



# Nanotechnologies for Organic Electronics and Optoelectronics

Univ.Prof.Dr.Günther Leising

Institute of Nanostructured Materials and Photonics  
JOANNEUM RESEARCH  
Weiz, Austria

# Outline

- **JOANNUM RESEARCH Company Profile**
- **Materials**
- **Components**
- **Processes**
- **Packaging**
- **Summary**



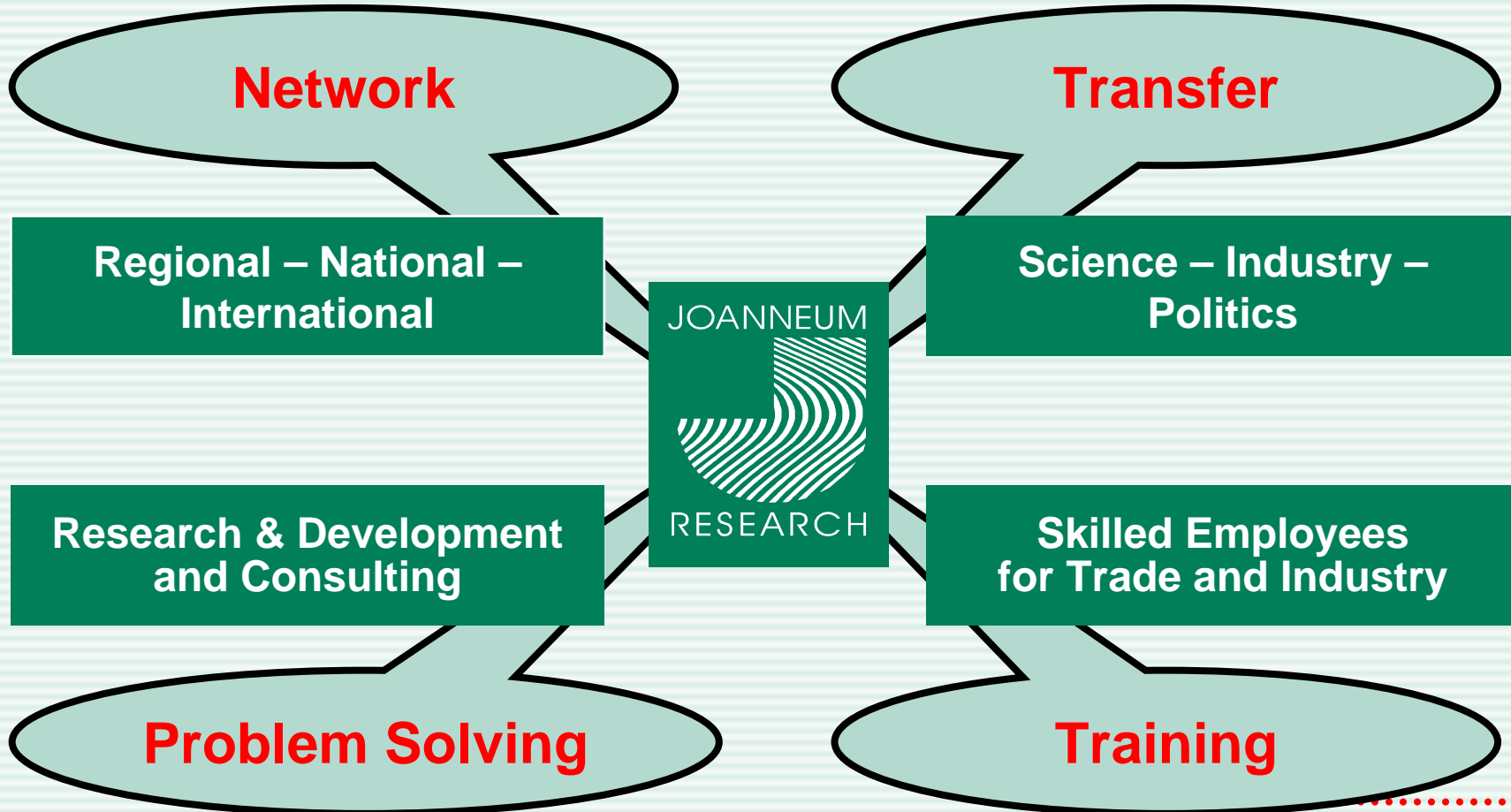
Institute of Nanostructured Materials and Photonics  
Univ.Prof.Dr.Günther Leising



Province of Styria

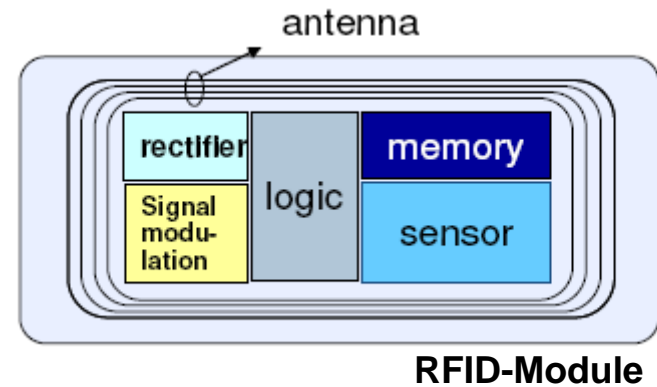


15 Institutes 380 employees



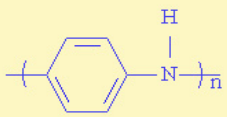
TRADITION of INNOVATION

# Materials

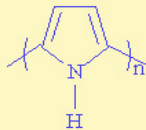


- organic/inorganic **electroactive materials**
- organic/inorganic **dielectric materials**
- organic/inorganic **photoactive materials**
- organic/inorganic **sensoractive materials**
- organic/inorganic **optical materials**
- inorganic **conductors (Cu)**
- organic/inorganic **packaging material**

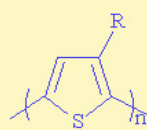
# Materials



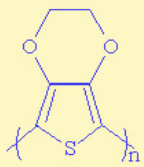
*Polyaniline*



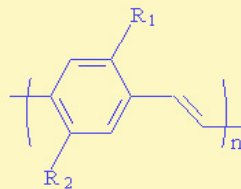
*Polypyrrole*



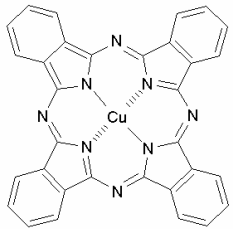
*Polythiophenes*



*Polyethylenedioxythiophene*

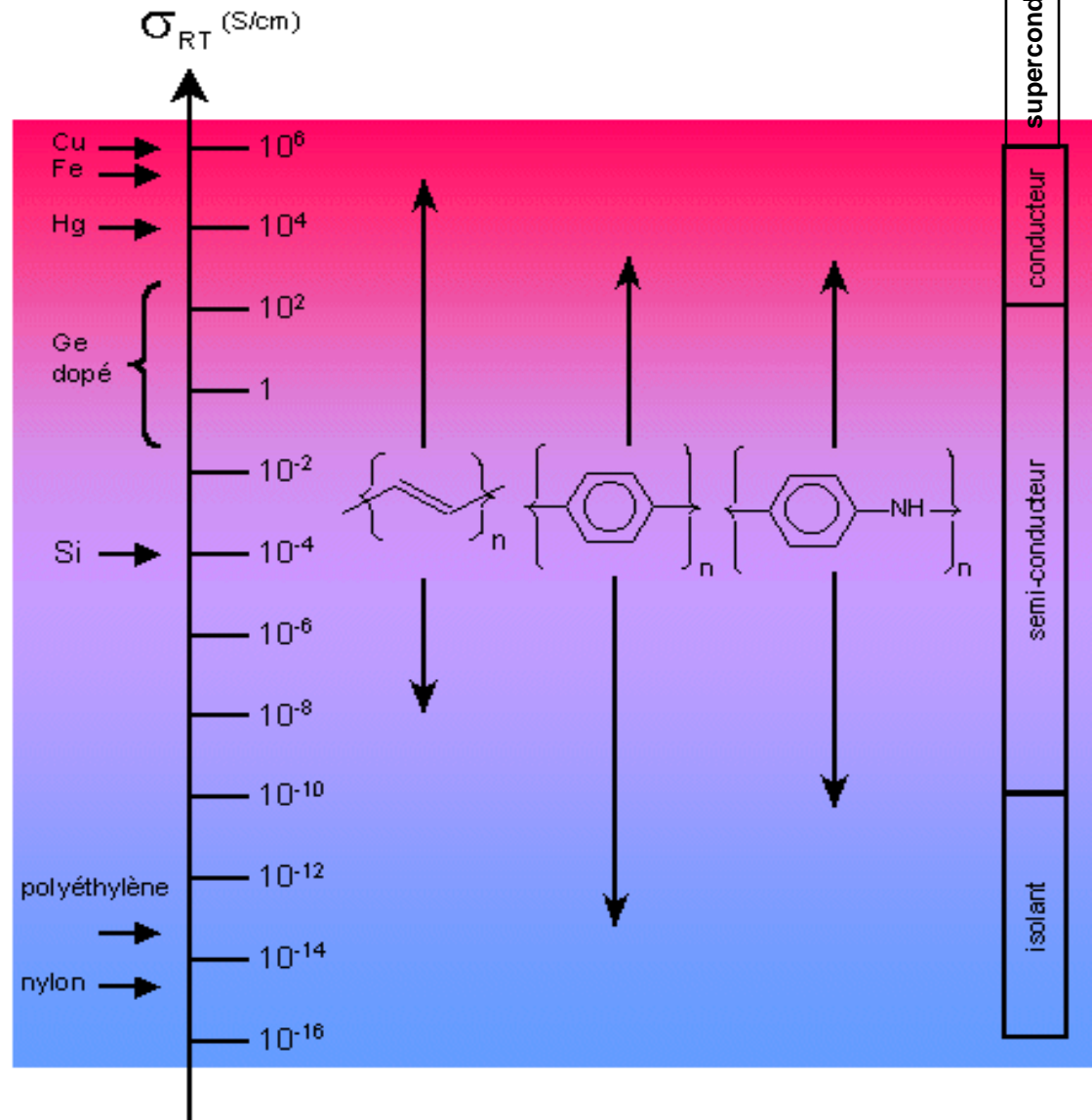


*Poly(p-phenylene vinylene)s*



Class of materials known as  
polyacenes or acenes

- benzene
- naphthalene
- anthracene
- naphthacene (teracene)
- pentacene







# The Scale of Things -- Nanometers and More

## Things Natural

Dust mite  
200  $\mu\text{m}$

Ant  
~ 5 mm

Fly ash  
~ 10-20  $\mu\text{m}$

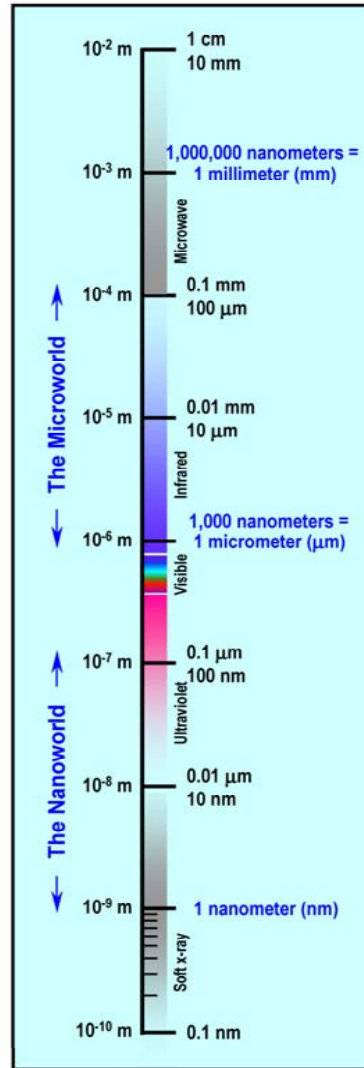
Human hair  
~ 10-50  $\mu\text{m}$  wide

