



Institut für Hochfrequenztechnik  
Technische Universität Braunschweig



# Institut für Hochfrequenztechnik

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# Transparente OLED-Displays

Sami Hamwi, Patrick Görrn, Jens Meyer, Thomas Winkler, Hans-Hermann Johannes, Thomas Riedl, Wolfgang Kowalsky

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- transparente Elektroden für transparente OLEDs
- transparente Barrierschichten für organische Bauelemente
- transparente Dünnschichttransistoren für AMOLED



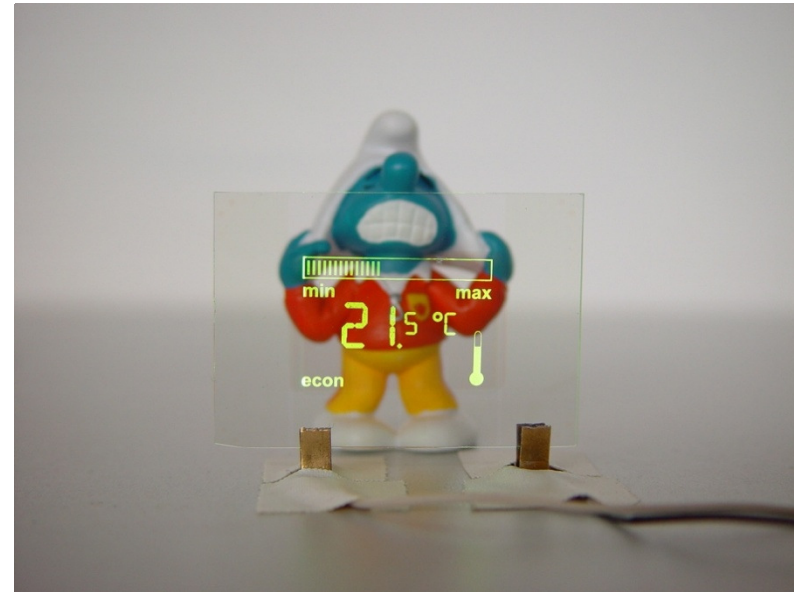
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# Transparente OLED Displays



Minority Report

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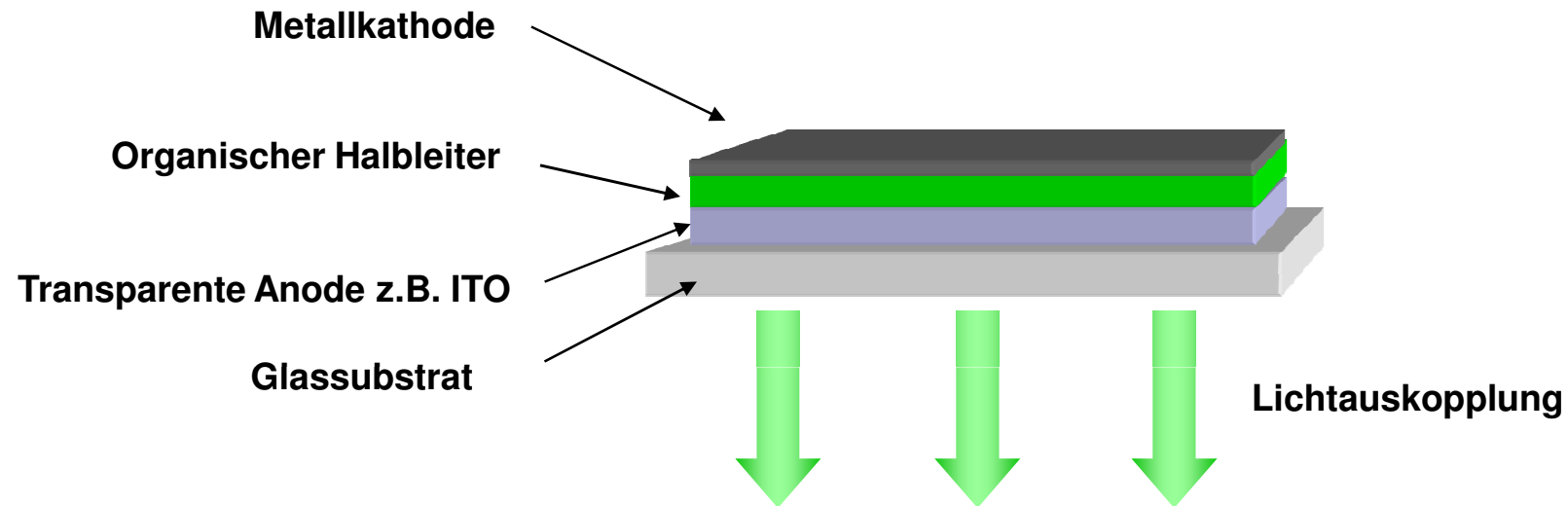


