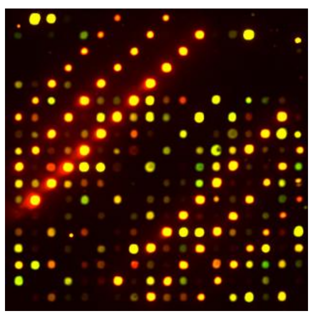
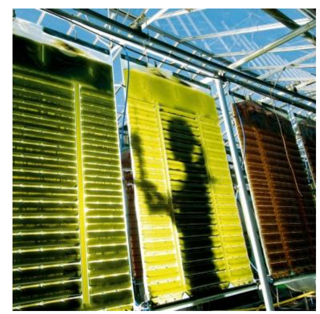
Statement for *Techbreak*

Christian Oehr
Fraunhofer Institute for
Interfacial Engineering and Biotechnology





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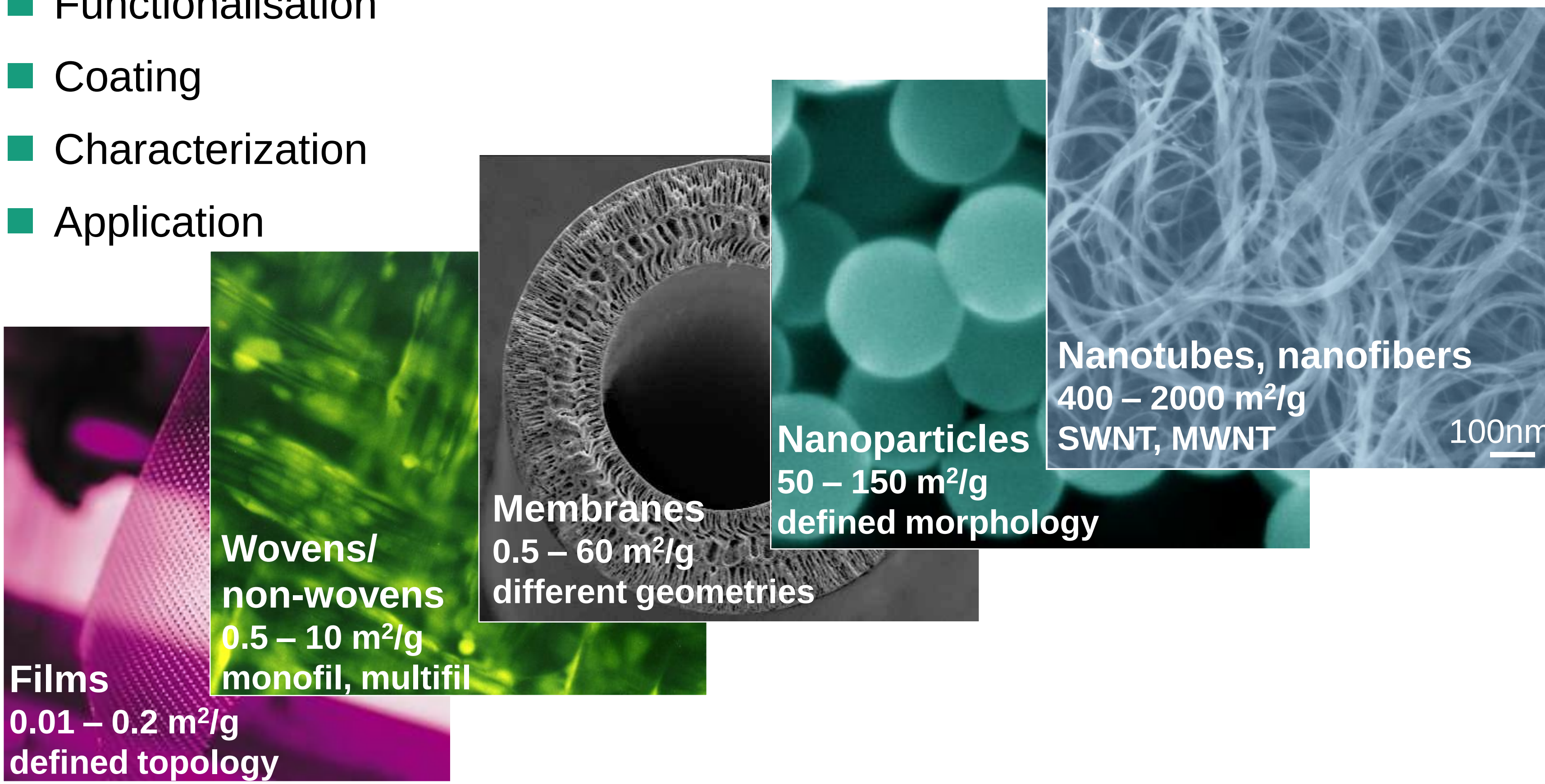
Materials and their interfaces

- Synthesis
- Functionalisation
- Coating
- Characterization
- Application



Joseph von Fraunhofer (1787 - 1826)

Researcher

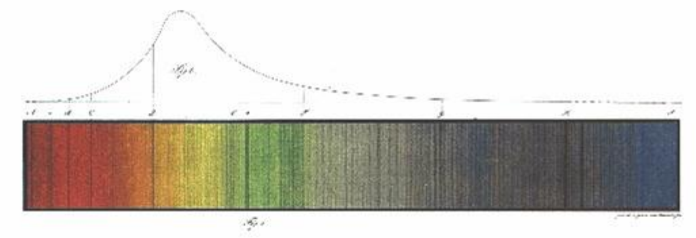
discovery of »Fraunhofer Lines« in the sun spectrum

Inventor

new methods of lens processing

Entrepreneur

head of royal glass factory



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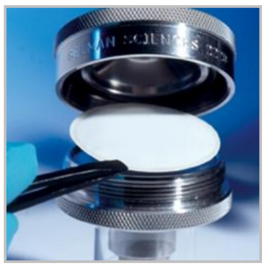
Frontline themes - Tomorrow's opportunities

Assisted Personal Health

The electronic guardian angel

Decentralized integrated water management

Saving precious water



Bio-functional surfaces

High tech with a sensitive skin

Energy-efficient modernization

More than just a facade

Food chain management

Always fresh on the table

Solid-state light sources

Bright and efficient illumination

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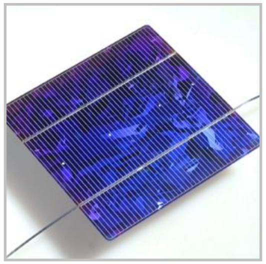
Frontline themes - Tomorrow's opportunities



Energy storage in power grids

Solar and wind-generated electricity on demand

Visual analytics

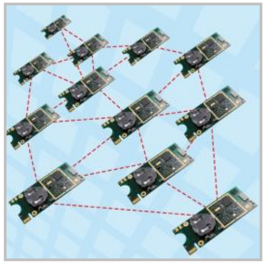
A clear overview in the data jungle

Green powertrain technologies

New impetus for eco-friendly cars

Hybrid material structures

Combining the best of the best



Energy self-sufficient sensors and sensor networks

Vigilant clusters

Integrated localization technology

On the move – quick and safe

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Shift of topics in technology forecast (according VDI Meta-Study, Sept.2010)

2004		2006		2010
ICT		Sustainability & Environment		Energy
Electronics		ICT		Sustainability &Environment
Materials Technology		Biotechnology & Life Sciences		Health & Food
Biotechnology & Life Sciences		Health (incl. med. technol.) & Food		ICT
Health (incl. med. technol.) & Food		Energy		Transport and Traffic Logistics
Production and process techniques		Production and process techniques		Biotechnology & Life Sciences
Energy		Materials Technology		Defense and Security
Nano- and Microsystems Technol.		Nano- and Microsystems technol.		Buildings & Living
Transport and Traffic Logistics		Transport and Traffic Logistics		Production and process techniques
Defense and Security		Aerospace		Materials Technology
Sustainability & Environment		Buildings & Living		Nano- and Microsystems technol.
Aerospace		Defense and Security		Aerospace
Ocean engineering and navigation		Electronics		Ocean engineering and navigation
Services		Optical technologies		Optical technologies
Optical technologies		Services		Services
Buildings & Living		Sustainability and environment		Electronics

Countries: USA, UK, France, Spain, India, Japan

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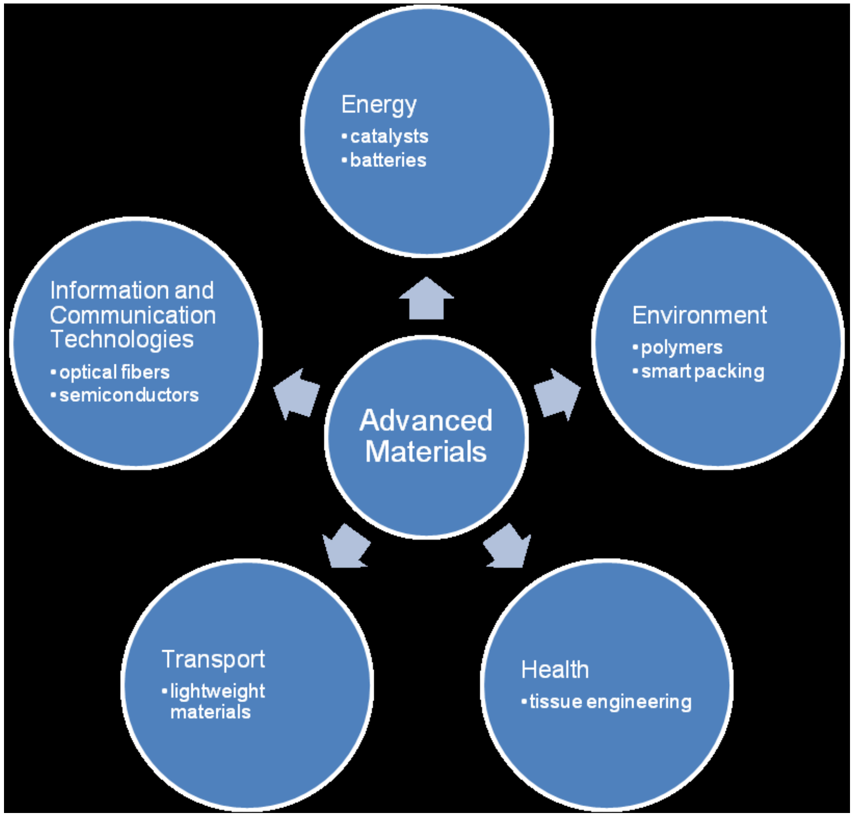
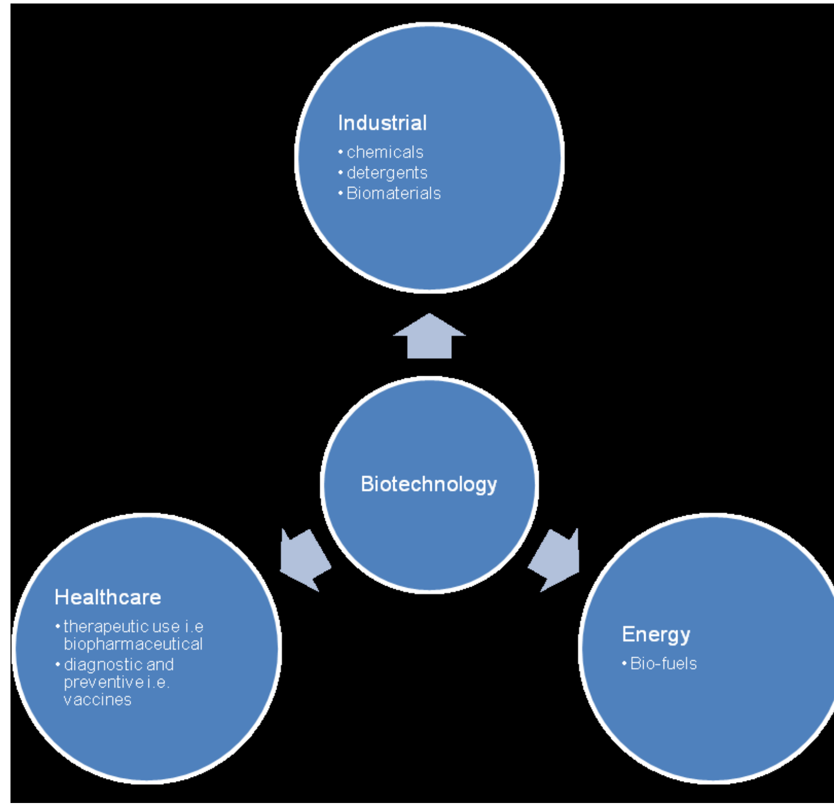
Goals in Material Science and Technology