Red blood cells  
with white cell  
~ 2-5  $\mu\text{m}$

ATP synthase  
~10 nm diameter

DNA  
~2-1/2 nm diameter

Atoms of silicon  
spacing ~tenths of nm



## Things Manmade

Head of a pin  
1-2 mm

MicroElectroMechanical devices  
10-100  $\mu\text{m}$  wide

Red blood cells  
Pollen grain

Zone plate x-ray "lens"  
Outermost ring spacing  
~35 nm

Nanotube electrode

Nanotube transistor

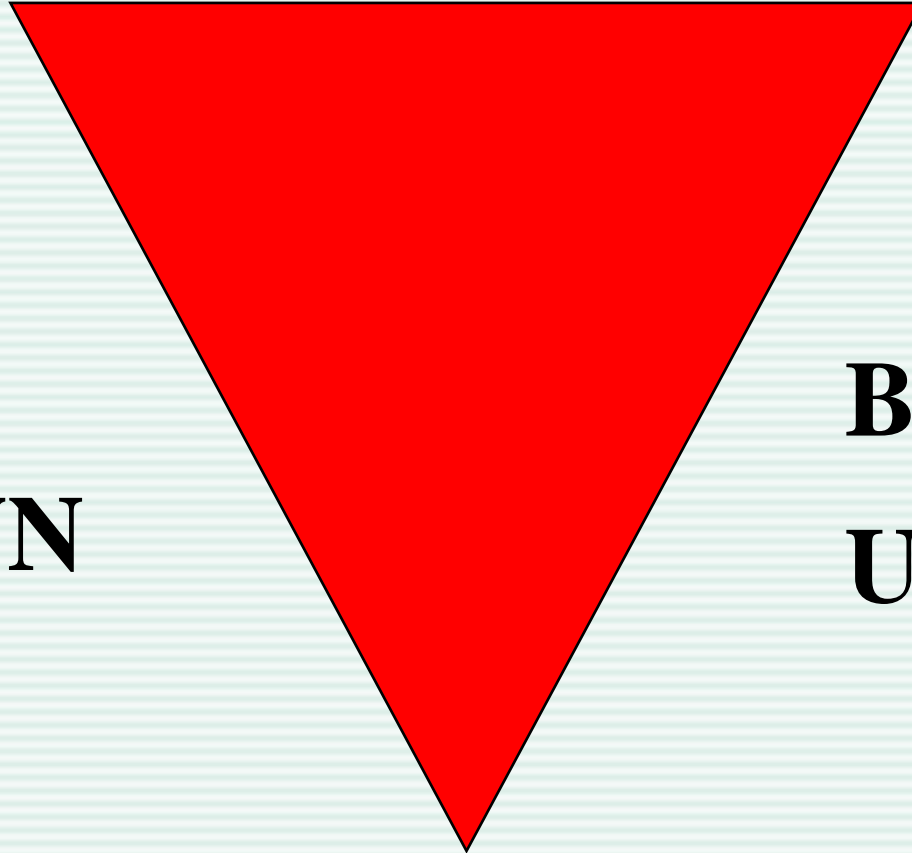
Quantum corral of 48 iron atoms on copper surface  
positioned one at a time with an STM tip  
Corral diameter 14 nm

Carbon nanotube  
~2 nm diameter

**21st Century Challenge**

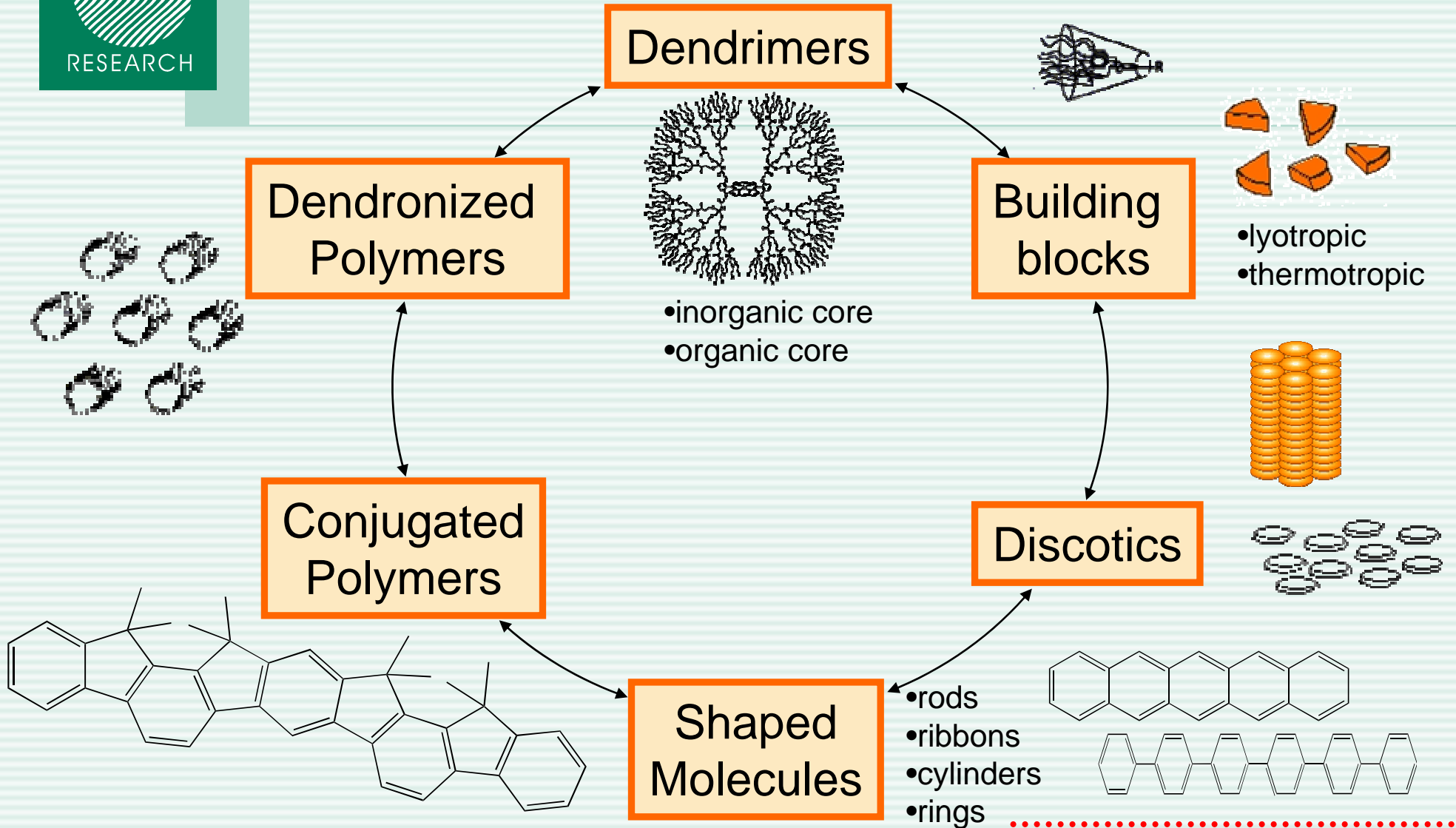
Combine nanoscale building blocks to make novel functional devices, e.g., a photosynthetic reaction center with integral semiconductor storage

