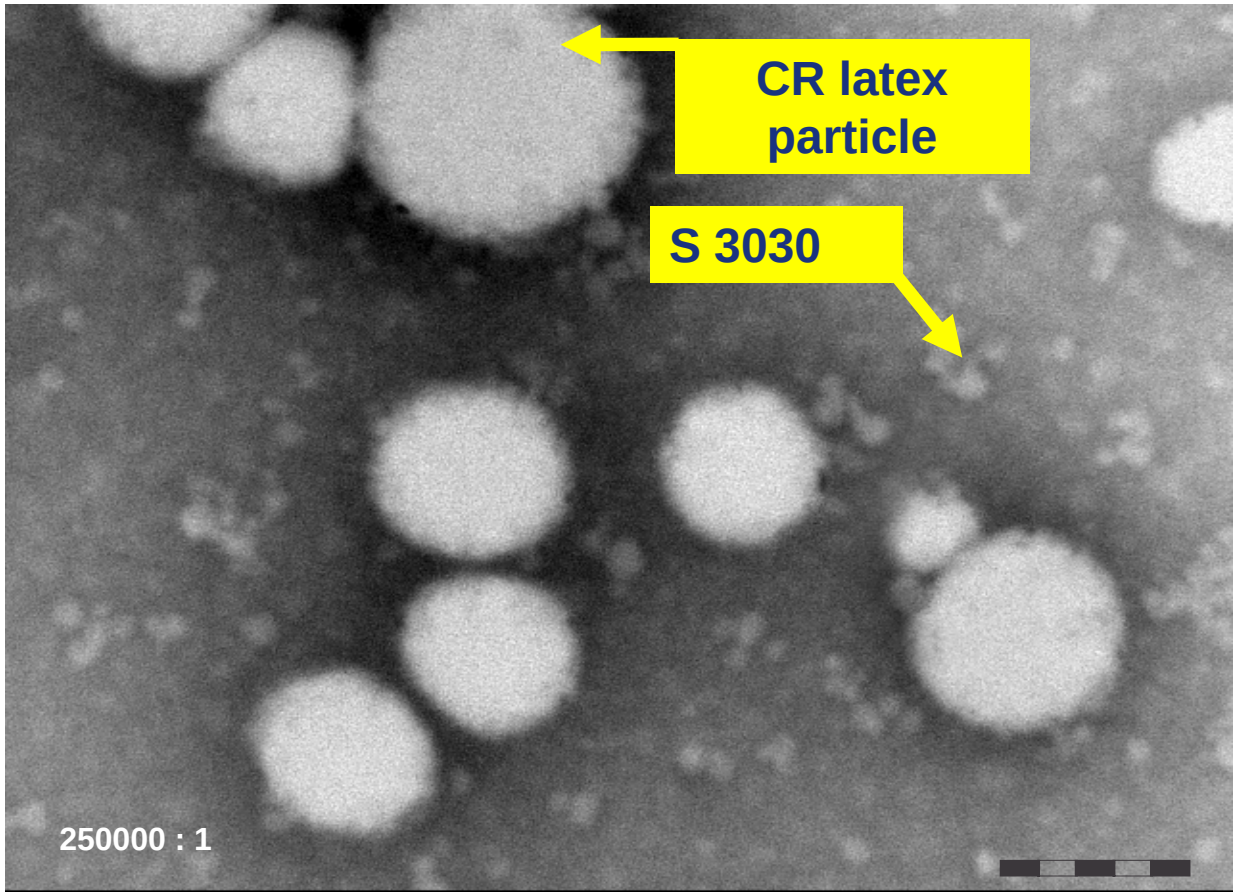
Adhesive Nanocomposits
Combination of Polycloroprene- and SiO-Dispersions



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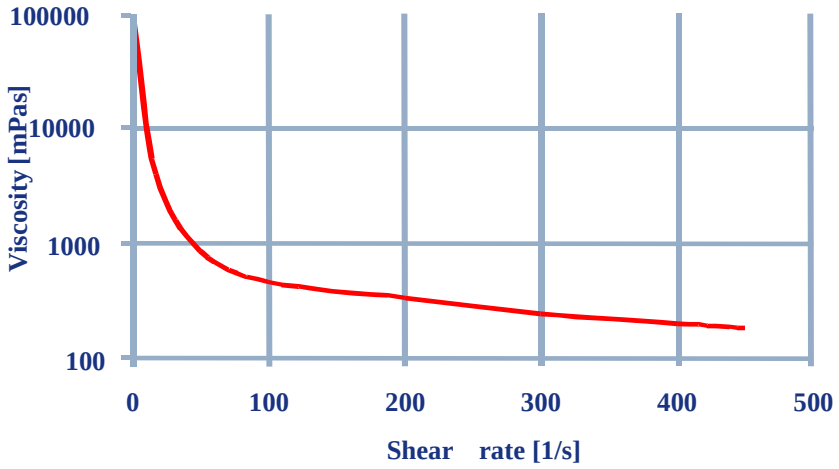
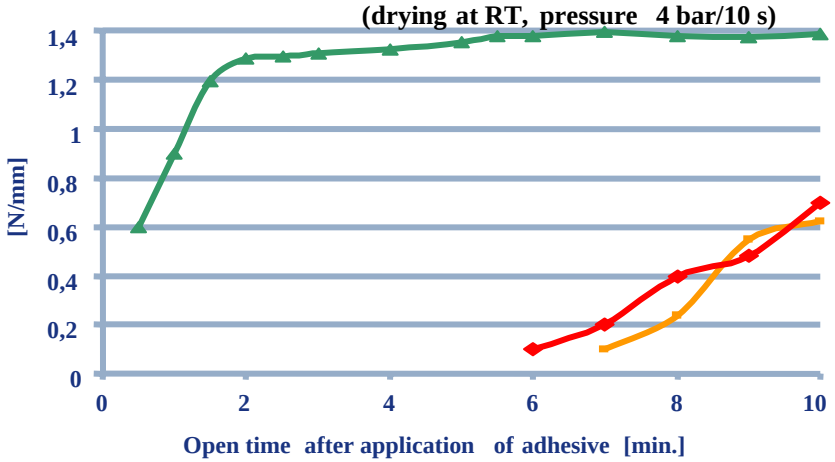
Adhesive Nanocomposits
Combination of Polycloroprene- and SiO-Dispersions