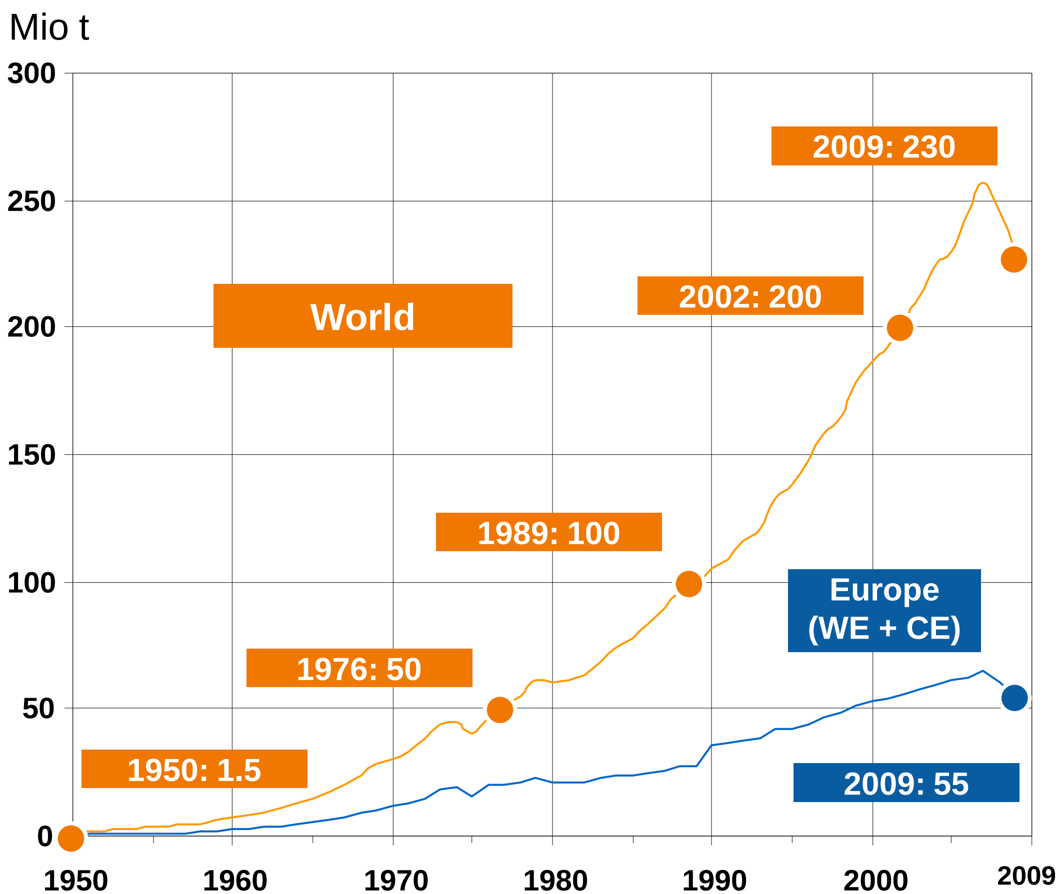
ESPI Report, June 2010

Advanced Materials

- Metals
- Ceramics
- Polymers
- Composites

Plastics – a success story
Plastics Production 1950 - 2009

PlasticsEurope
Der Verband der Kunststofferzeuger



Includes Thermoplastics, Polyurethanes, Thermosets, Elastomers, Adhesives, Coatings and Sealants and PP-Fibers. Not included PET-, PA- and Polyacryl-Fibers

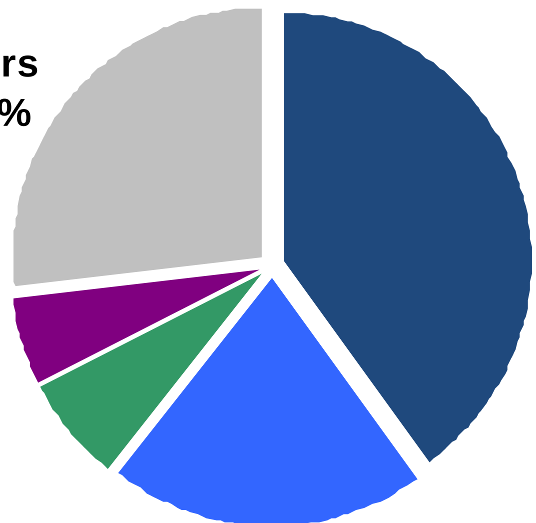
- **Plastics are a global success story**
- **Continuous growth** for more than 50 years
- **Plastics production ramped up from 1.5 Mio t in 1950 to 230 Mio t in 2009**
- **Plastics Production be gripped by the Economic Crises by end of 2008 and in 2009**

Compound Annual Growth Rate (CAGR) is **about 8,7%**

Source: PlasticsEurope Market Research Group (PEMRG)

Fraunhofer IGB

Europe 2009
Plastics demand* by market segments



45.0 Mio t

* EU27+N, CH incl. Other Plastics (~5.4 Mio t)

- **Packaging**
  by far represents the largest end-use market
- **Building & Construction, Automotive and E & E follow**
- **Others**
  includes consumer, household, appliances, furniture, agriculture, medical, etc.
- **Over the last years**
  the share of end-use applications remained fairly stable

Source: PlasticsEurope Market Research Group (PEMRG)

Drivers for plastics use

PlasticsEurope
Der Verband der Kunststofferzeuger

Low density

Copper	8.90 g/cm^3		
Steel	7.80 g/cm^3	PVC	1.40 g/cm^3
Aluminium	2.70 g/cm^3	PE	0.96 g/cm^3

Tailor-made properties

scratch resistant - impact resistant - galvanizable - oil resistant - stiff - flexible heat resistant - sterilisable - insulating - conducting - corrosion resistant - biologically degradable - inflammable - non-inflammable - transparent - intransparent…

Easy processability

low energy and little investment, but skilled and qualified staff

Good price/performance relation

Energy efficiency

Challenges for plastics in application

Temperature Stability

energy engineering

Conductivity and Transparency

- thin film photovoltaics
- replacement for ITO

UV Stability

lots of efforts with polycarbonate (automotive)

Permeability

transparent barriers for food
insulation panels
flex. Photovoltaics
flex. OLEDs

Coatings are needed for
Thin films (micro...)

- **Protection**
  against mechanical stress scratch and wear resistance, hardness
  against chemical attack corrosion and solvent resistance

- **Specified transport properties**
  Optical transport lenses, mirrors, waveguides etc…
  Electrical transport conductive and dielectric layers etc…
  Material transport
  Material specific permeation separation membranes
  permeation → 0 barrier layers

- **Material transport out of layered systems**
  Defined release (medicament) dosage systems

Surface Funtionalisation is needed for
Ultra-thin films (nano...)

- Tailored surface energy (wettability <–> water repellency) (solid-liquid-gaseous)

- Tailored contact between polymers and other phases
  <u>static</u>: solid-solid, (Adhesion)
  <u>dynamic</u>: solid-(liquid)-solid (Tribology)

- Interaction with biological systems
  (binding and adsorption of biomolecules, biocompatible or bioactive surfaces)

- Separation membranes and ion-exchange materials

- Basic research and analytical methods

Example: light weighting in transportation

PlasticsEurope
Der Verband der Kunststofferzeuger

Innovative products make it possible to cut CO_2 emissions and energy consumption:

- On average only 12-15% of modern cars are now made from plastics
- The resulting weight savings reduce fuel consumption by 750 liters for the 150, 000 km life of the average car
- Oil consumption for European car owners is reduced by 12 Mtonnes a year and CO2 emissions are reduced by 30 Mtonnes.