**TOP  
DOWN**



**BOTTOM  
UP**

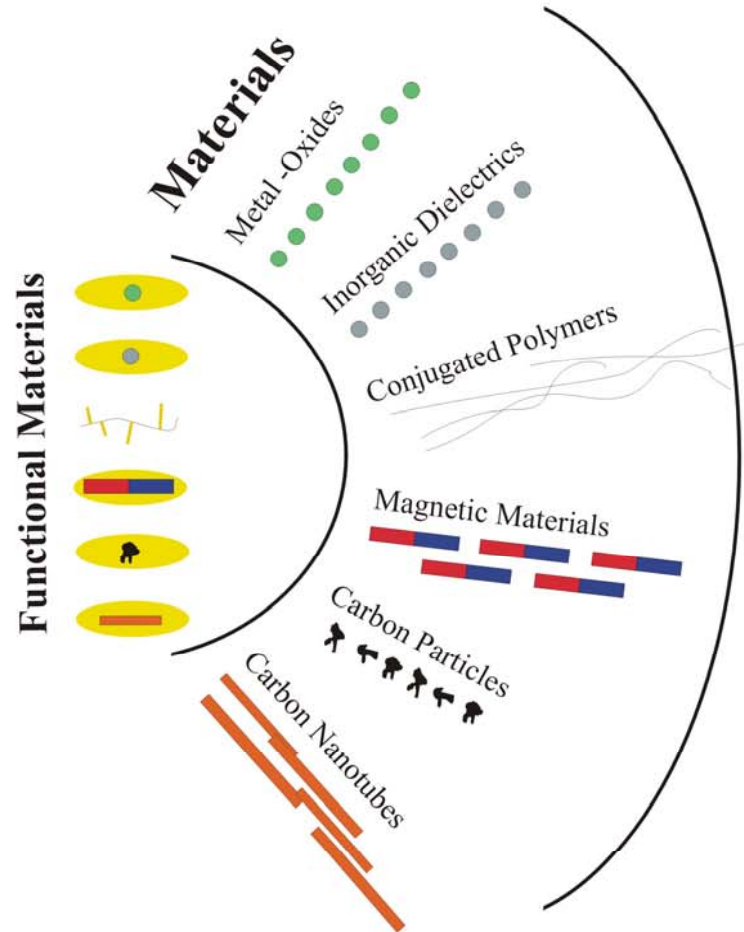
# Nanotechnology



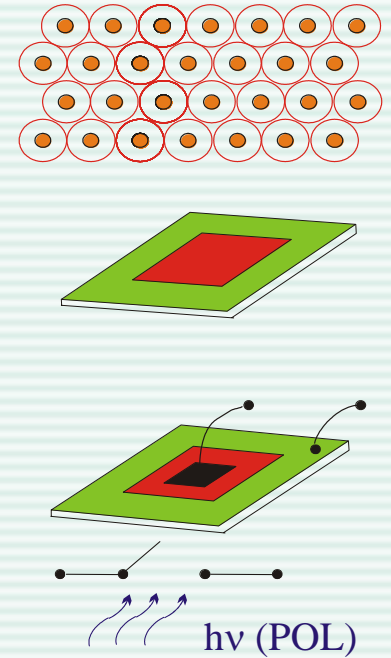
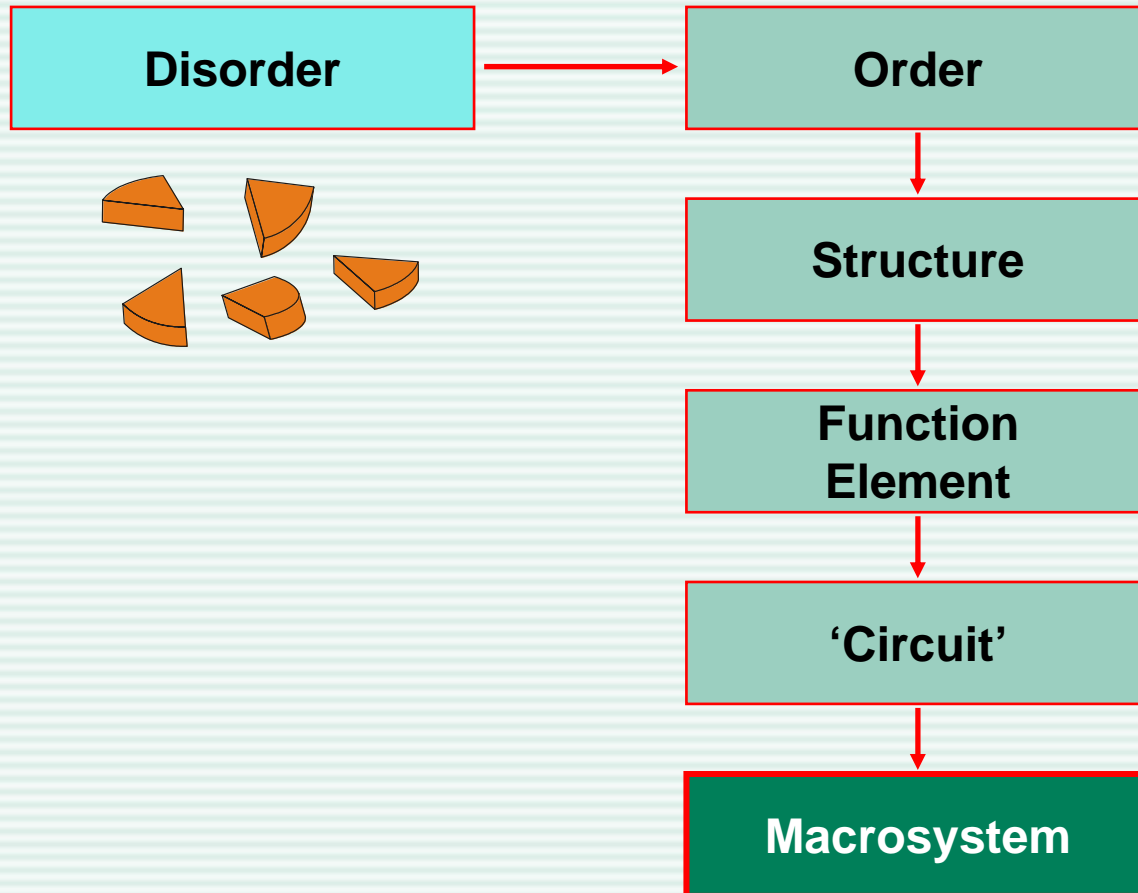


# Nanotechnology

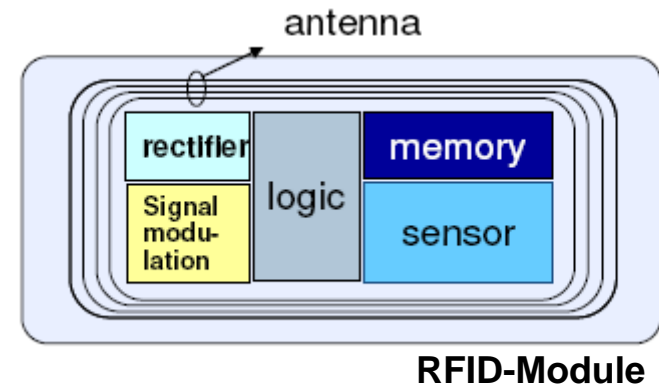
**Materials  
for selective /  
structured  
deposition**



# Nanoaufbau



# Components



- passive components (R, C, L, antenna)
- nonlinear components (diode, Zener, foldback)
- active components (FET, LED, laser)
- information storage (memory)
- sensor components (photodiode, ...)
- energy storage (battery, ...)
- optical components (lenses, waveguides, ...)
- conducting lines and vias

# oFET - Materials

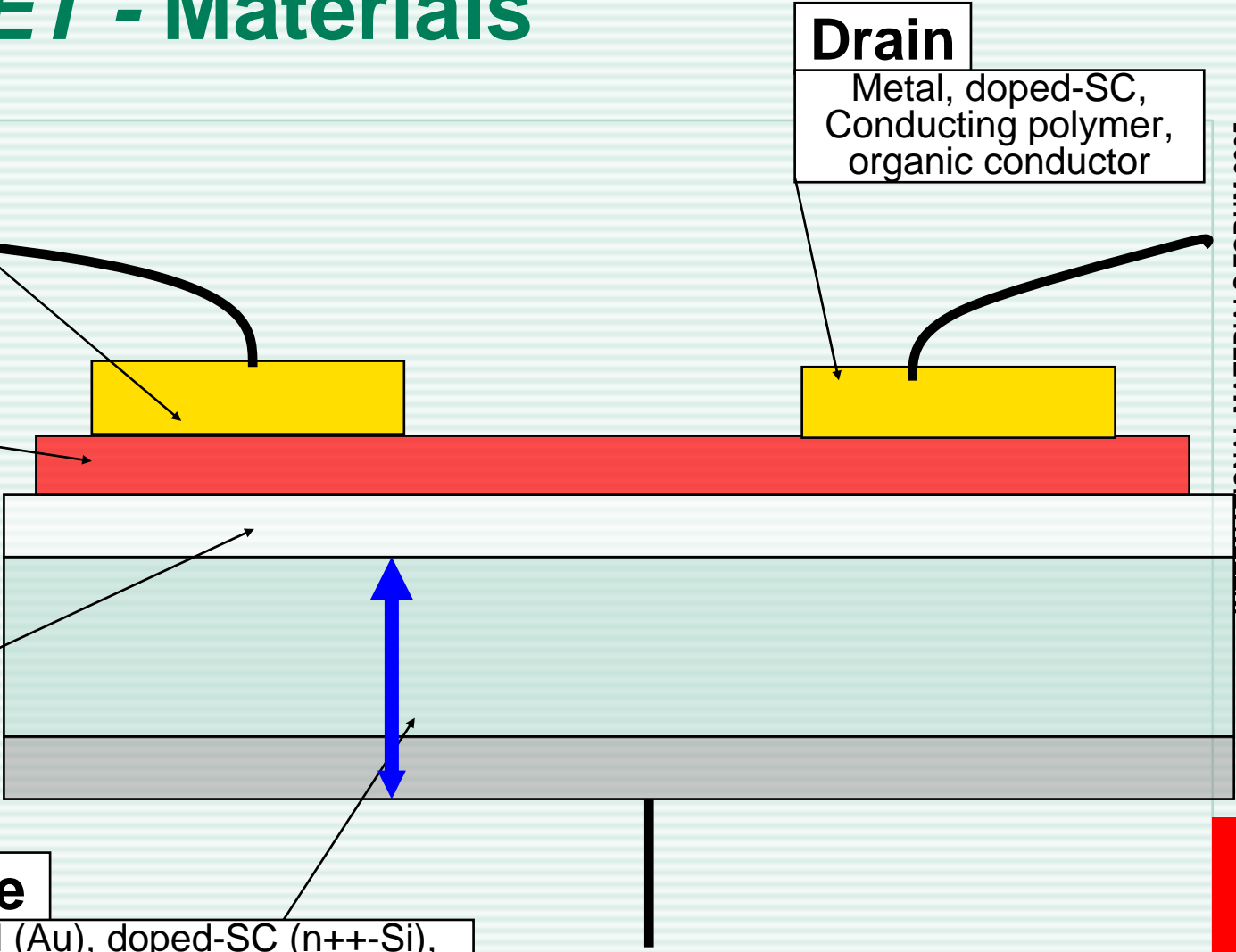
**Source**  
Metal, doped-SC,  
Conducting polymer,  
organic conductor

**Drain**  
Metal, doped-SC,  
Conducting polymer,  
organic conductor

**Semiconductor**  
Conjugated polymer,  
organic semiconductor  
semiconductized material

**Dielectric**  
- Inorganic  
(SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, mica,..)  
- insulating polymer (PMMA)  
- functional polymer (PVP)  
- organic layer

**Gate**  
Metal (Au), doped-SC (n++-Si),  
Conducting polymer, organic  
conductor



INTERNATIONAL MATERIALS FORUM 2005

ISO 9001 certified

.....  
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# oFET - Structuring

## Source

- evaporation
- spin-coating
- ink-jet printing
- nanoimprinting

## Drain

- evaporation
- spin-coating
- ink-jet printing
- nanoimprinting

## Semiconductor

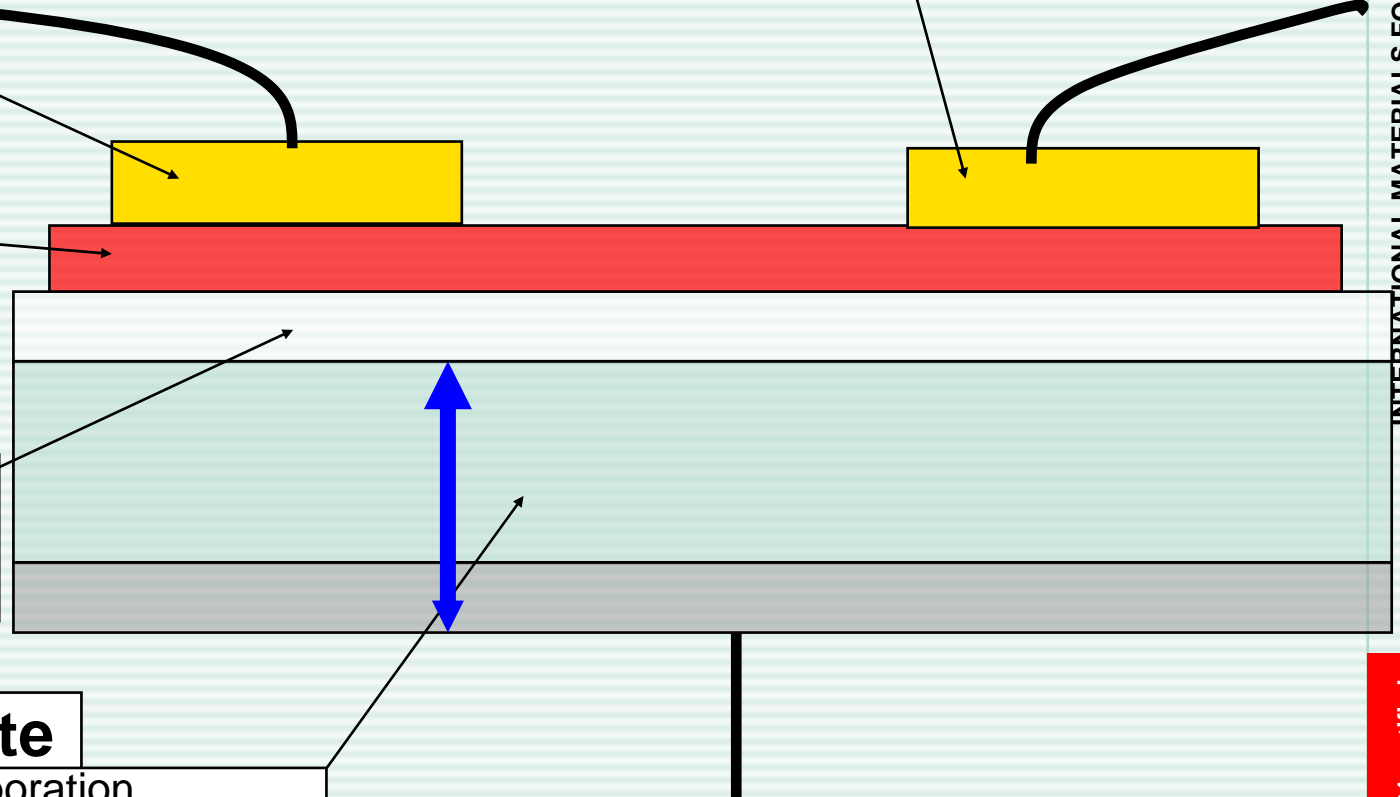
- evaporation
- spin-coating
- dip-coating
- SAMs
- transferprinting
- nanolamination