Rheology



Initial peel strength

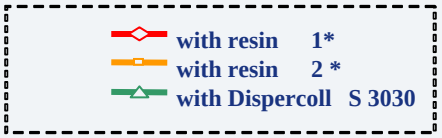
(wet bonding) on leather



Dispercoll S acts as a shear thinning agent

Dispercoll S improves the initial peel strength

Formulation	solids (%)	pbw
Dispercoll C 84	55	100
antioxidant	20	2
Dispercoll S 3030	50	30
metal oxide dispersion	50	4



*Terpene-phenole resin

Due to improved properties, bonded parts can be handled earlier

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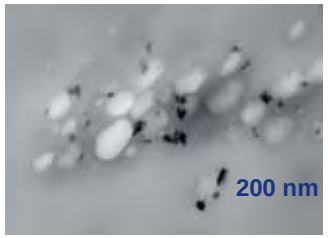

Thin Layer and Surfaces

Surface Modification:
Scratch Resistance,
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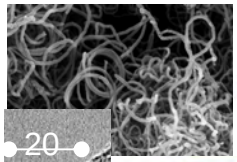
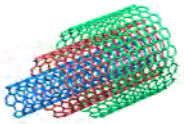
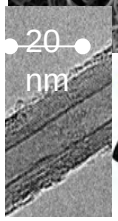
Adhesives:
Bonding Strength
Thermal Stability
Processing