Top 10 GHG reducing products of the Chemical Industry

PlasticsEurope
Der Verband der Kunststofferzeuger

Thermal insulation of buildings

Fertilizers and crop protection

Efficient lighting

Plastic packaging

Anti-fouling coatings for ships

Man made fibres

Plastics in cars

Low temperature laundry detergents

Fuel additives, lubrificators

Plastic piping

Fraunhofer IGB

Example: packaging, barriers for

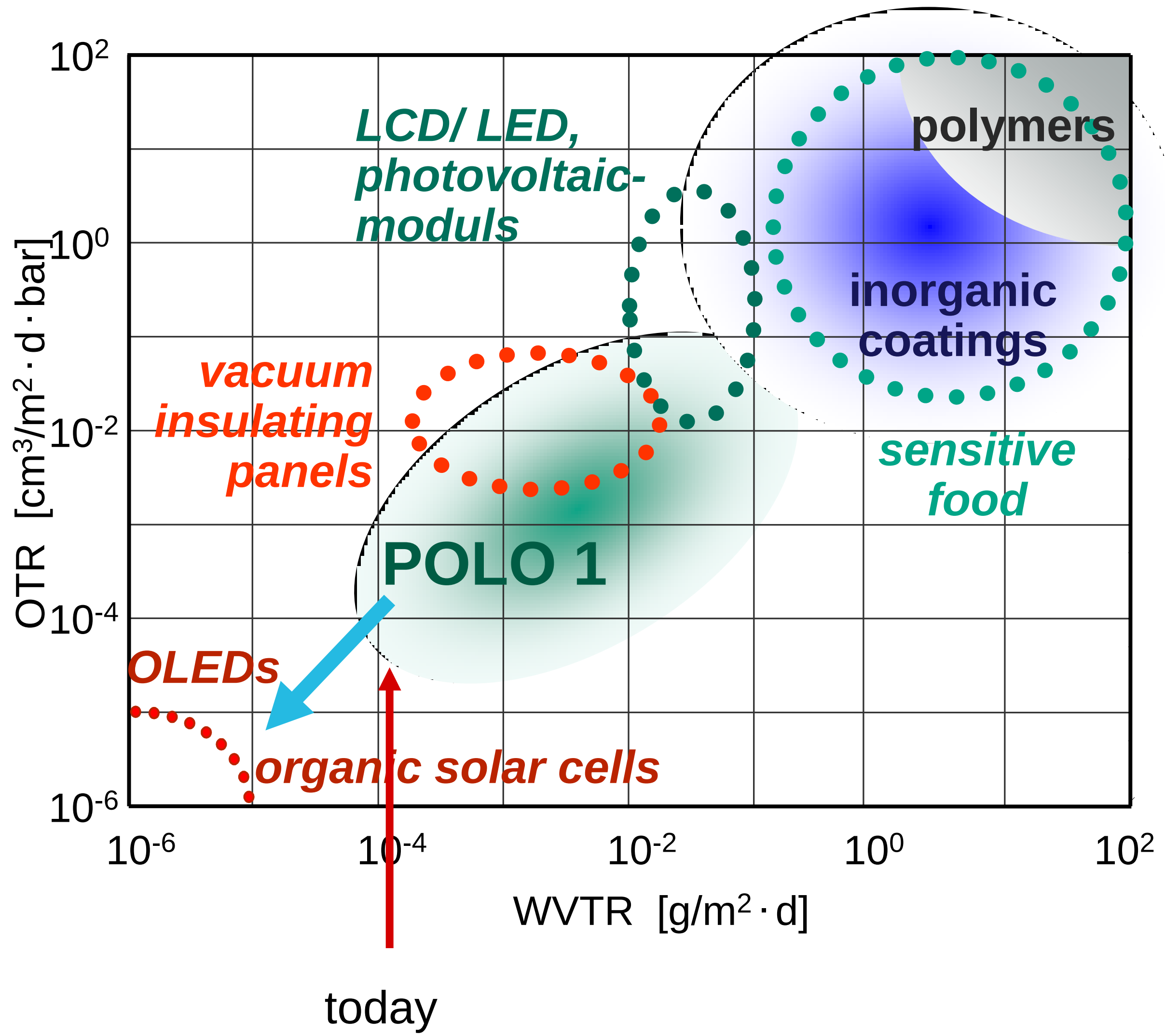
- **Food**
- **Vacuum panels**
- **Photovoltaics**
- **Org. LEDs**

Other properties by coating: enhanced emptying, anti counterfeiting, integr. sensors and O_2 scavengers etc.

Barriers

Performance of polymers and film systems (shaped regions)

wanted barrier values for special products (doted areas)

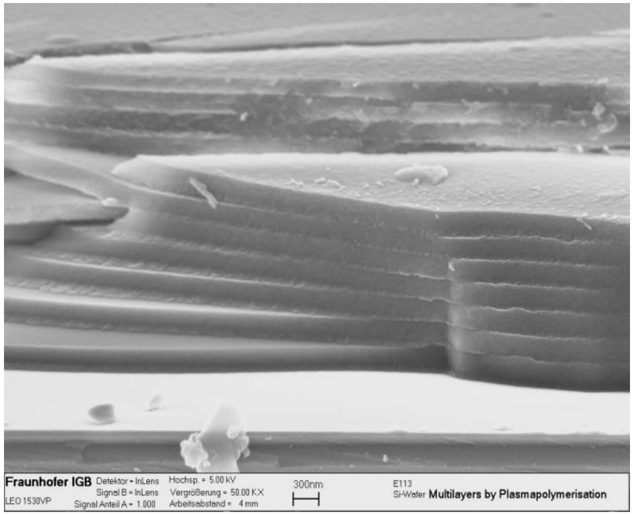


POLO 1:
PET-Al_2O_3-ORMOCER®

Fraunhofer POLO

Fraunhofer IGB

Plasmadeposited multilayer



- for barriers (div. application) e.g.for OLEDs
- liquid and gas phase deposition of stacks of inorganic and organic layers
- „Pilot Production of Ultrabarrier Substrate for Flexible Displays“ (Vitex Systems, mixed process)

Problem: incremental success in barrier properties/measurements reliability
Solution: highly sensitive IR-Spectrometer?

Fraunhofer POLO

Fraunhofer IGB

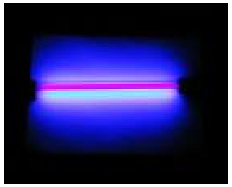
Composites

- New materials for gas separation (high temperature) (problem: coefficient of thermal expansion)
  O_2, CO/H_2 (chemical process engineering)
  CO_2 separation from biogas etc
- New materials for water treatment, reverse osmosis and osmosis power plants
- New materials for energy conversion (photovoltaic thermo-voltaic etc.), energy distribution and efficient use.
- Strategies against corrosion may differ in space and on ground application (Self healing corrosion protection?)

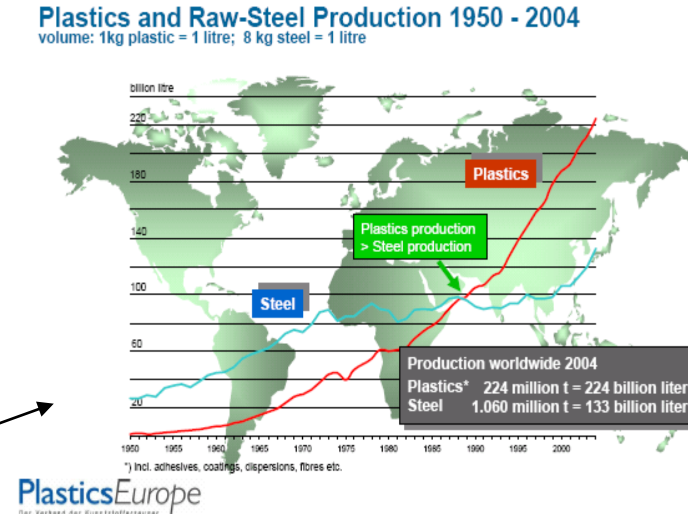
Thin film deposition, methods highly recommended

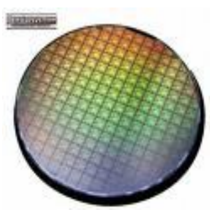
- Sol-Gel Deposition
- Printing
- Gasphase Processes (Plasma enhanced)

Development of plasma technology

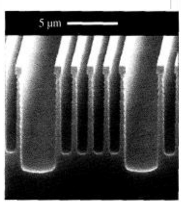


lightening, lamps





micro electronics



Glass coating

wear/corrosion protection

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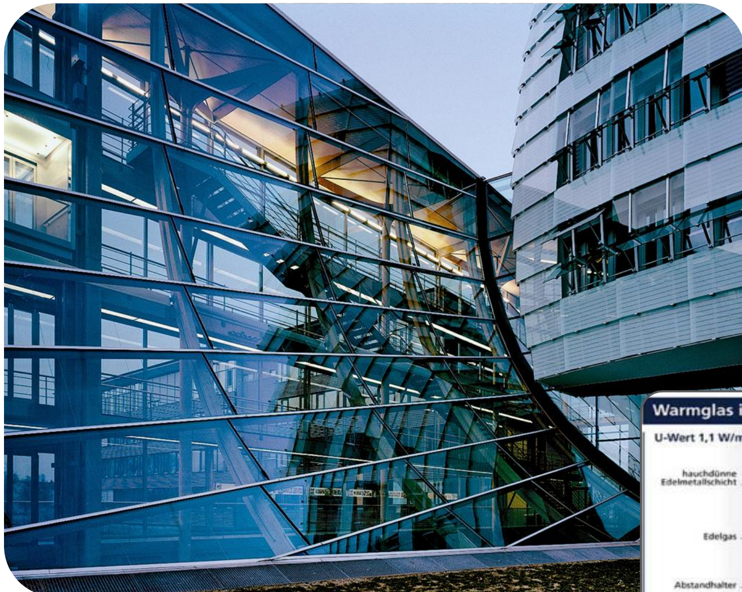
Success stories of Plasma technique

example 1: coating of architecture glass

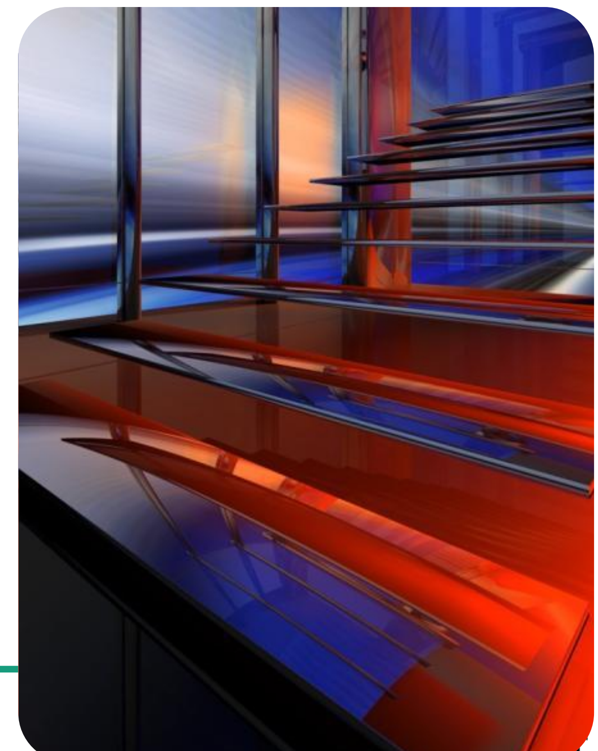


Heat insulation

Switchable sun protection

Selfcleaning

Permanent sun protection



Without Plasma surface techniques
no chance,
To fullfill the German
Energy-saving-decree 2002

IGB

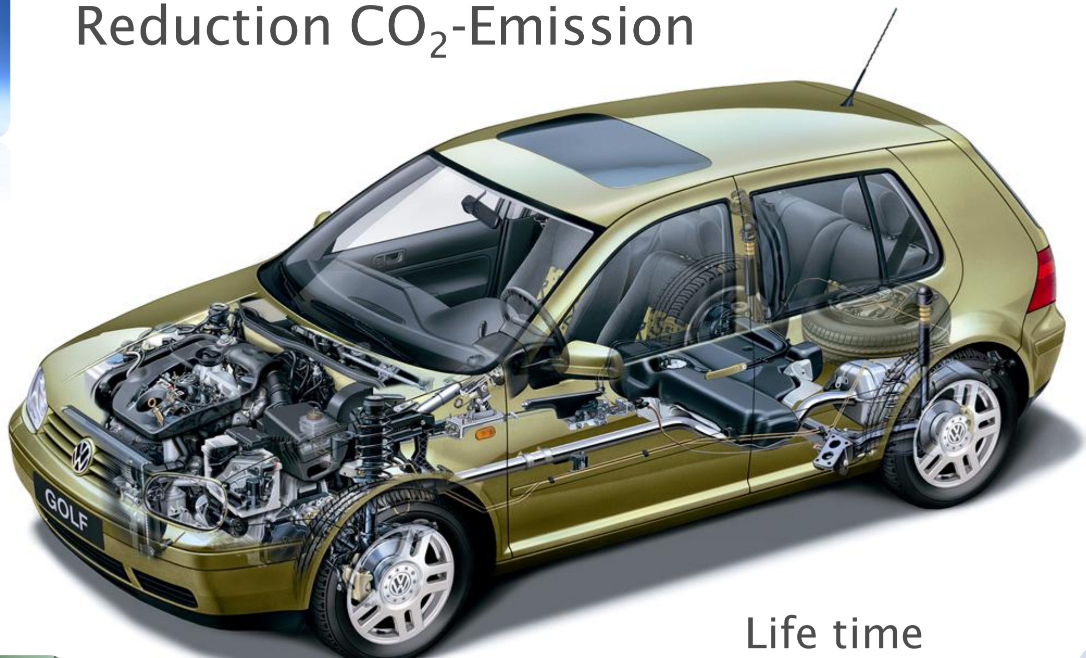
Quellen: Euroglas | Interpane | Fraunhofer IST