## Dielectric

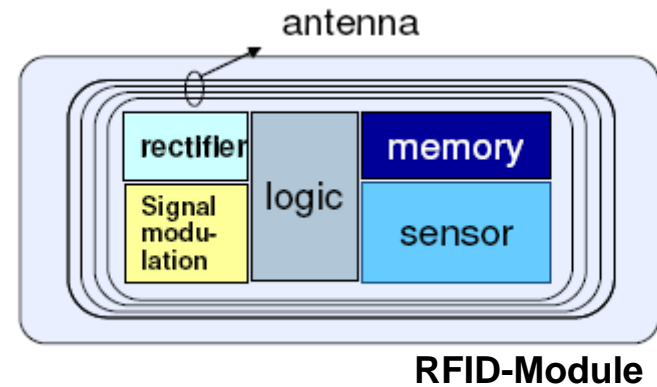
- evaporation
- spin-coating
- dip-coating
- SAM

## Gate

- evaporation
- spin-coating
- ink-jet printing



# Processes



- **Soft-Lithography**
  - Nanoimprinting**
  - Hot-Embossing**
- **Thin-Film Growth (PVD)**
- **Ink-Jet Printing**
- **3D-Structuring (Two-Photon Absorption)**





# Soft Lithography

## Embossing

Soft Stamps  
(Soft Lithography)

Hard Stamps

Solvent Assisted  
Micromolding

Nano  
Imprinting

Liquid  
Embossing

Flash  
(UV curable  
Polymer)

Soft  
Embossing

Thermo-  
setting  
Polymer

## Printing

SOFT Stamps  
(Soft Lithography)

Micro-Contact  
Printing

## Molding

Soft Stamps  
(Soft Lithography)

Replica  
Molding

Micromolding  
In Capillaries

Microtransfer  
Molding



# Nanoimprinting

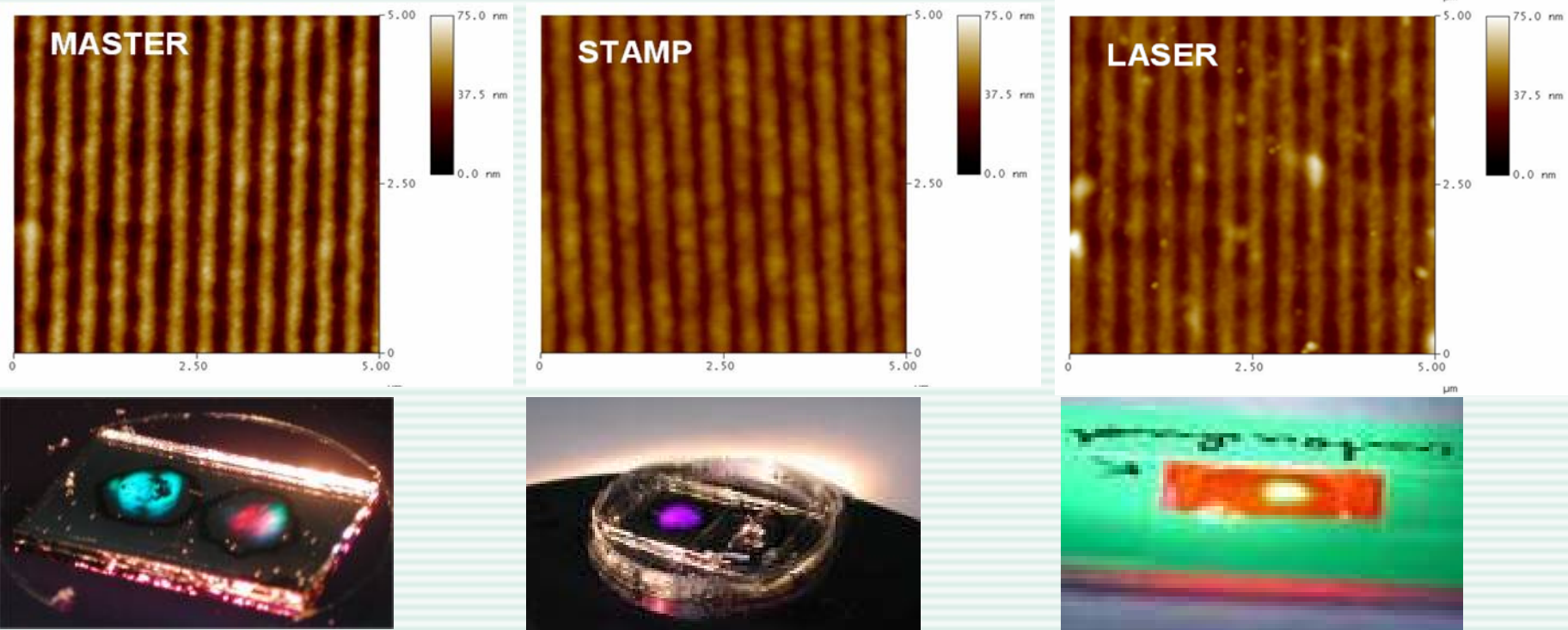


2002

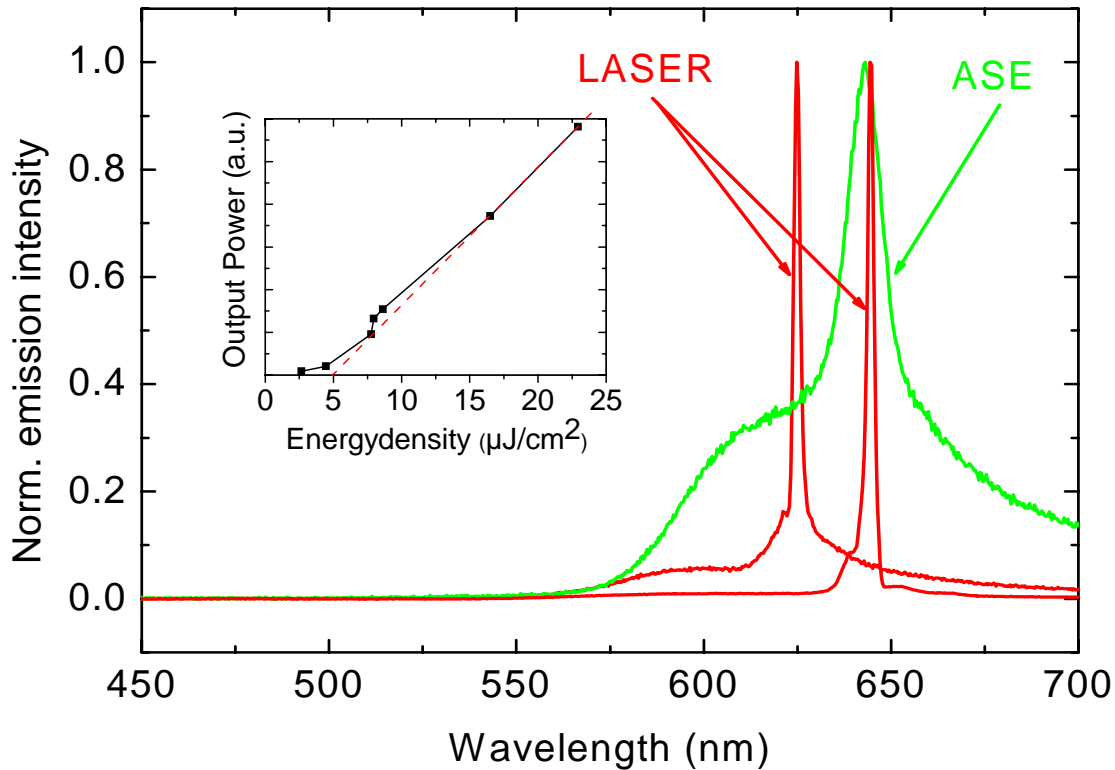
- replicative technique
- High resolution (-> 10nm)
- parallel structuring
- room temperature process (UV-Imprinting)
- direct structuring of flexible, substrates (Hot Embossing)
- high and low aspect ratio
- cost effective
- high volume (-> DVD)

# Imprinted Polymer Laser

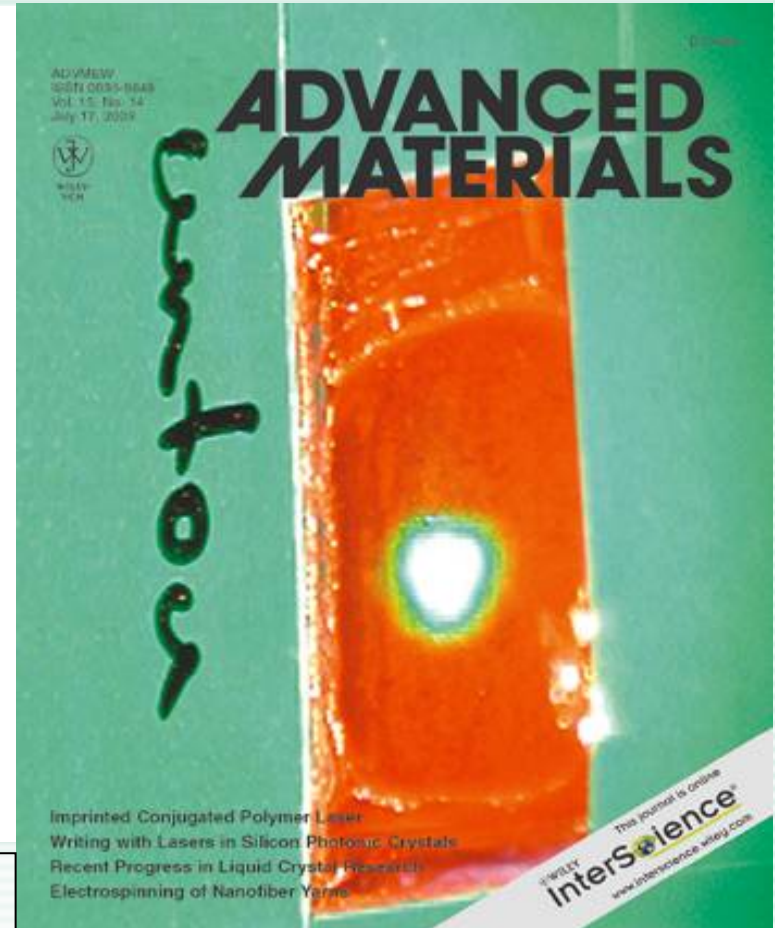
Christian Doppler Laboratory for Advanced Functional  
Materials, AT&S, JOANNEUM RESEARCH