Nanoparticle / - additives

Carbon nanotubes – baytubes®



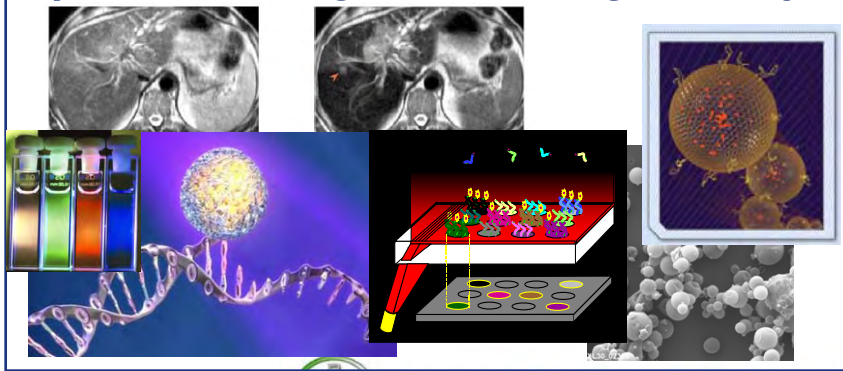




Quantendots – Baydots®

Nanobiotechnology

Liposomes, Diagnostics, Drug Delivery



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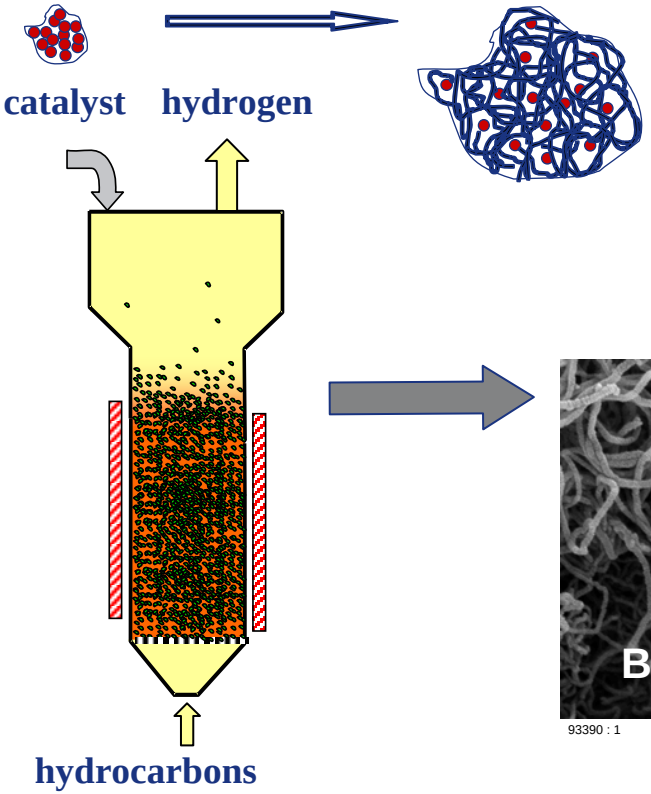
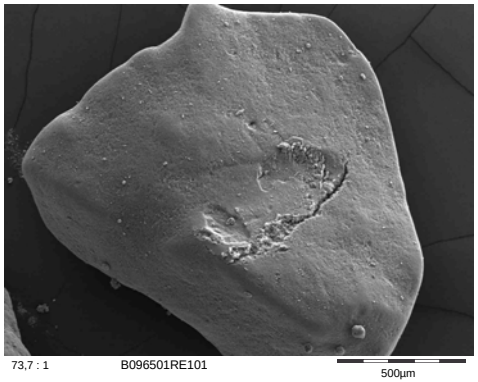
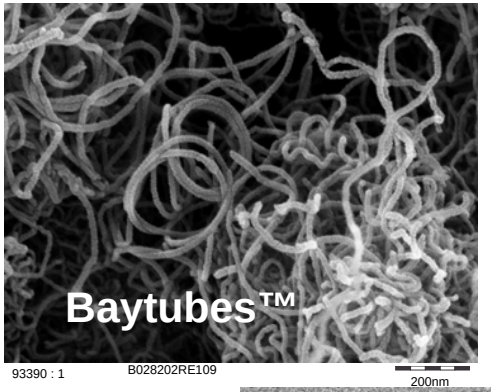
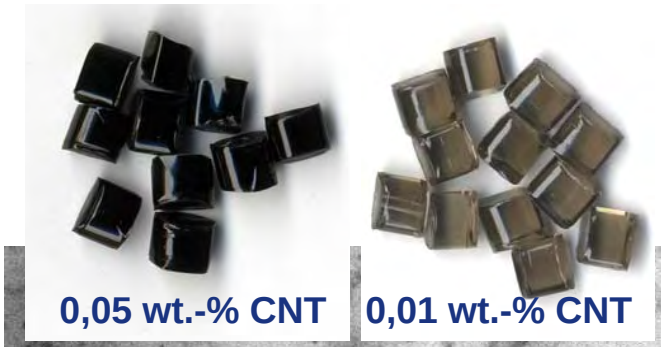
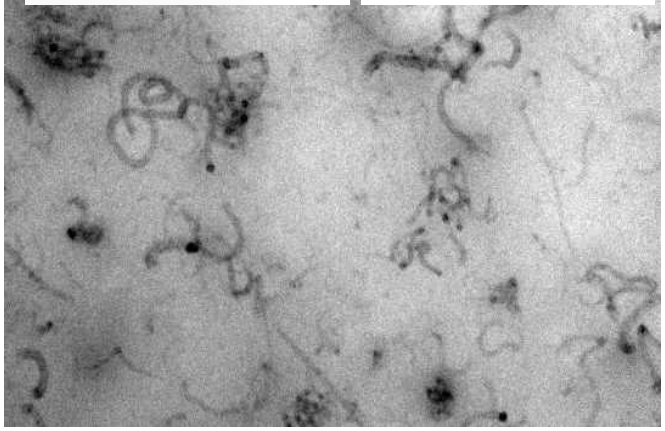
Carbon Nanotubes in Nanocomposites:

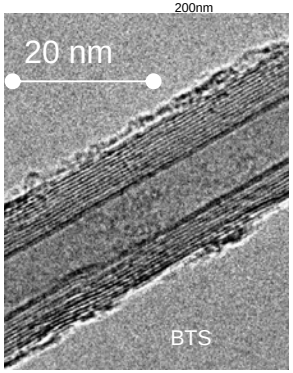












Baytubes™
Agglomerates of multi-walled carbon nanotubes (MWCNT)

Carbon nanotubes applications
- **Electrical conductivity**
- **Mechanical reinforcement**
- **Heat conductivity**

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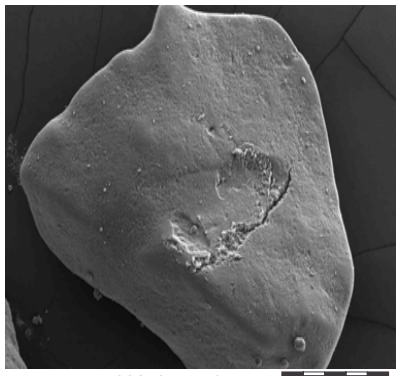
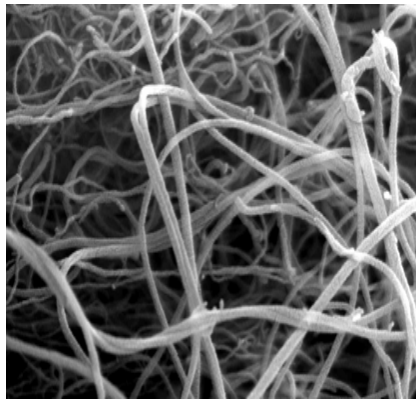
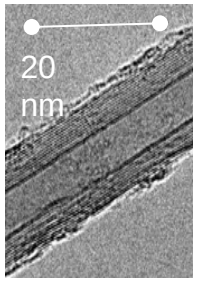
CNT (baytubes®)– Characterization

- baytubes® are macro-sized agglomerates with a large diameter up to several mm. The chemical purity is very high and consistent (>95%).