Success stories of plasma technique

example 2: Automotive

fuel -reduction

Reduction CO_2-Emission



Life time

Material reduction

corrosion protection

Light construction

Wear protection

Reflection

Fraunhofer IGB

Quellen: Robert Bosch | Volkswagen | Fraunhofer IST

Success stories of plasma techniques to be expected

Example 3: Solar cells

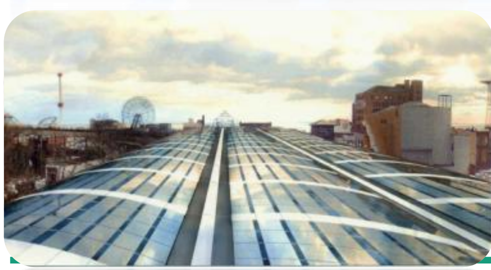
Photovoltaic with Plasma

Flexible cells on soils

Growth rates
of 15 – 30 %

Integration in
Gebäude-Architektur

High
efficiency



Quellen: Schott Solar | Applied Materials | first solar | DBmobil

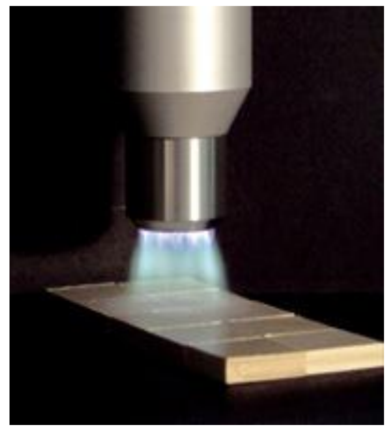
Ressource efficiency

Surface treatment by:

Liquid based methods

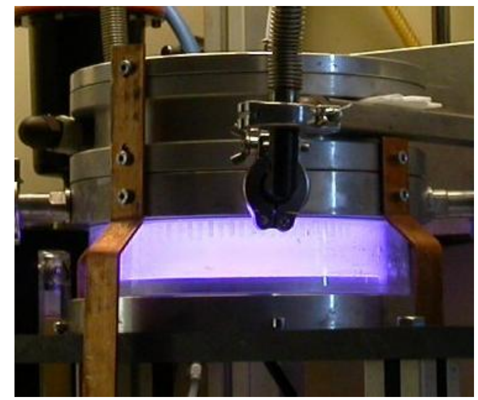
solvent: e.g. H_2O
3,3 10^{22} molecules cm^{-3}

Gasphase based methods
(atmos. pressure plasma)



"solvent": air, N_2,Ar,He
2,7 10^{19} molecules cm^{-3}

Gasphase based methods
(low pressure plasma)



"solvent": vacuum, carrier gas
2,7 10^{15} molecules cm^{-3}
(working pressure: 0.1 mbar)

BMBF-identified topics for Innovation in the future

Plasma contribution

Material technologies
Barriers, protective coatings

Information- and Communication technology
Silicium-Technology / printed circuits

Research for health and medical devices
Dialysis, Implants, contact lenses

Nanotechnology
ultrathin films, CNT-Functionalization

Micro system techniques
Hydrophilic / hydrophobic pattern

Safety Technology
copy ,protection antimicrobial finish

Optical Technologies
Antireflective layers, corrosion protection for reflectors, lamps

Energy technologies
Photovoltaics, films for fuel cells for osmosis power plants

Space technologies
Tribological films

Aeronautic technologies
Aluminum Corrosion protection

Biotechnology
antibacterial active coatings

Automotive - and traffic technologies
Aluminum corrosion protection, polymer activation

Maritime Technologies

Plants

Production technologies
gluing, de-smearing for printed circuits, Replacement of chromic-sulfuric acid, membranes

Services

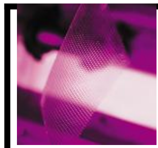
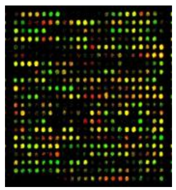
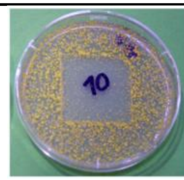
Climate- und environmental technologies
gluing, Replacement of chromic-sulfuric acid, Teflon processing, coating of architecture glass

- Essential contrib.
- Important contrib.
- Contribution
- No application

Biotechnology and Healthcare

- Materials that do not disturb biological functions
- Materials that trigger biological response
- Minimized unspecific protein adsorption
- Replacement for collagen as syn. Scaffold
- Replacement of PVC ?
- Prologation of implant function
- Materials with sustainable antimicrobial activity for temporarily use and long-term implants

Interface between Technical Materials and Biology

 Interface and...	enhanced Interaction	decreased Interaction
Proteins and other biological active molecules 	Specific binding of bio-molecule >> diagnostics e.g. new pyrogene test, heterogeneous bio-catalysis, specific scavengers	Decreased protein adsorption >> minimized fouling
Microbes 	Immobilized Microbes/ plasma sterilization	bacteriophobic, bacteriostatic, bacteriozidic surfaces
Mammalian cells 	Growing and proliferation of cells for artificial organs and test-kits	minimizing problems with temporary Implants, minimized restenosis etc.

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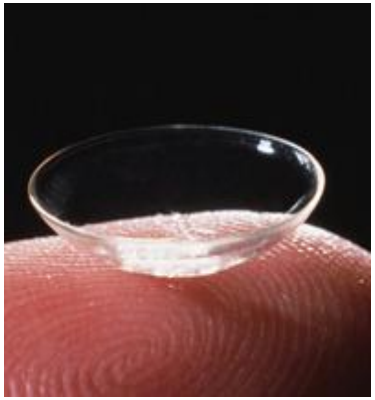
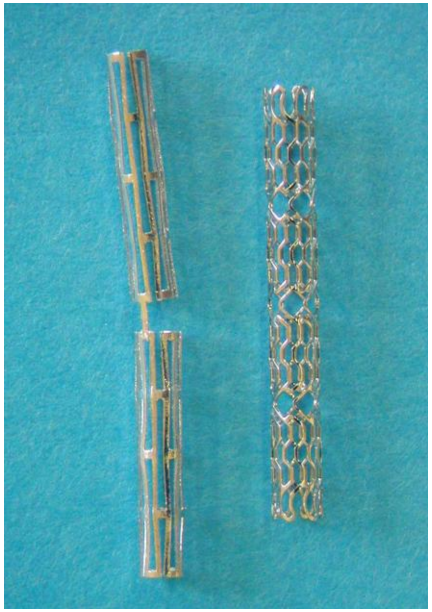
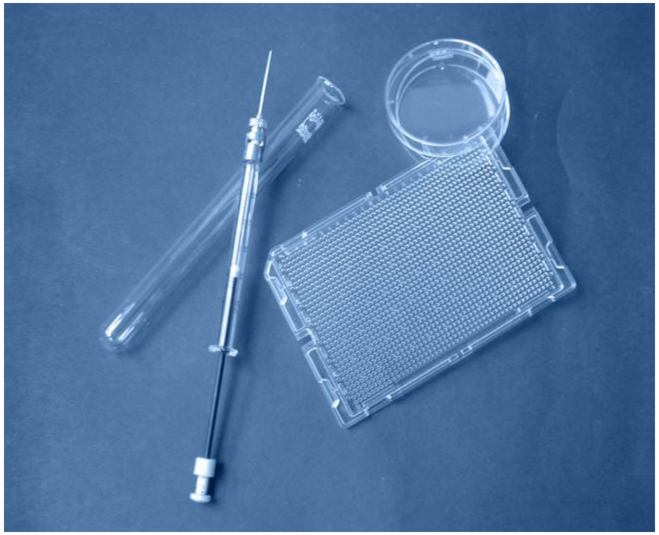
Thin Plasma Films deposited for