# Imprinted Polymer Laser



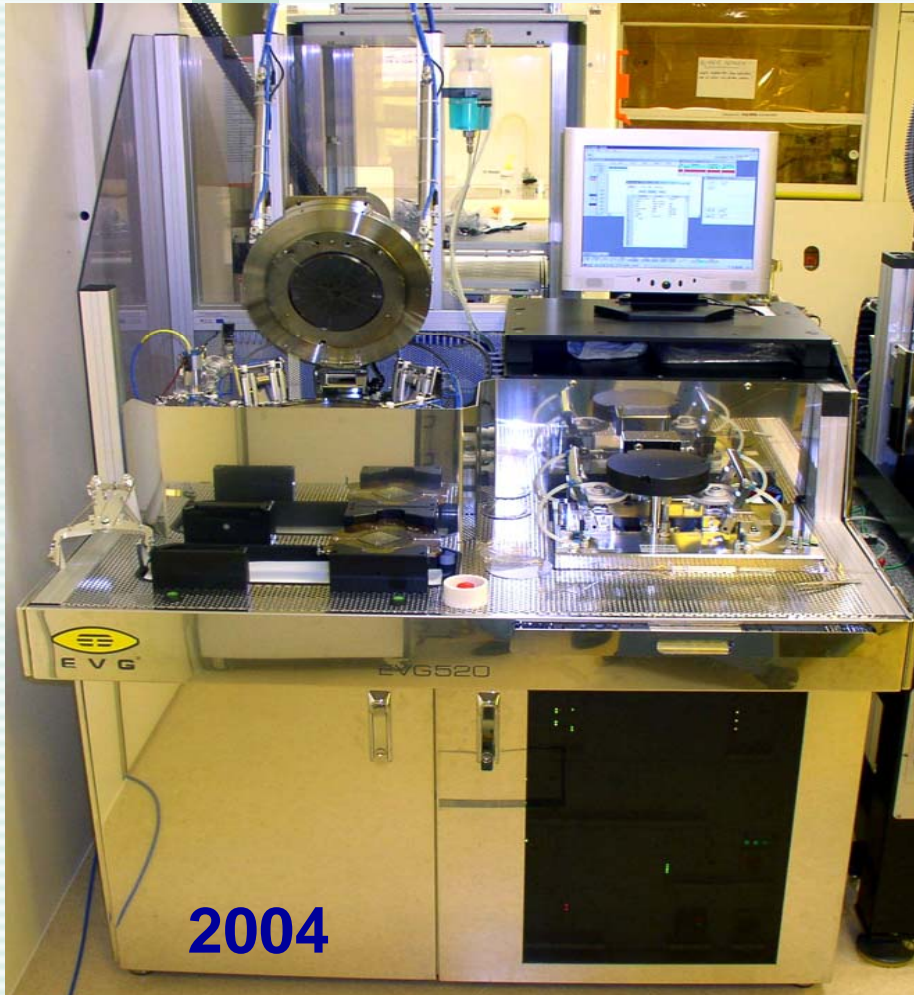
Christian Doppler Laboratory for Advanced Functional  
Materials, AT&S, JOANNEUM RESEARCH



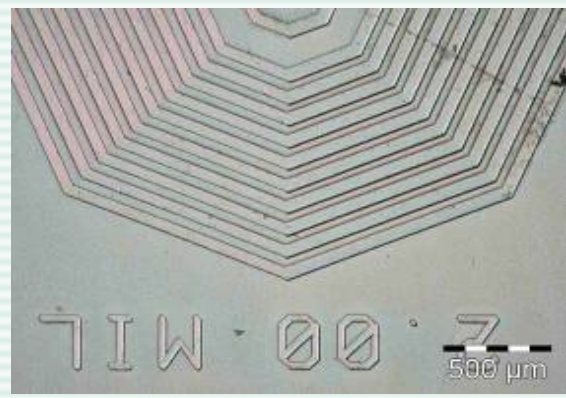
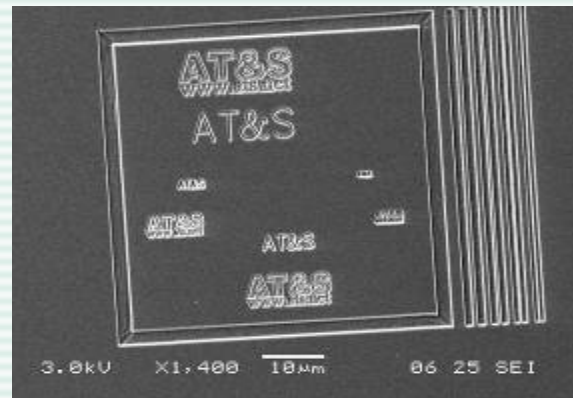
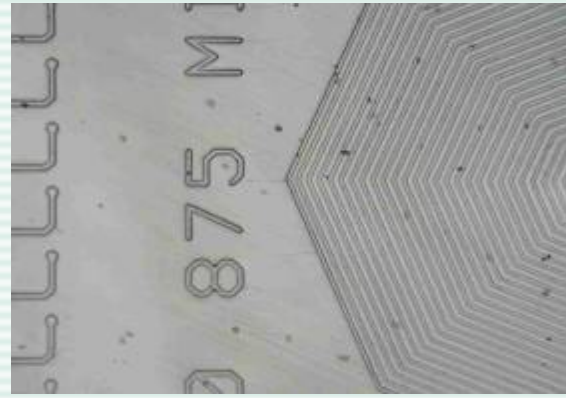
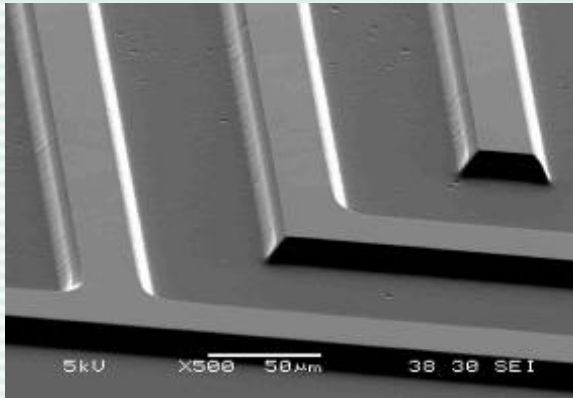


# Mask-Aligning

## Hot-Embossing



# Microimprint Lithographie



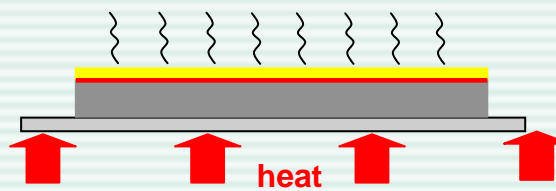
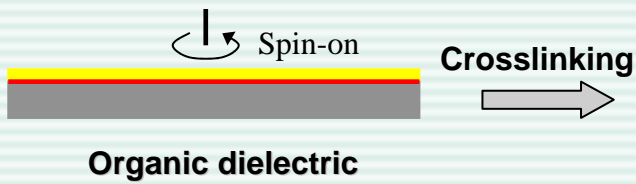


# Nanoimprint-Lithography 1

## 1. Substrate and Gate-contact



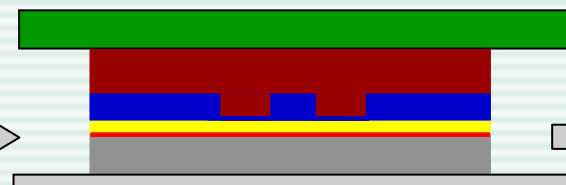
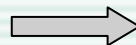
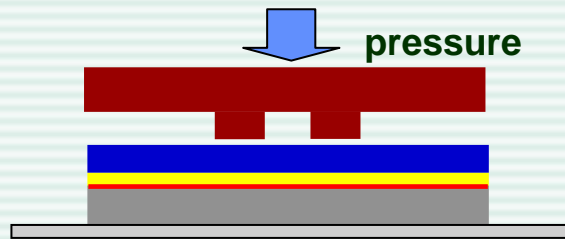
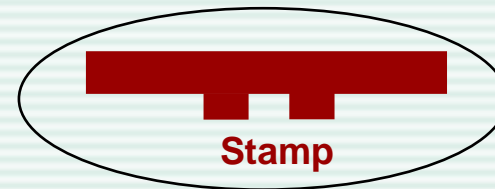
## 2. Gate-Dielectric



## 3. Imprint-resist



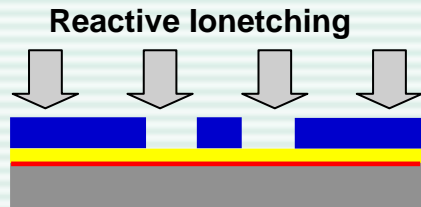
## 4. Hot-embossing (EVG 520)