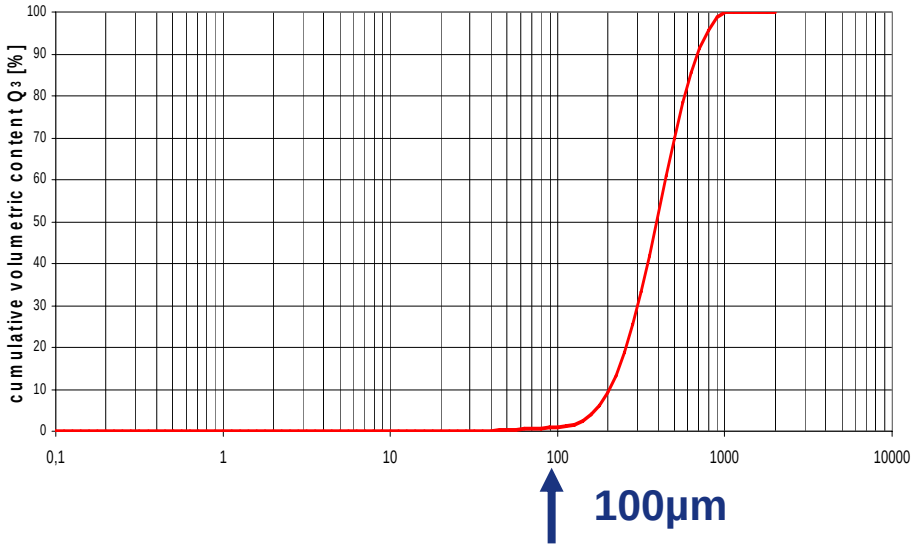


Magnification X1300





Particle-Size Distribution



More than 99.9 weight% of Baytubes are large agglomerates (µm to mm)

High mechanical strength
High electrical conductivity
High heat conductivity

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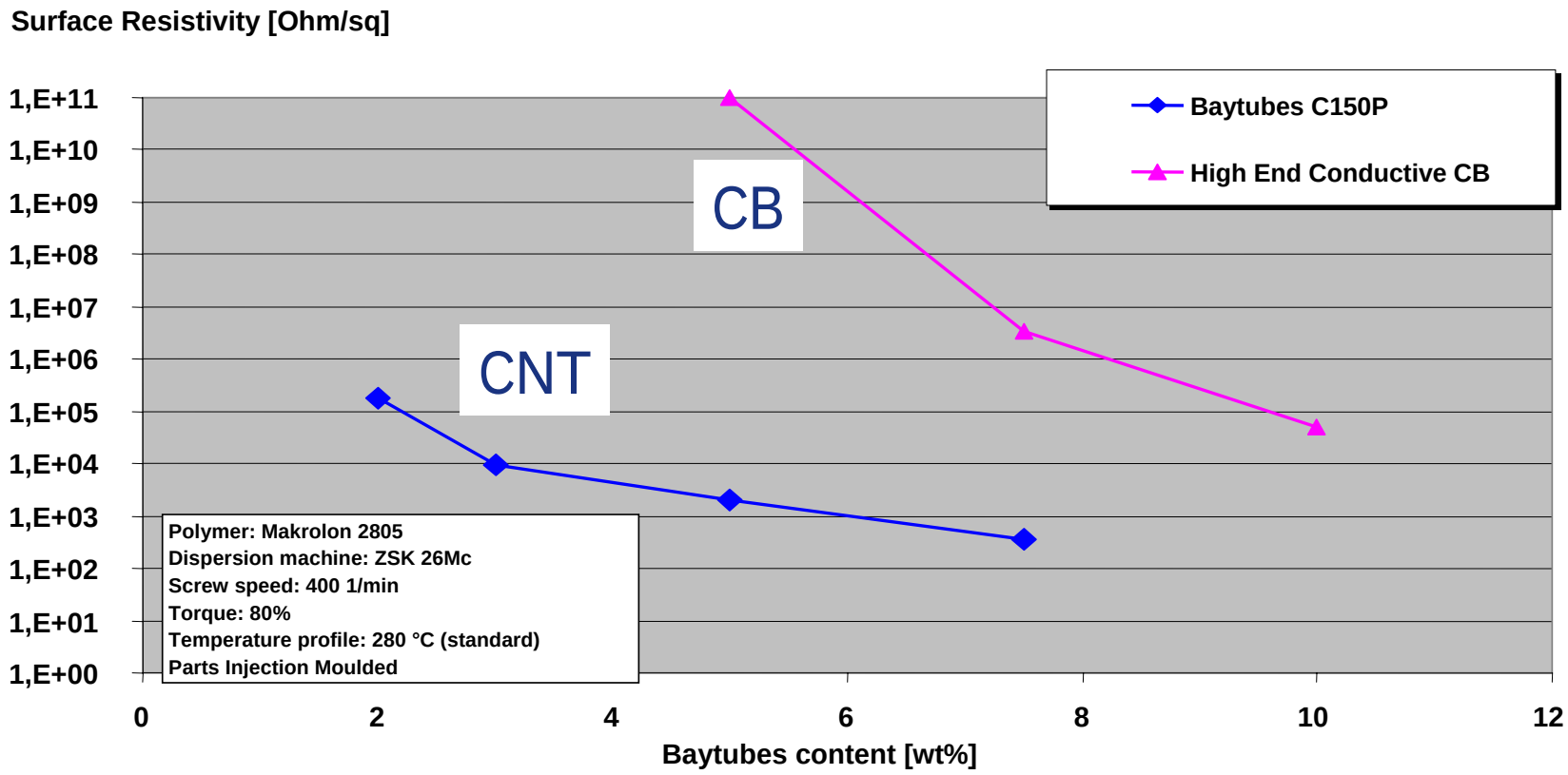
CNT (baytubes®) in Polycarbonate (PC)



CNT (baytubes®) show higher conductivity at lower loadings compared to high end conductive carbon black in polycarbonate.