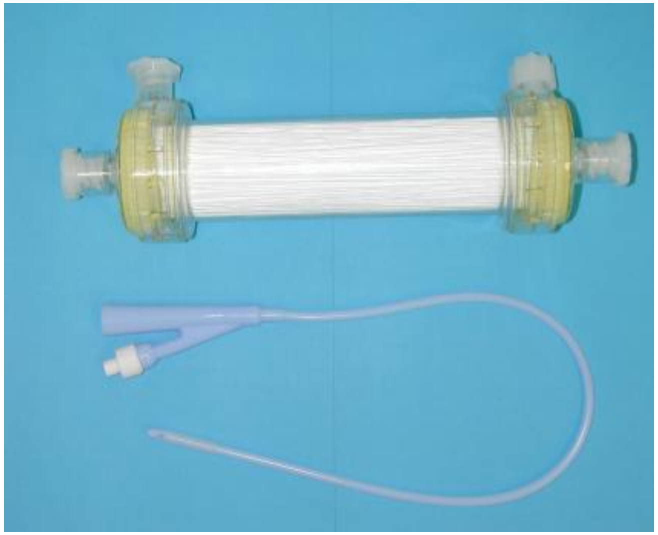
Diagnostics and **Therapy**

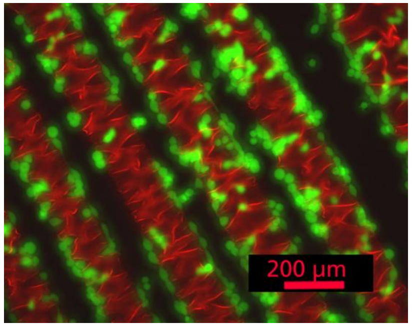




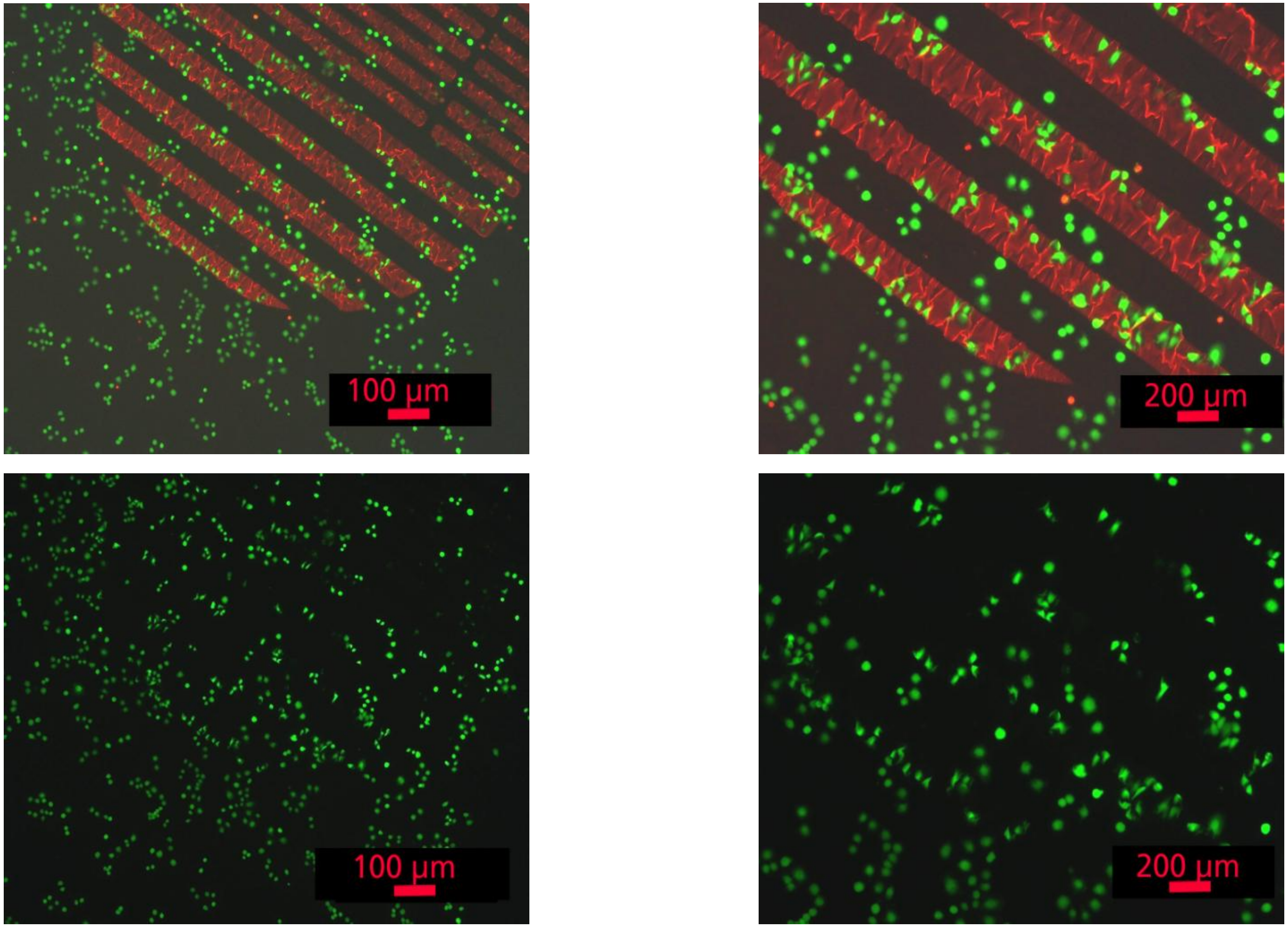
Replacement of Glass
in Medicine and Pharmacy







Human rhabdomyosarcoma cells: dyed with ethidium bromide (red) and calcein (green)



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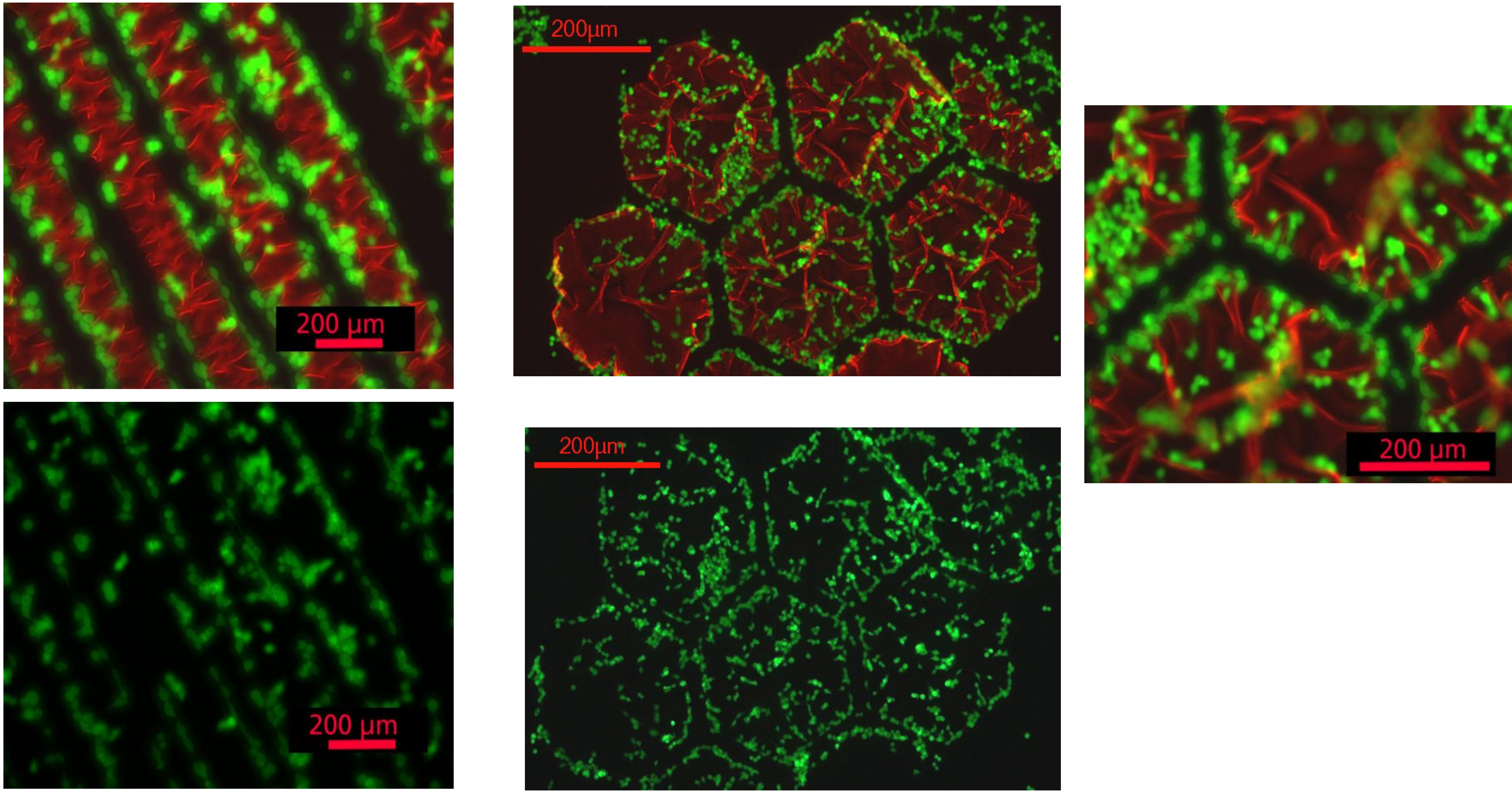
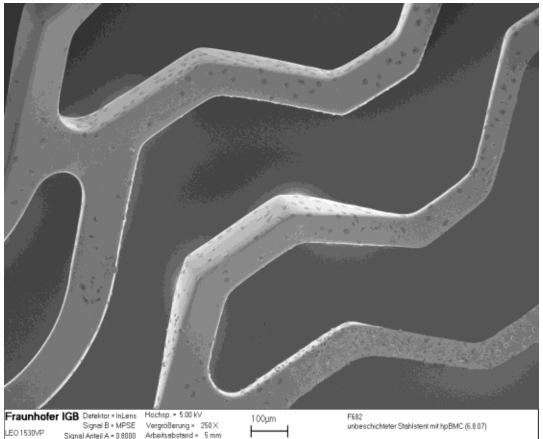
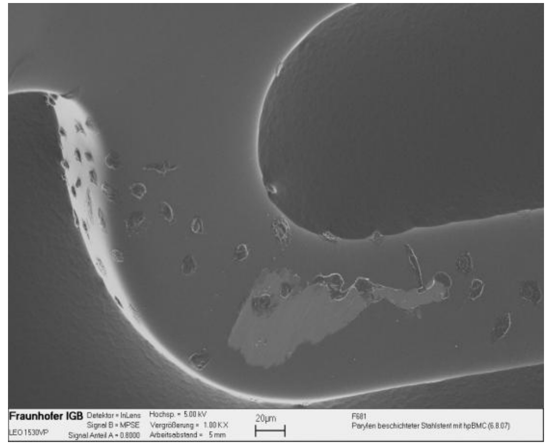
Rat insulinoma cells (Pancreas): dyed with ethidium bromide (red) and FDA (green)



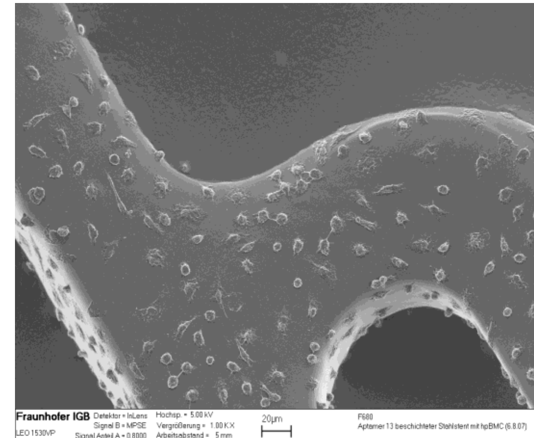
Progenitor endothelial growth on coated stents after two days of cultivation