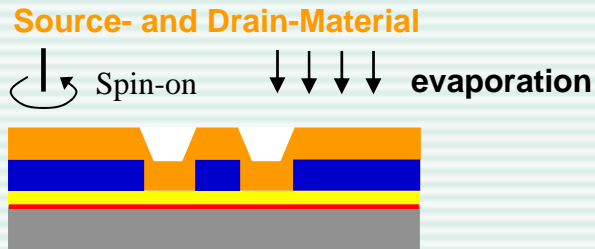


# Nanoimprint-Lithography 2

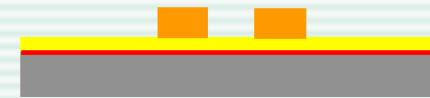
## 5. Etching



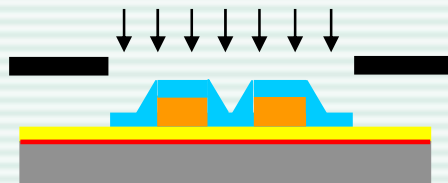
## 6. Source- und Drain-contacts



Lift-off



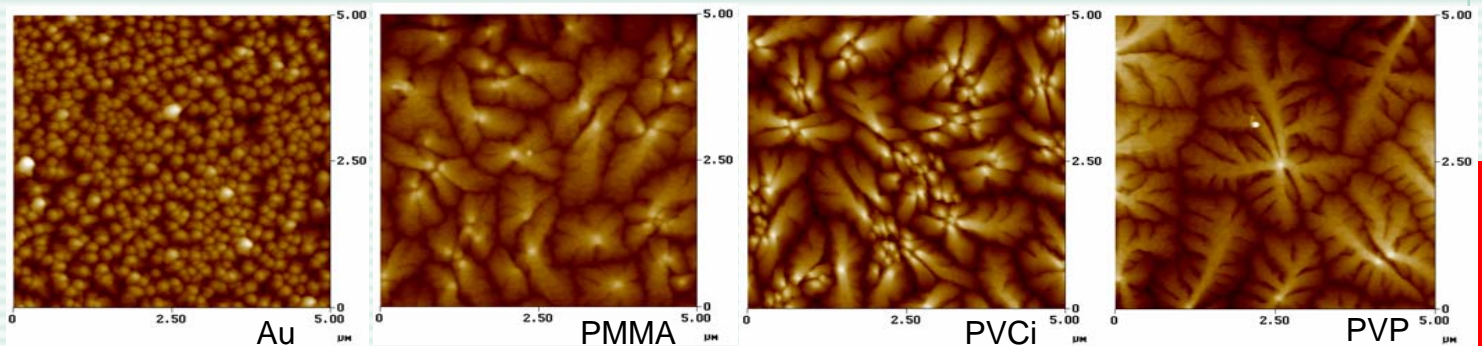
## 7. Organic semiconductor



Organic Semiconductor

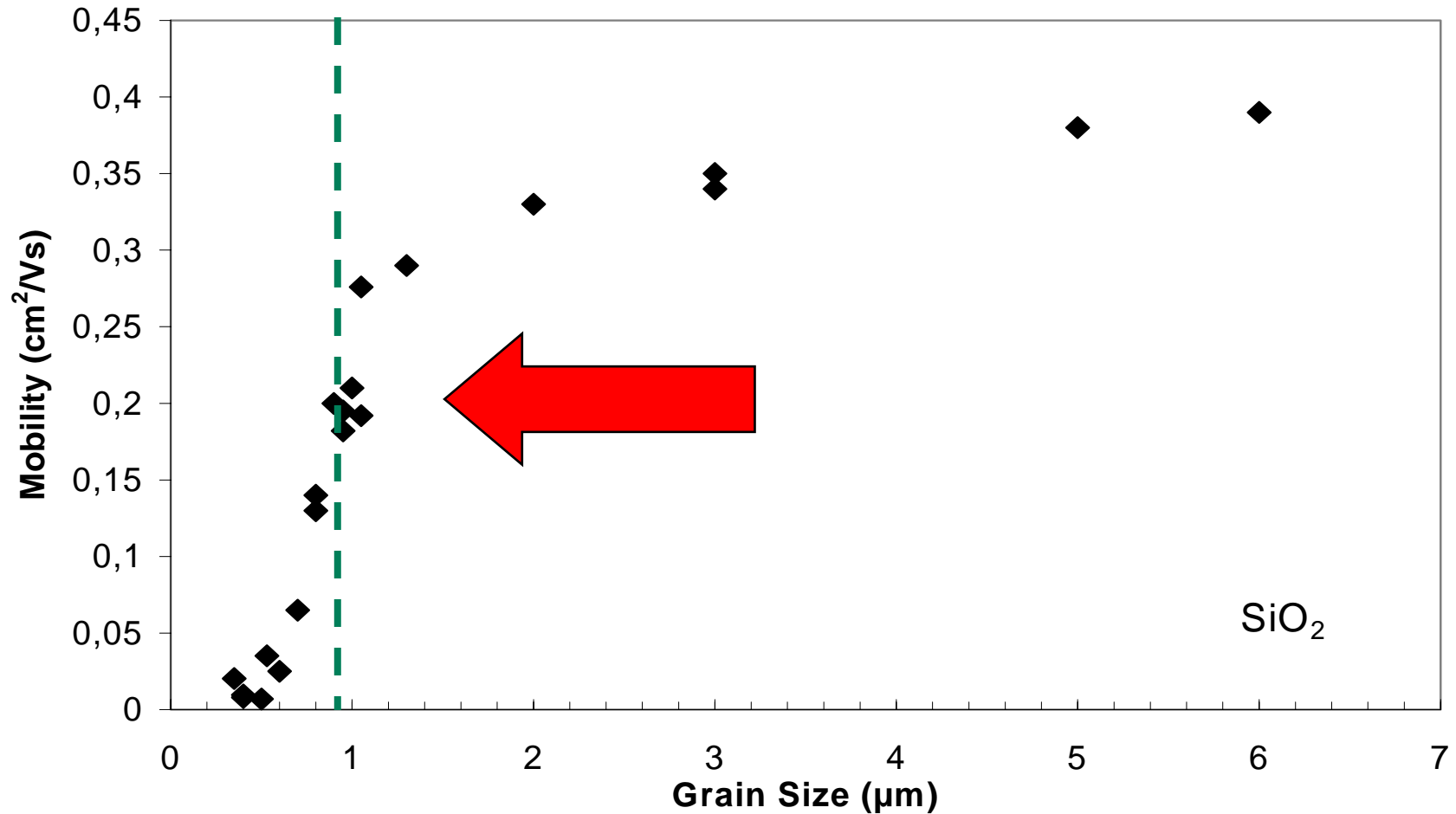
# Engineering of thin film growth

- **substrate** (surface energy, roughness,...) and **substrate treatment** (etching steps, chemical processes,...)
- **substrate temperature** during evaporation
- **deposition rate**
- **film thickness**



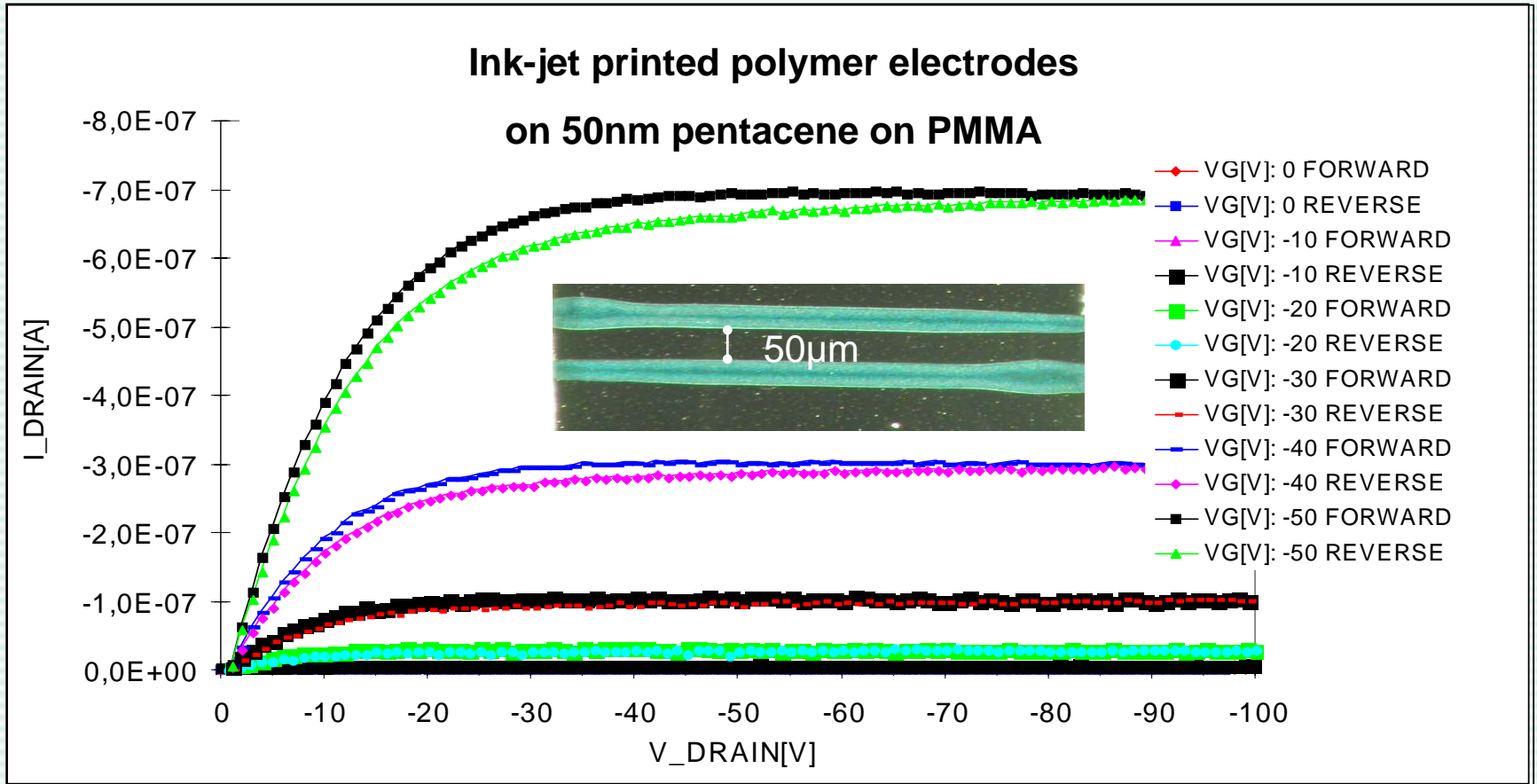
50 nm pentacene on different substrates, 5x5 $\mu$ m-AFM height images