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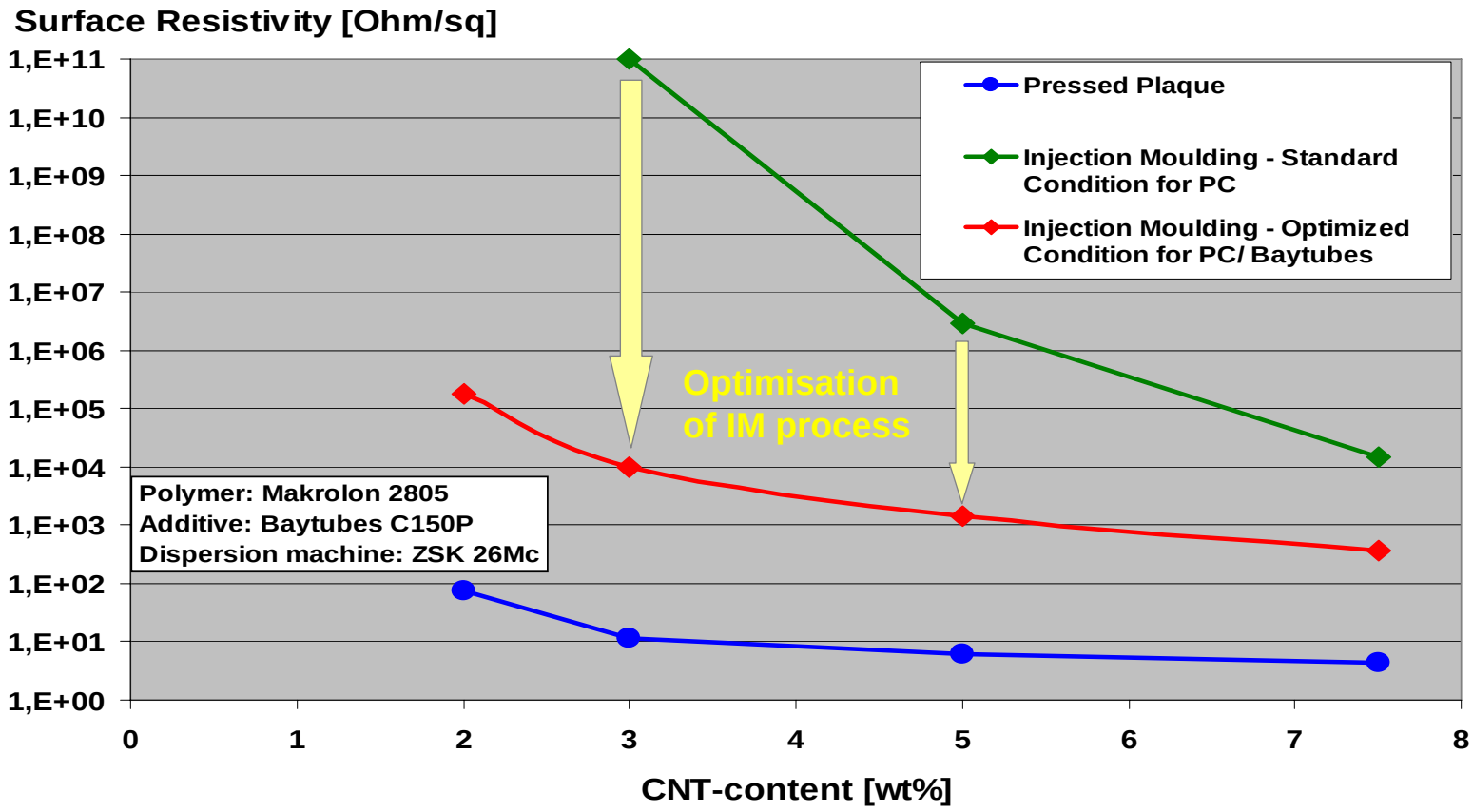
CNT (baytubes®) in PC – Processing



Processes and processing conditions show strong influence on the surface resistivity of the final part.