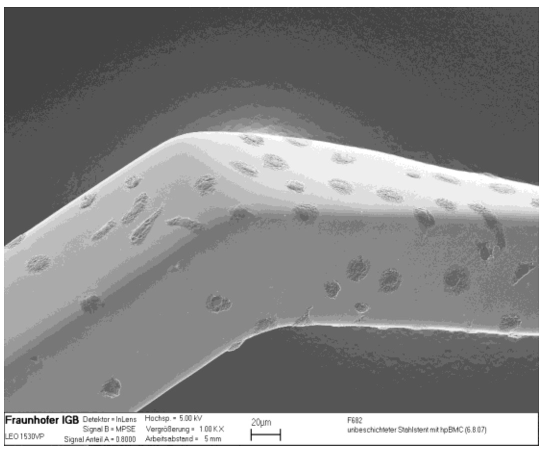
250x



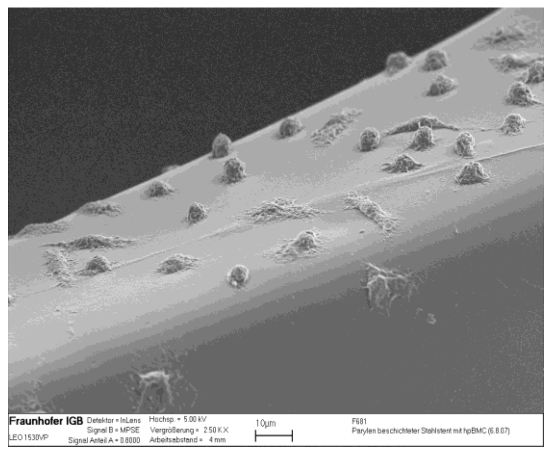
1000x



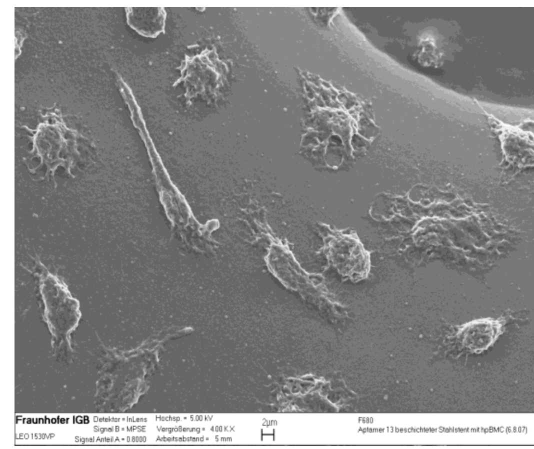
1000x



1000x



2500x



4000x

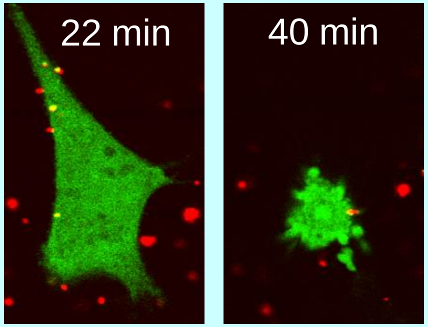
Not coated **+Parylene** **+Parylene +Aptamer**

NANOCYTES®-Applications

Life Sciences

Particle based Biochips

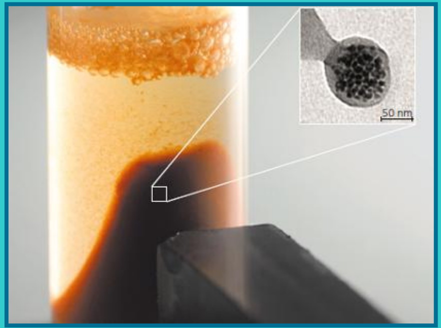
TNF-NANOCYTES®



Functional materials

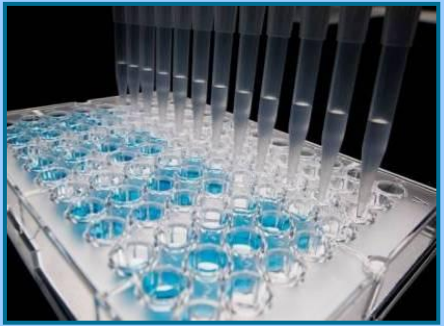
MIP-Membrane

Magnetit-MIP



Consumer

Enzyme immobilisation



Tailored inks for ink-jet printing

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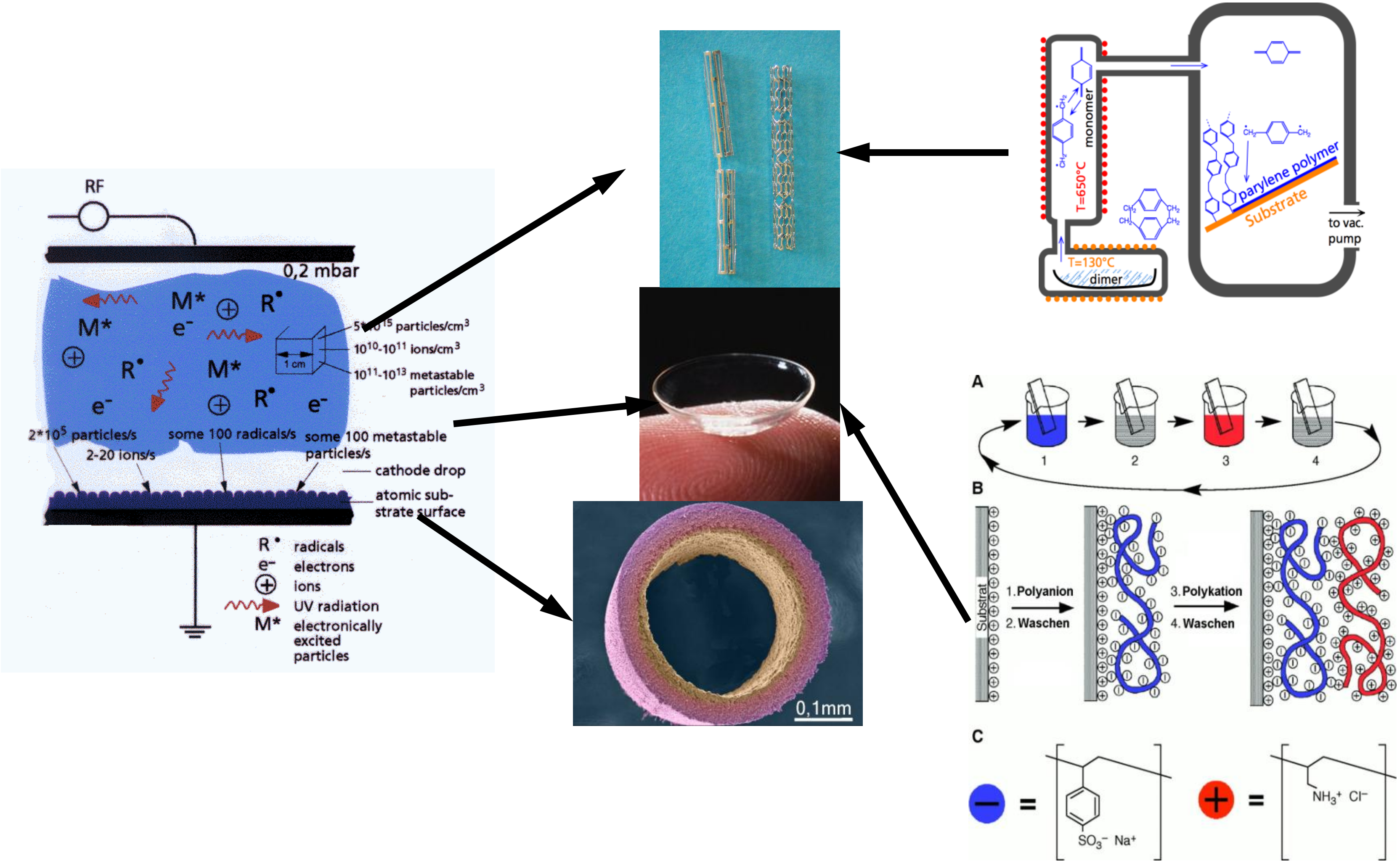
Competitive surface treatment methods



Von G. Decher

Application – plasma based products

Life Sciences

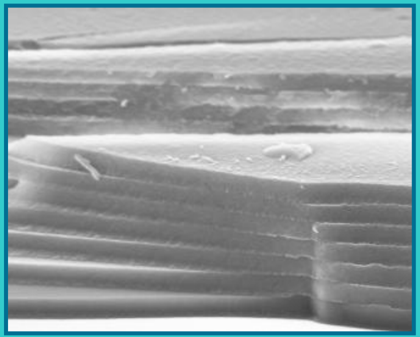
Medical devices

Sterilisation / Desinfection

Protective Layers

scratch-/wear protection

Barrier coatings



Functional films

wetting

Friction reduction

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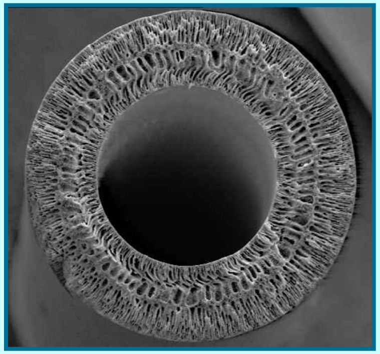
Types and applications of capillary membranes

Filtration

Al_2O_3

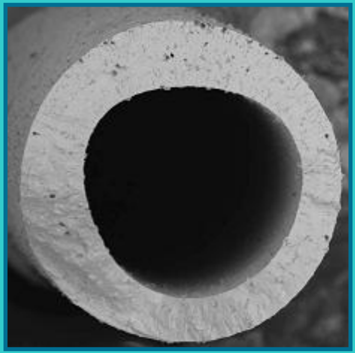


Metal

Gas separation

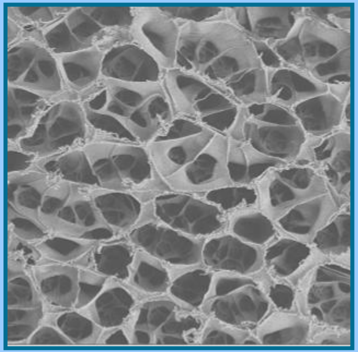
Palladium-coated

Dense perovskite

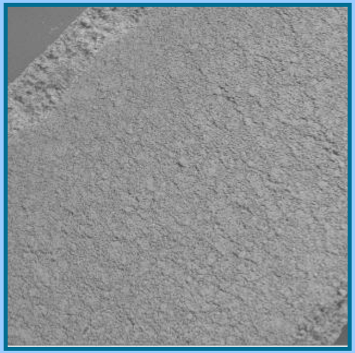


Life sciences

Biodegradable polylactide



Calcium phosphate

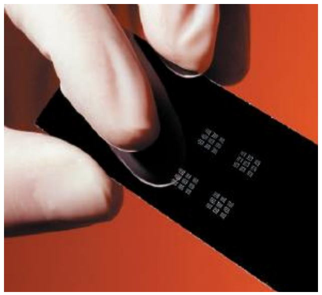


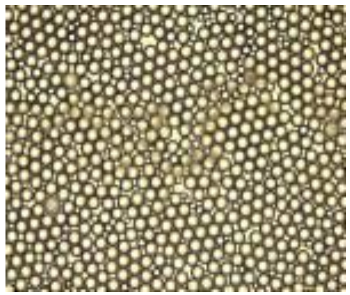
Fraunhofer
IGB

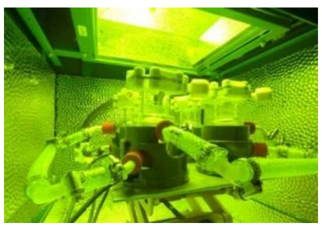
Using PET instead of glass for beverage packaging

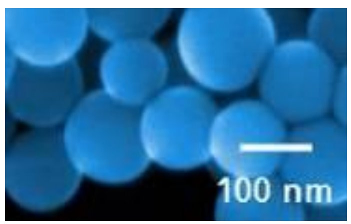
according BASF

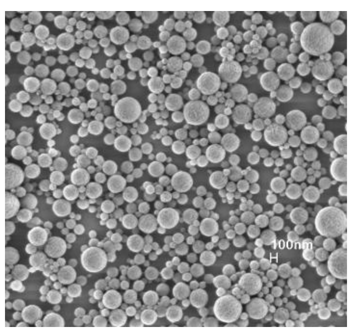
Particle based systems and formulation











- **tailored core-shell particles**
  - Drug Delivery, Drug Release & Drug Targeting
  - Biodegradible und biocompatible particles
  - Encapsulation of drugs
  - Organic and inorganic particle core with functional shell
- **Formulation of**
  - Drug-Matrix systems
  - Tailored inks for Micro-Printing
- **Molecular imprinted polymers (MIP) for synthetic receptors**
  - Sensoric and selective Absorption
  - Enrichment of of components