# grainsize – carrier mobility





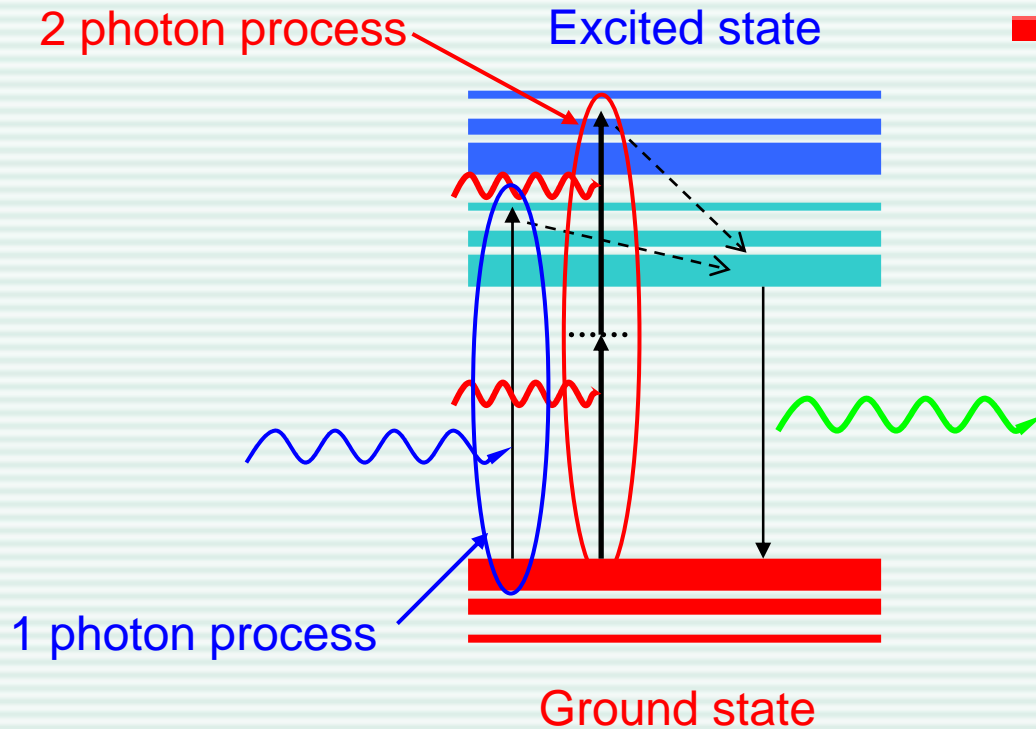
# All-organic FET



## Output Characteristics



# 3D-Structuring Two Photon Absorption (TPA)

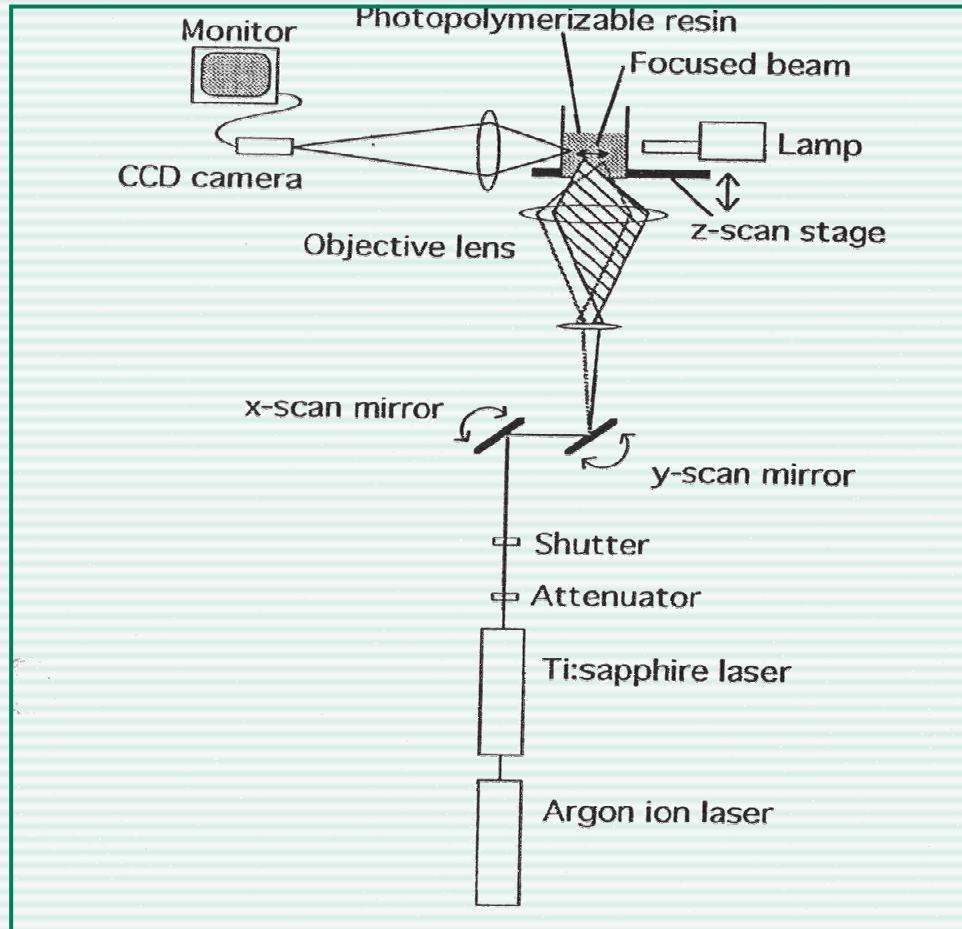


## Two-Photon-Absorption (TPA)

- ➔ Non linear process (prop.  $I^2$ )
- ➔ Absorption via virtual intermediate state
- ➔ High laser intensity required due to short life time of intermediate level



# Typical setup for TPA

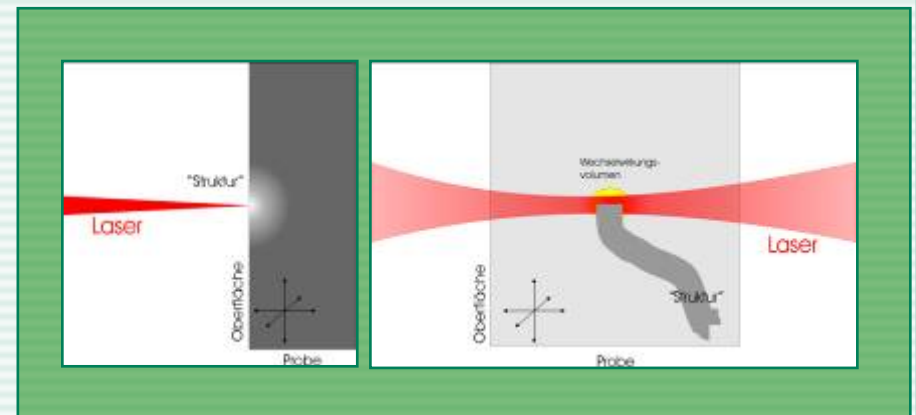
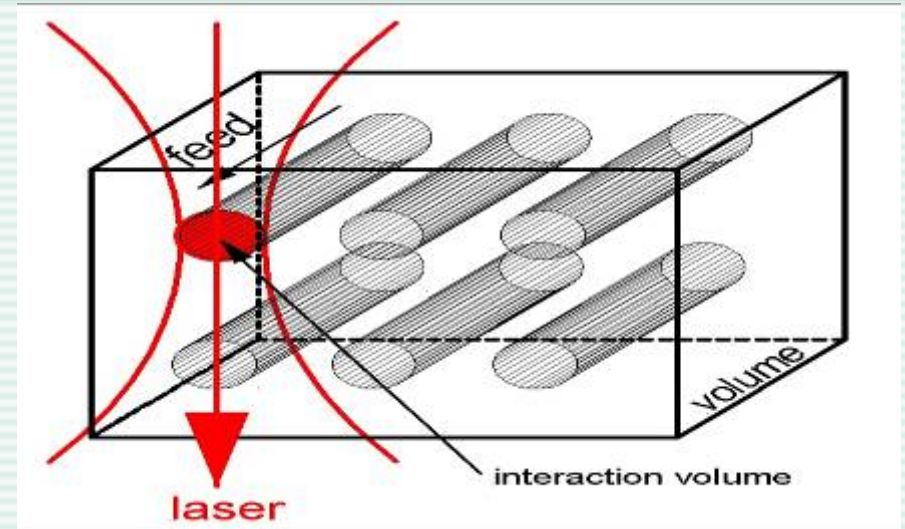




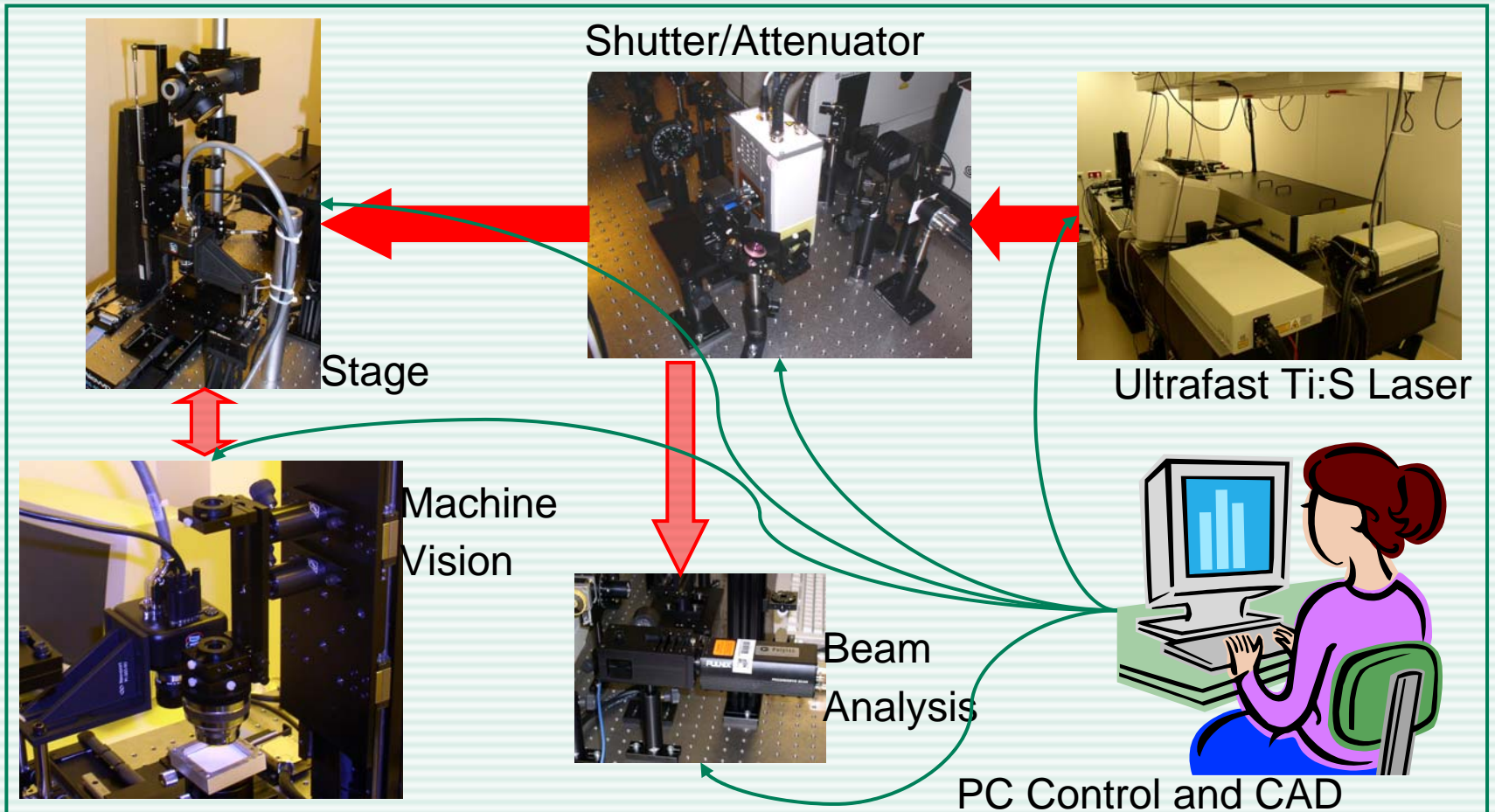
# Characteristics of polymer laser processing

- **Laser direct writing by means of multi photon absorption**
  - ➔ True 3D technique in transparent media with  $\mu\text{m}$  and sub- $\mu\text{m}$  resolution
  - ➔ maskless method
  - ➔ Single writing step
  - ➔ Well suited for small series or rapid prototyping
- **Structuring by means of non-linear absorption (2P photopolymerization)**
- **Lateral resolution and depth resolution depends on**
  - ➔ Velocity, sample feedrate
  - ➔ wavelength
  - ➔ numerical aperture
  - ➔ Intensity