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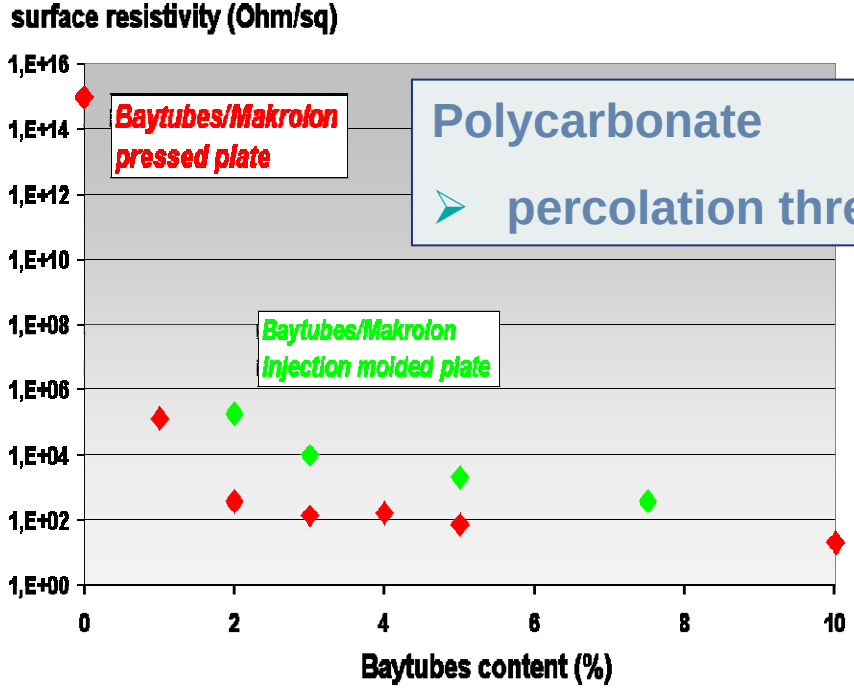
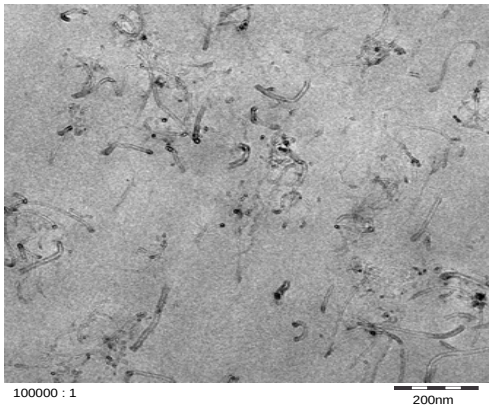
Carbon Nanotubes in Nanocomposit Applications