Some characteristics of liquid phase and gas phase with respe
to surface treatment

Liquid phase

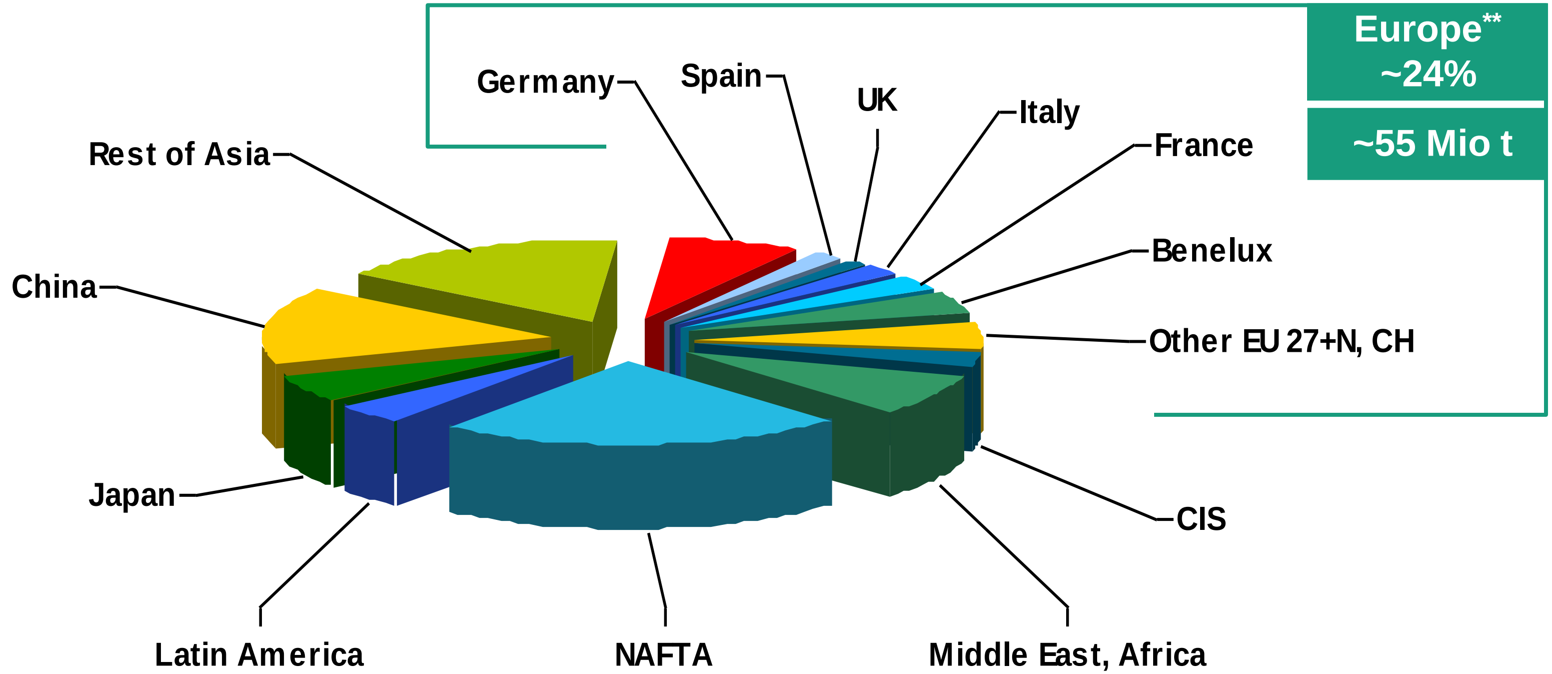
- Material consuming
- Conc. of reactive species:10^{-2} - 20%
- Diff. coeff. ca. 10^{-5} cm^2/s
  (e.g. Albumin $6*10^{-7}$ cm^2/s)
- Geometric restrictions (e.g. due to capillary depression)

Gas phase

- 10^6 less material consuming
- Conc. of reactive species:10^{-5}- 50%
  (in-situ produced)
- Diff. coeff. ca. 10^{-1} to 1 cm^2/s at atm. press.)
  (prop. to mean free path)
- Geometric restrictions prop. to mean free path (relat. to pressure)

Plastics production
World 2009

PlasticsEurope
Der Verband der Kunststofferzeuger



~230 Mio t

Global Plastics Production

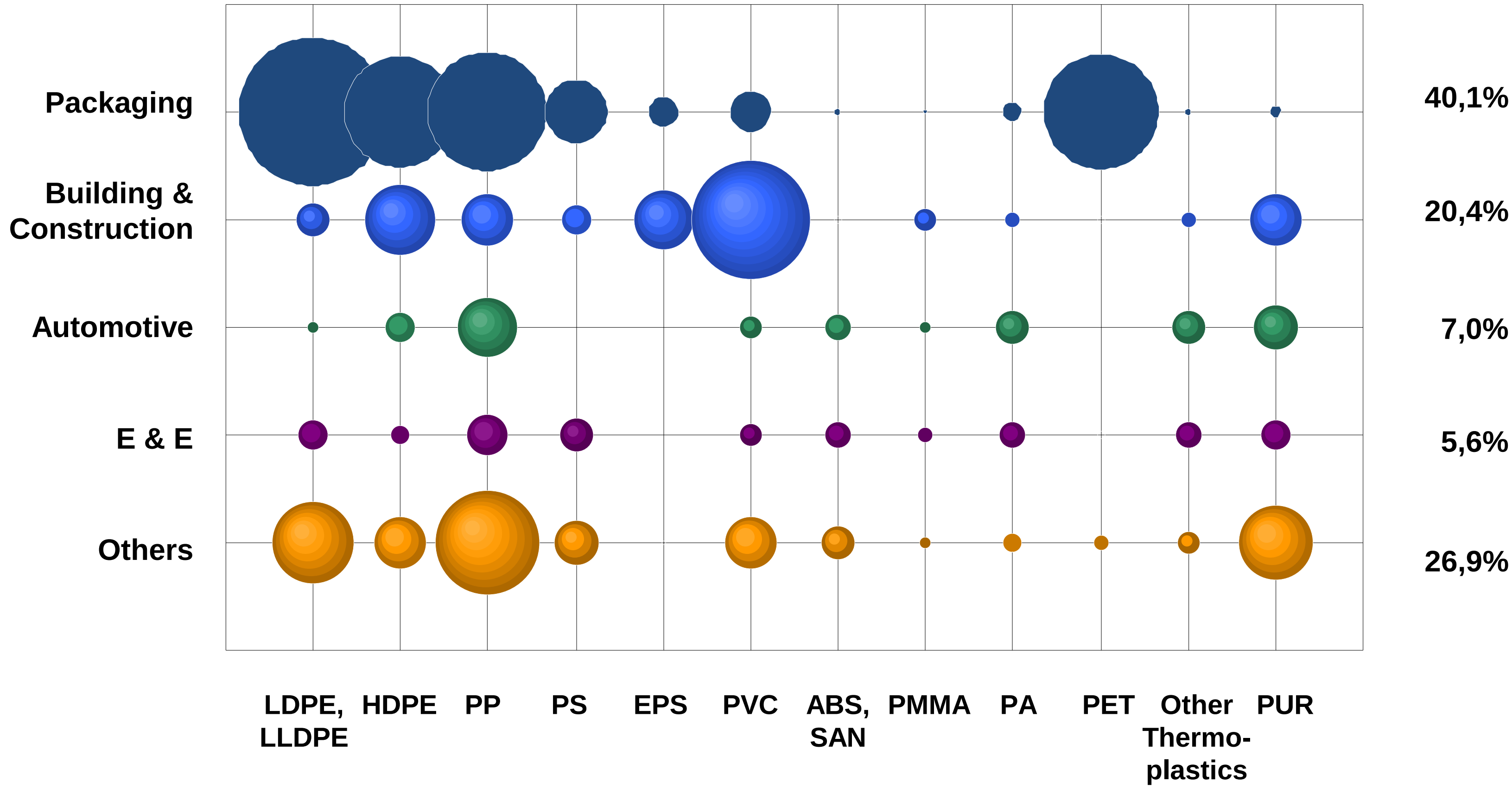
*) Includes Thermoplastics, Polyurethanes, Thermosets, Elastomers, Adhesives, Coatings and Sealants and PP-Fibers. Not included PET-, PA- and Polyacryl-Fibers
**) EU27 plus Norway and Switzerland

Fraunhofer IGB

Source: PlasticsEurope Market Research Group (PEMRG)

Europe 2009
Plastics demand* by market segments

PlasticsEurope
Der Verband der Kunststofferzeuger



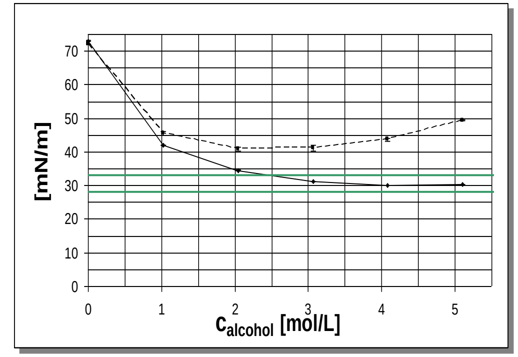
45.0 Mio. t

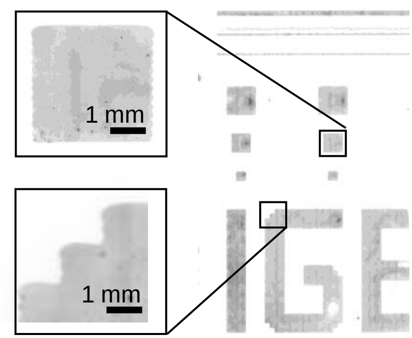
* EU27+N, CH incl. Other Plastics (~5.4 Mio t)

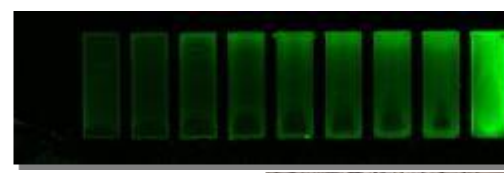
Source: PlasticsEurope Market Research Group (PEMRG)

Inkjet Printing

- Ink Formulation
- Semiconducting Inks, Inks Containing Nanomaterials, MOFs, CNTs, etc.
- Biofunctional Inks, Protein Printing
- Printing of Functional Nanomaterials and Microparticles
- Substrate Preparation, Thin Films