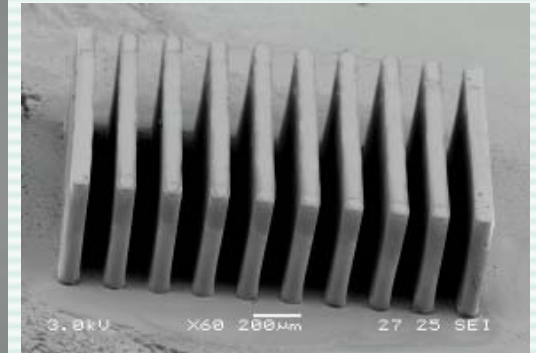
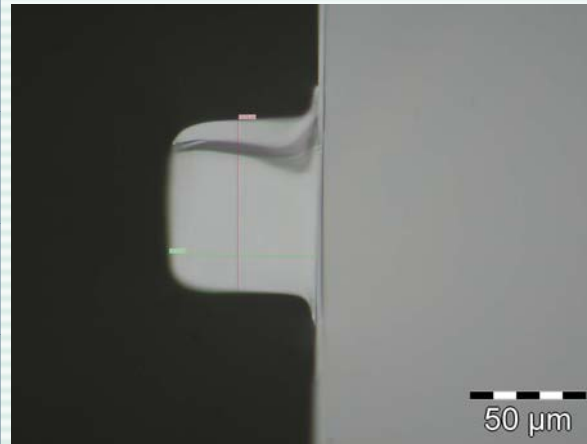
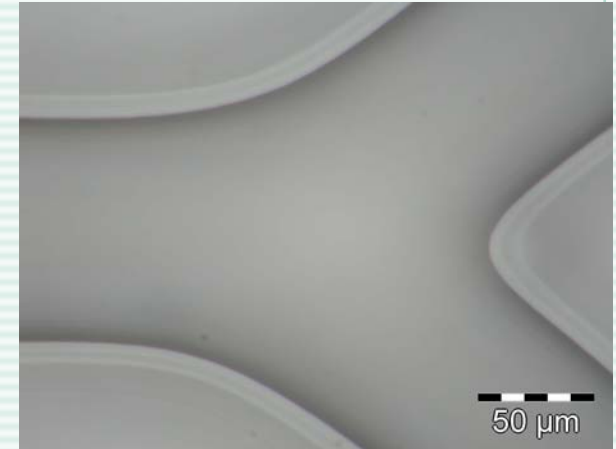
**resolution < 50nm**



# Scheme of TPA-Setup @ NMP

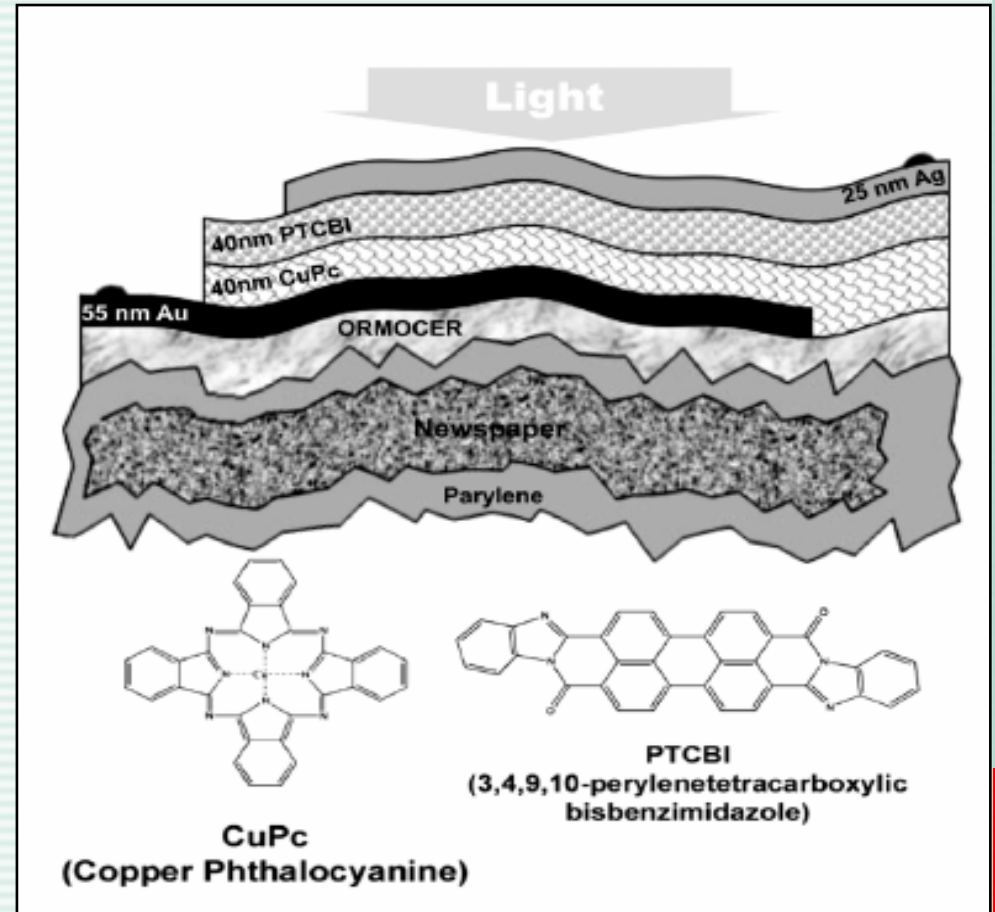
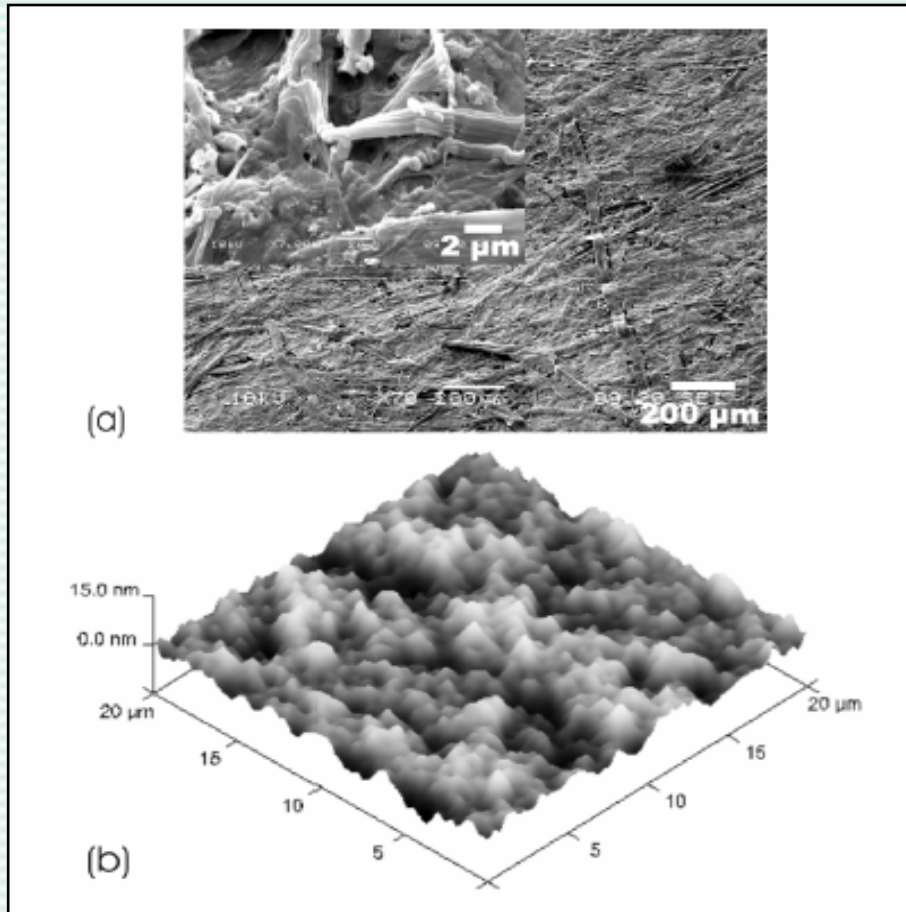


# Optical Waveguides





## Organic photodiode an newspaper



phys. stat. sol. (a) 202, No. 5, R50–R52 (2005) / DOI 10.1002/pssa.200510010

## Organic photodiodes on newspaper

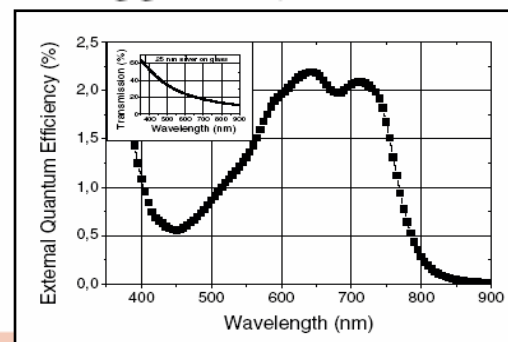
B. Lamprecht\*, R. Thünauer, M. Ostermann, G. Jakopic, and G. Leising

Institute of Nanostructured Materials and Photonics, JOANNEUM RESEARCH Forschungsgesellschaft, Franz-Pichler-Straße 30, 8160 Weiz, Austria

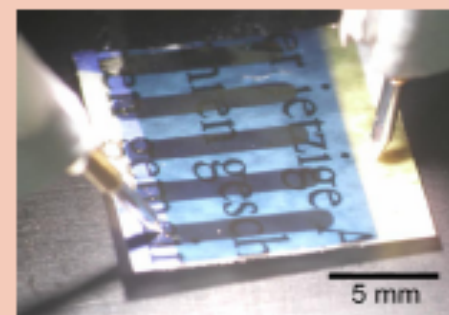
Received 16 February 2005, revised 2 March 2005, accepted 3 March 2005  
Published online 8 March 2005

PACS 61.43.Dq, 68.37.Hk, 68.37.Ps, 68.55.Jk, 73.61.Ph, 85.60.Dw

\* Corresponding author: e-mail [bernhard.lamprecht@joanneum.at](mailto:bernhard.lamprecht@joanneum.at)



We report on the fabrication and characterization of organic photodiodes deposited on ordinary newspaper sheets. Parylene acts as water and chemical barrier layer, an ORMOCER layer serves as an excellent smoothing and base layer for the diodes, which correspond to classical Tang-type bilayer cells. The photodiodes show excellent diode behaviour in current-voltage measurements of the devices under dark and illumination conditions. The spectral response covers the UV and visible spectral range.



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# Summary

- **ALL-ORGANIC - > appealing approach**
- **every-day life substrates (paper, textiles)**
- **cost and reliability decide about materials and processes**
- **replicative processes for high volume manufacturing → Nanolithography – nanoimprinting**
- **packaging strategy open**
- **Integrated organic electronics**
  - > **disruptive technology**

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RESEARCH

# Thank you !

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