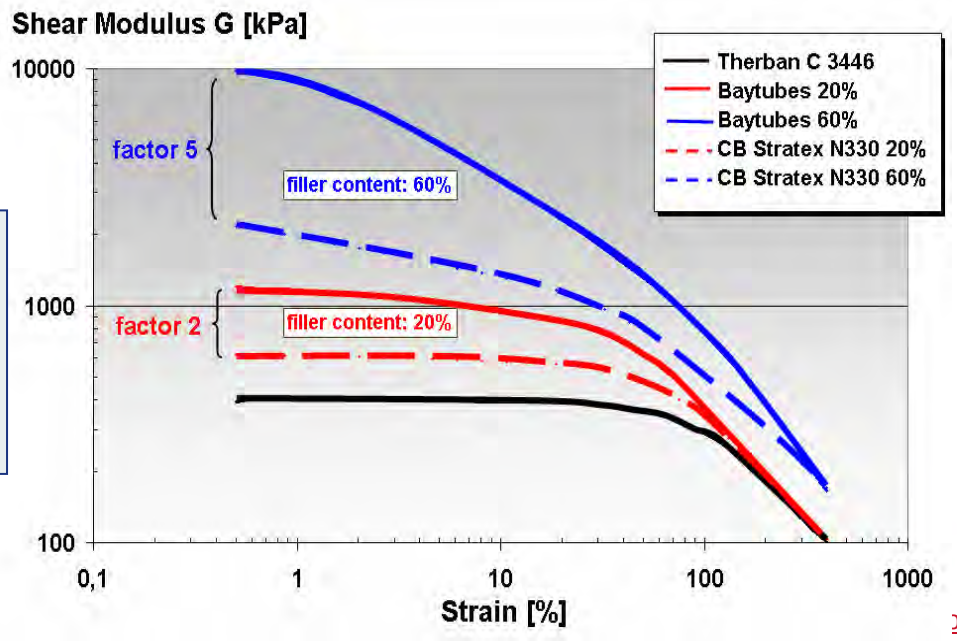
Polycarbonate

- **percolation threshold ~ 1 %**

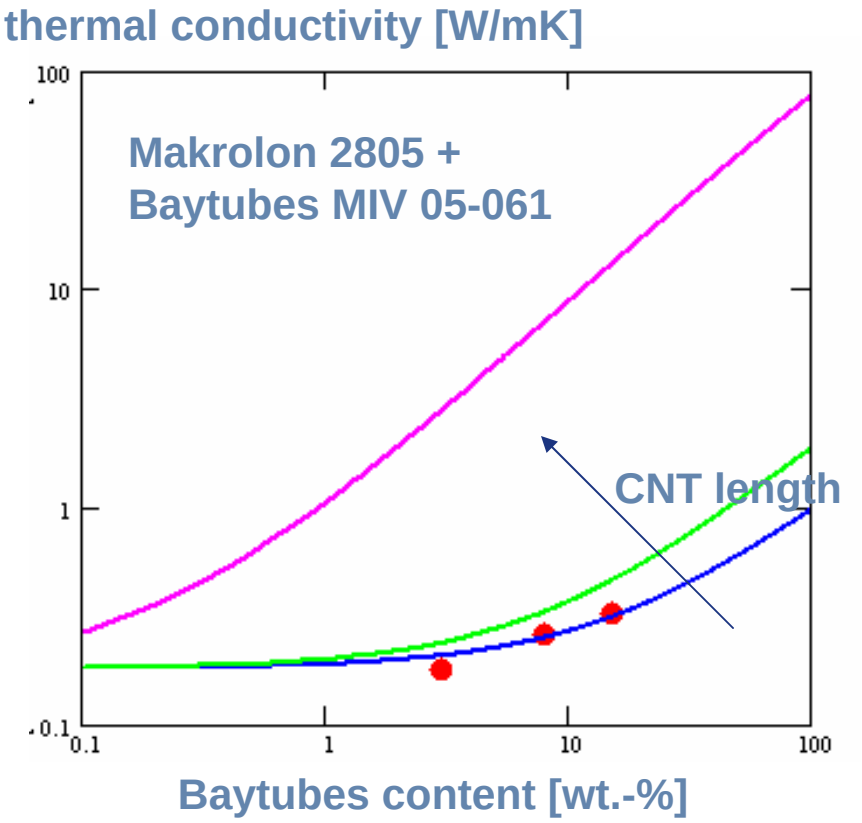


Rubber

- **2- to 5-fold increase of stiffness at equal content of Baytubes compared to conventional filler**



Thermal Conductivity of CNT Nanocomposites



correlation acc. to C.-W. Nan
in: Appl.Phys. Let., Vol. 85, (2004),16, S. 3549-3551

-> based on assumption that thermal resistance at polymer-fiber interface is dominant

- CNT length: 50 µm
- CNT length: 1 µm
- CNT length: 500 nm
- measurement of PC/Baytubes composites

- **thermal conductivity should increase with increasing CNT length**
- **good accordance measurement - calculation at assumed CNT length of 500 nm, which correlates well with the CNT length measured by TEM**

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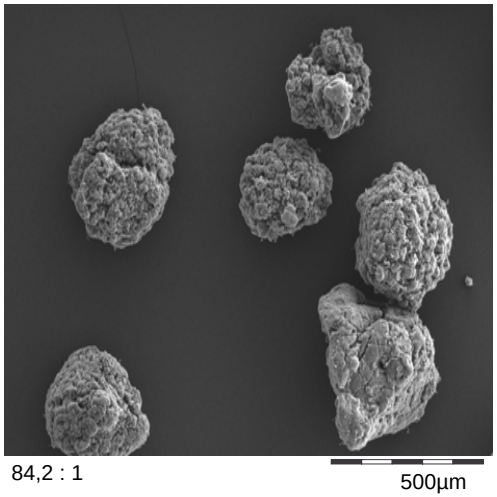
Dispersion is Key

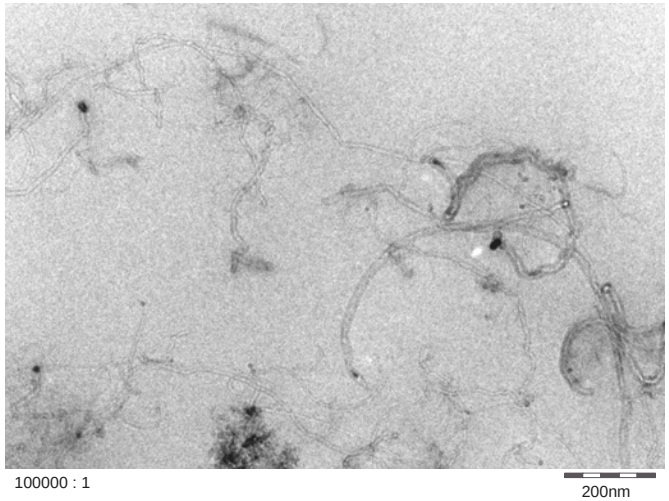
1. Disentanglement of the CNT agglomerates „as grown“

2. Dispersion of CNTs in polymer matrix



Ø= 0,2 - 1 mm

‚as delivered‘



Ø= 5 - 20 nm
L= >> 1 µm

‚in composite‘

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Carbon Nanotubes - Applications

CURRENT	SHORT TERM	MID TERM	LONG TERM
Conductive polymers & composites (transportation, electronics)	Sensors & instruments (microscope probe, tips, gas leak, detection)	Coatings (conductive thin films)	Superconductor Electrodes
	Electromagnetic shielding	Catalysts (petrochemicals)	Microwave antennas
	Sporting goods (tennis racket)	Solar energy converters	Self-assembling yarns
	Displays	Textiles & fibers	Aerospace (radar-absorbing skin)
		Lithium ion batteries	Medical implants
		Lamps	Drug delivery
		Semiconducting materials	Flat screen displays
		Advanced ceramics	Circuits
		Fuel cells	
		Caulks & sealants	