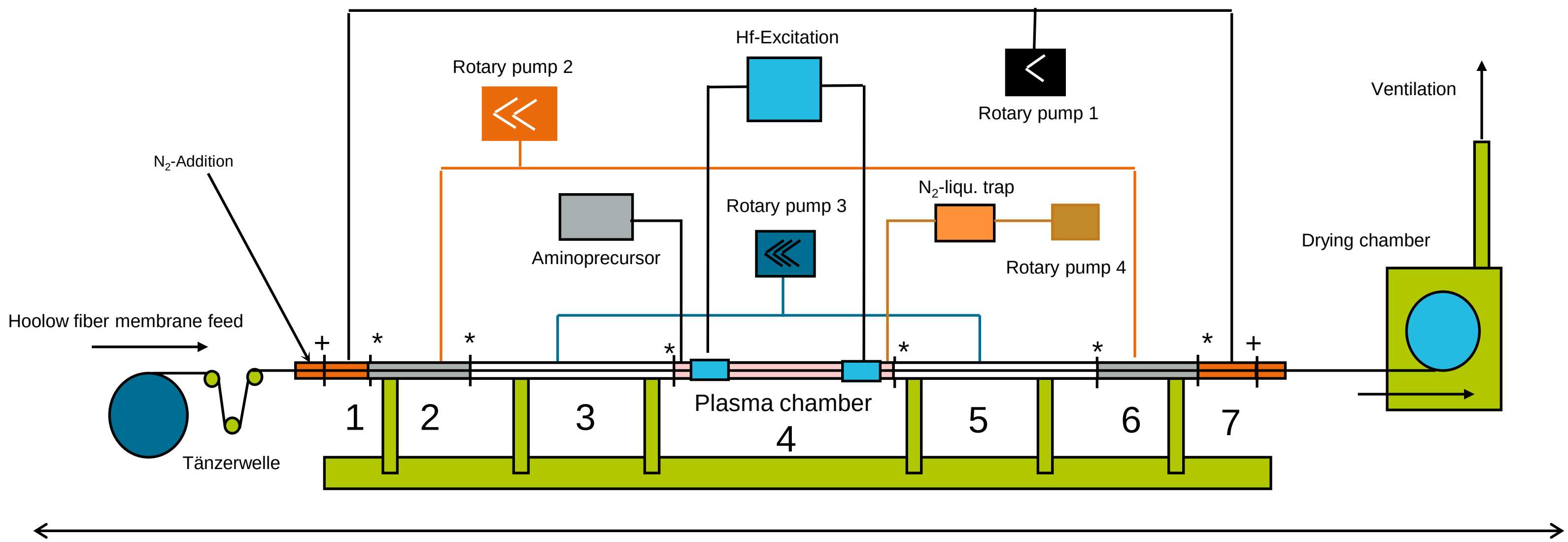


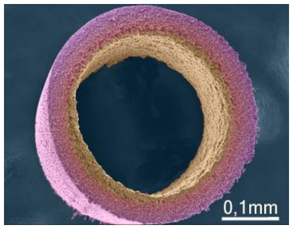
Source: Dimatix

Scalable in-line air to air low pressure plasma modification unit

Transport velocity variation: 5 - 100 m/min

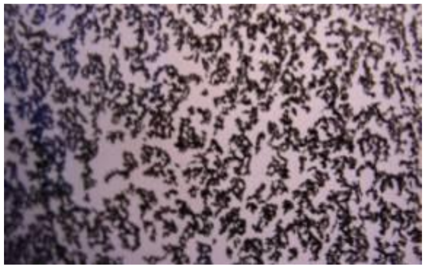
Plasma exposure time: 4 s – 200 ms

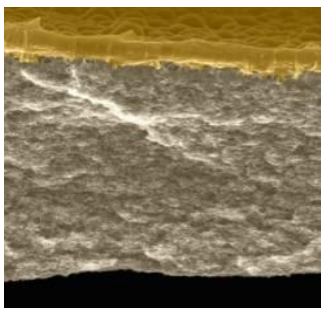


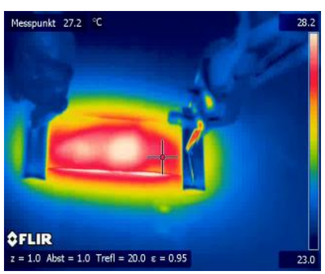


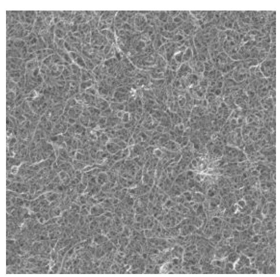
+ Feed through: 0.5 mm Ø
* Feed through: 0.7 mm Ø

Carbon based Materials









- **Characterization and processing of carbon nanotubes, graphene and carbon fibers**
  - Optimisation of Dispersion of CNTs in polymers
  - Characterization of CNTs by ESCA, REM, AFM, BET oder Raman-Spectroskopie
  - Plasma-Functionalisation of CNT-powder and Bucky Papern
  - Testing of biocompatibility and toxicity
  - Production of: polymercomposites, electric conducting polymer composites, membranes and electrode materials

Cost comparison: Plasma- or wet chemical treatment for contact lenses

	LBL-Coating (20 nm)		Plasmacoating (20 nm)	
	Material needed for coating (kg)	Cost in US Dollar	Material needed for coating (kg)	Cost in US Dollar
Invest cost		250 000		3 000 000
Coating materials	7,6 Mio. kg (0,05% aqueous)	181 277	11 kg	290
Effluent treatment cost		5 971 292		0
Depreciation		25 000		300 000
Total coast without labor		6 177 569		300 290
28 Mio. lenses /year		22 Cent per Lense		1 Cent per Lense

H. Yasuda: LCVD and Interf. Engin. 2005,

Coating techniques used for surface tailoring

Irradiation
e-beam, γ crosslinking

Corona
hydrophilicity

Plasma(-CVD,-Polym.)
regioselective deposition,

Texturing
photoresist, screening or printing techniques

Photocoupling
grafting,

Polymer coating

Dip coating
LbL,SAM,nanocytes ®

Sputter coating
radiopacity

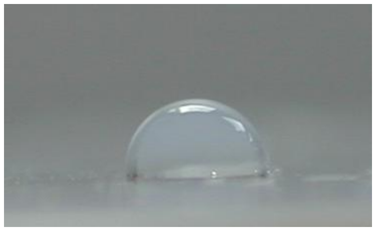
Ozonisation
activation for grafting

Electroless deposition
metallic layers

Silanization
coupling to metals

Parylene®
barrier, lubricity

Wettability is relevant for:



Microfluidics
diagnostics

Water transport
capillarity, goretex®, sympatex ®

Adhesion

Coating

Protein-Adsorption
fouling, biocompatibility

Wetting

Lamination

Varnishing

Gluing

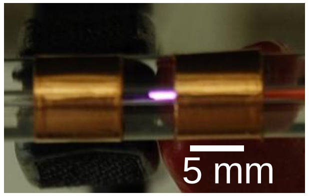
Soldering

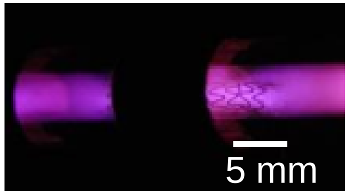
Contamination

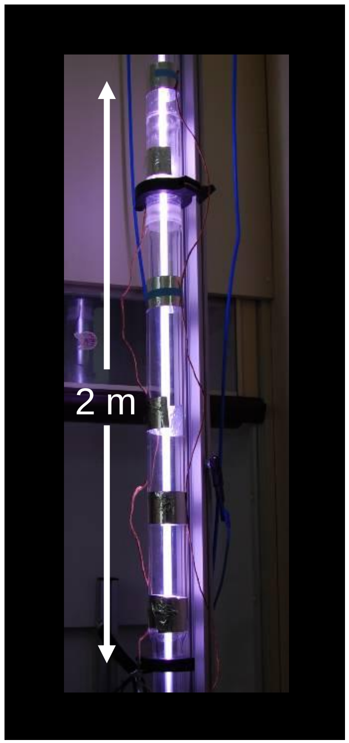
Printing

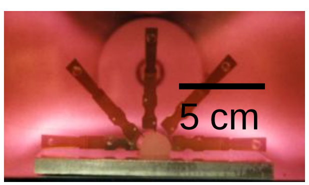
Cleanability
easy-to-clean

Plasma – from micro to macro





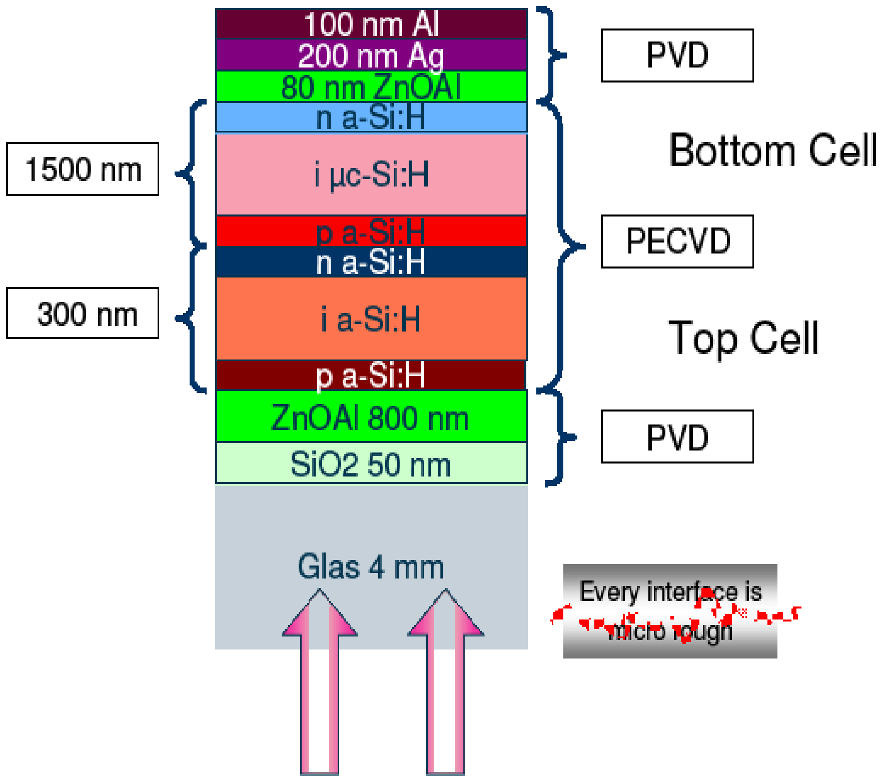




- Plasma purification/sterilization/ medical engineering
  - Inactivation of bacterial contaminations
  - Pyrogen degradation
- Plasma modification
  - Hydrophilic / hydrophobic / oleophobic
  - Functionalization: amino, carboxy...
- Coating
  - High-efficiency barriers, permselective layers
  - Scratch-resistant, wear protection
  - Easy-to-clean, reduced friction
- Geometries
  - 1D, 2D, 3D
  - Coating (≥ nanoparticle size)
  - Coating inside of capillaries (diameter ≥ 100 µm)

Schematic Design of an a-Si/µc-Si Tandem Cell

LEYBOLD OPTICS



Fraunhofer IGB