Replacement of

E-conductive carbon black

and other conventional fillers

Freedonia Study Nanomaterials 2003

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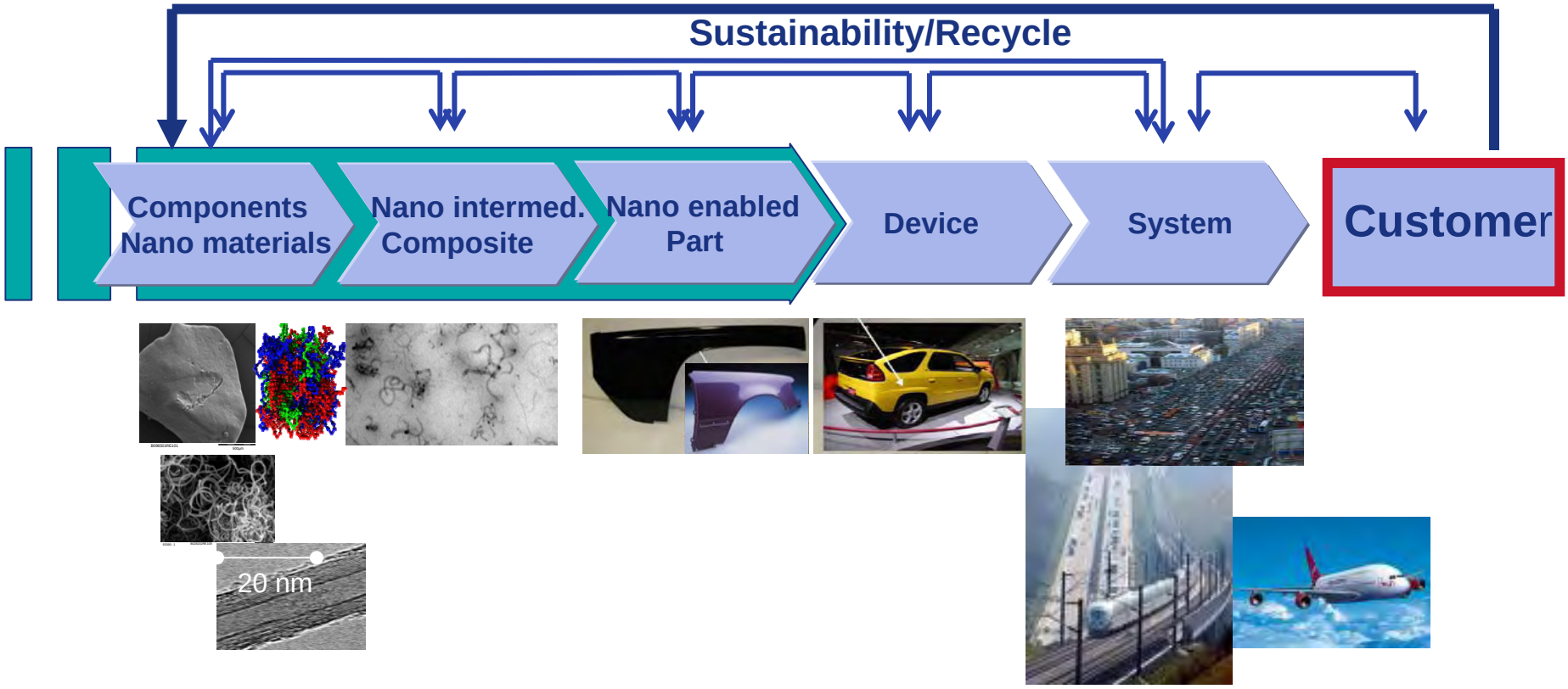
Carbon Nanotubes Value-Chain: Light Weight Nanocomposites

There are no nanotech markets, products and companies, **there is only a nanotech value chain (products enabled by nanotech)***



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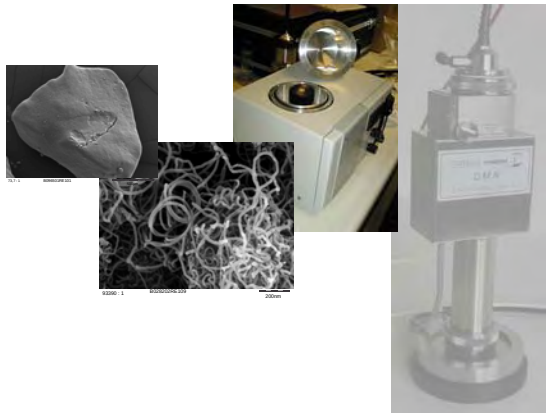
*Source: Lux Research

Responsible Care for Nanotech

- **Product Stewardship Program**
  - Bayer Internal Projects
    - Safety Assessments
    - Ensure products are safe
  - BMBF-Supported Projects
    - NanoCare
    - TRACER

- **Support Global Harmonized Methods**
  - Support of ISO Activities
    - Nomenclature, Characterization, HSE
  - Support of OECD Activities
    - Eco-Tox testing (OECD guidelines)



- **Support Stakeholder Dialog**
  - Association Level
    - VCI, DECHEMA, CEFIC, ACC

DECHEMA VCI cefic CHEMSTAR® BAYER Bayer MaterialScience

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Summary

- **Nanotechnology** offers enormous economic **potentials and chances**
- Nanotech is already a **part of our daily life**
- Nanotech is an **enabling platform along the value-chain** (more then “simply” produce and handle nanoparticles) and it is about **systems**
- **Nanocomposits are essential for automotive applications**
- **Responsible Care** of Safety Issues

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Thanks for your attention!

High Tech is Powerful

Bayer MaterialScience

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Acknowledegements

The author gratefully acknowledge the kind support by the Working Group Nanotechnology at Bayer

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