## Transparente OLED



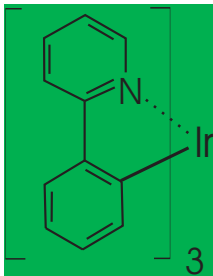
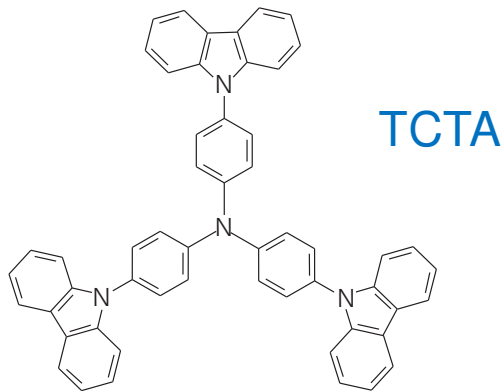
- Punktion, Biopsie
- Krebstherapie, Brachytherapie
- Herzchirurgie

<http://www.medarpa.de/>

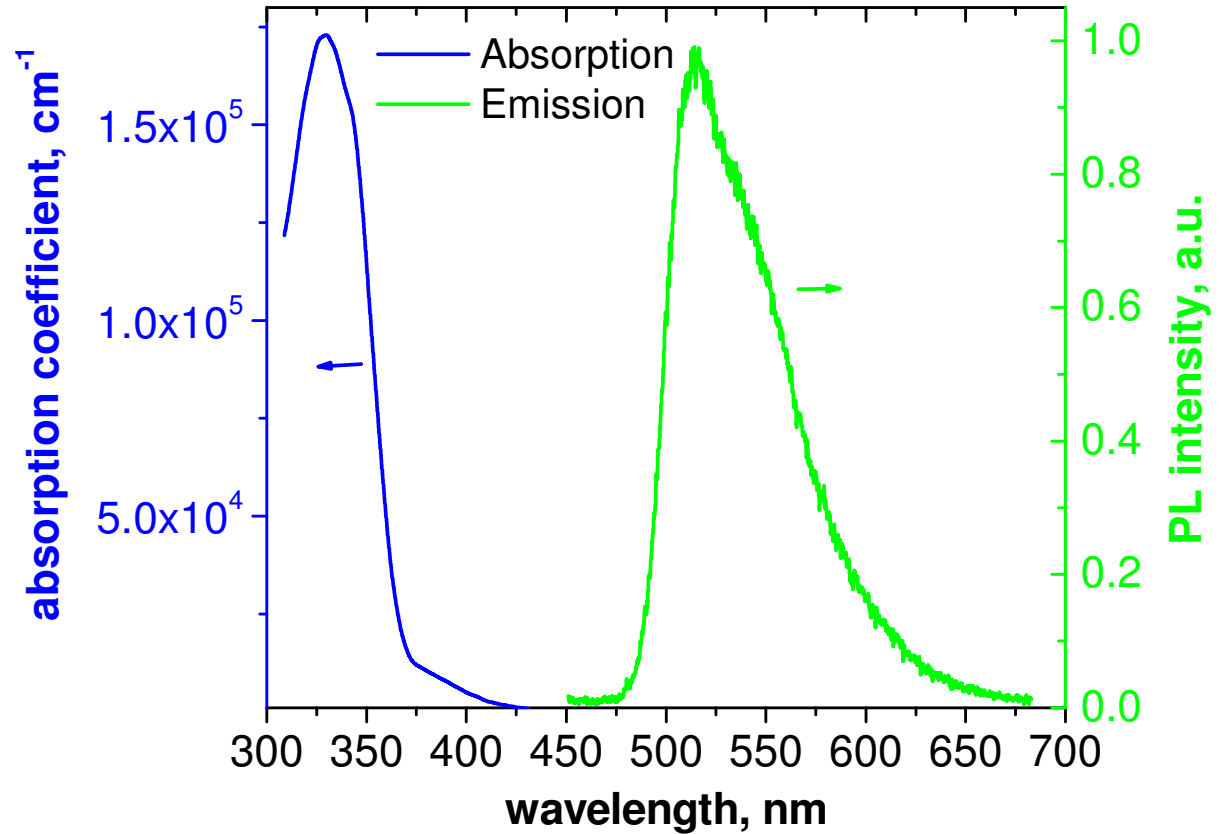




## guest-host systems

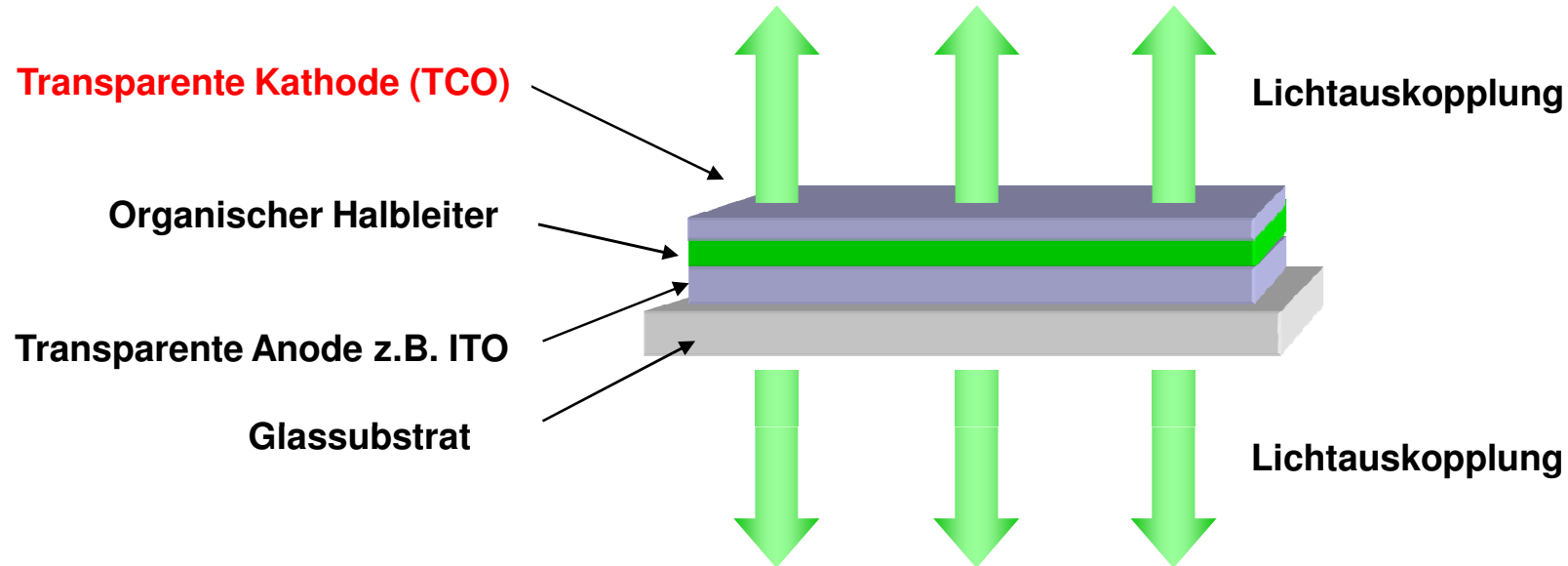


tailored organic layers:



+ absorption in the UV (< 400 nm)  
+ emission in the visible

→ large „Stokes shift“



⇒ völlig transparente OLEDs





Organische Halbleiter sind sehr empfindlich!

→ niedrige Prozesstemperaturen ( $< 80\text{ °C}$ )

→ vermeide Sauerstoff + energiereiche Strahlung

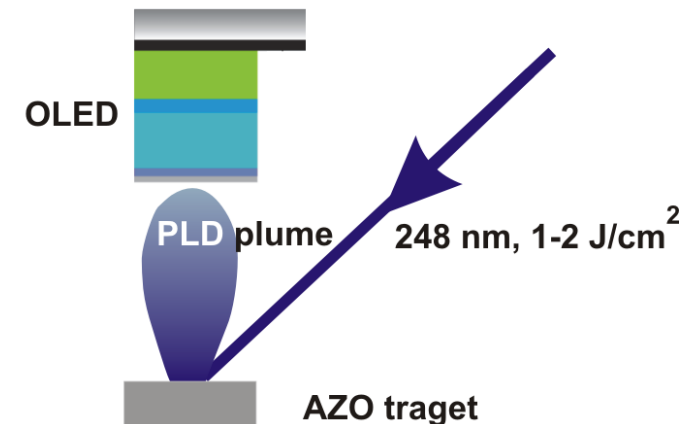
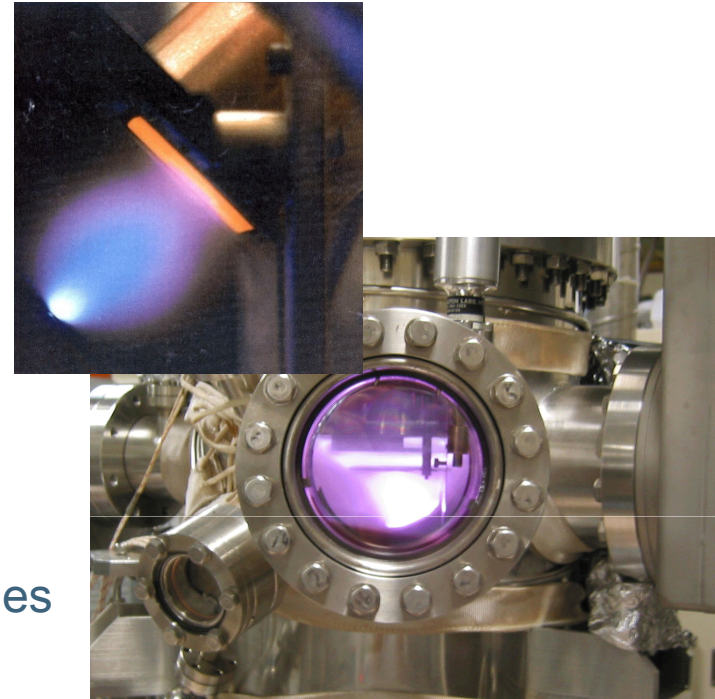
Kritische Energie:

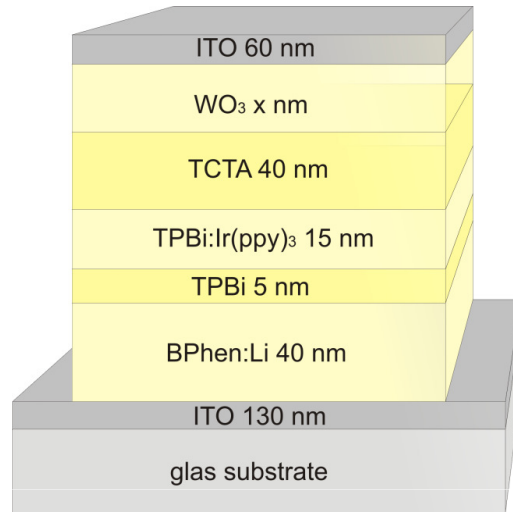
C-C (3.73 eV), C=C (6.21 eV)

Typische Schädigungsprodukte: Ladungsträgerfallen  
nichtstrahlende Spezies

**aber:**

- Transparente Oxide beinhalten Sauerstoff
- Sputterdeposition, gepulste Laserdeposition
- Teilchenenergien  $\sim 1\text{-}100\text{ eV}$  ?
- UV Strahlung





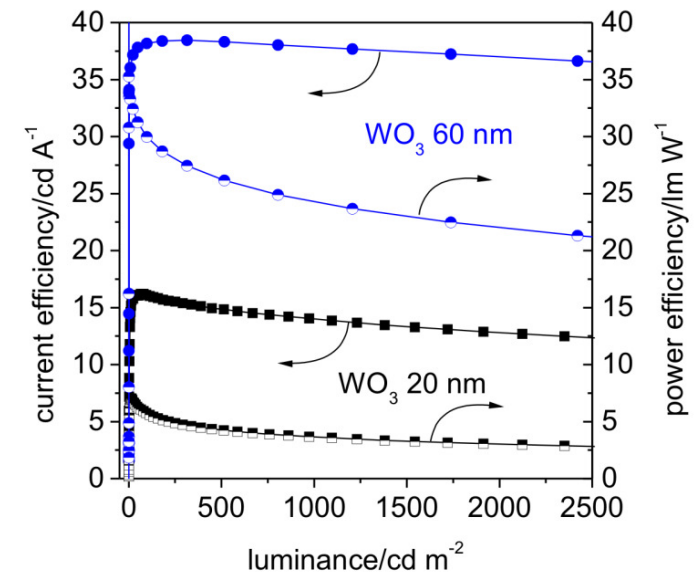
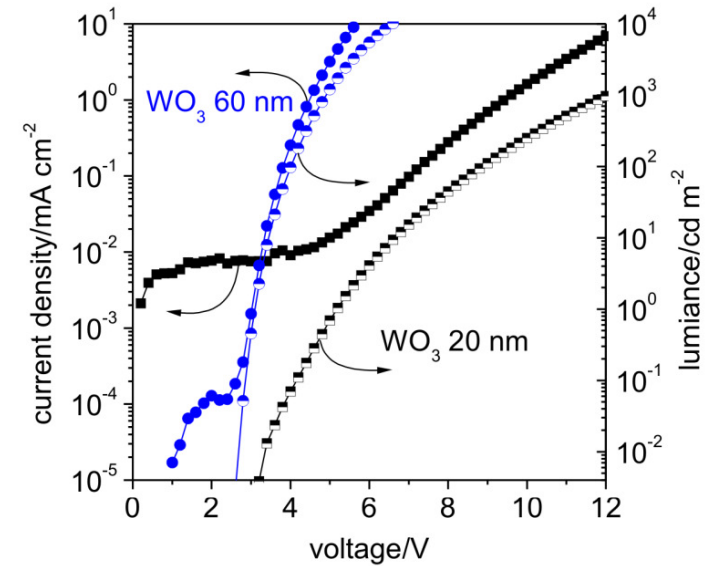
→ großes  $Z$  von Wolfram (Wirkungsquerschnitt!)

→ thermisches Aufdampfen von WO<sub>3</sub>

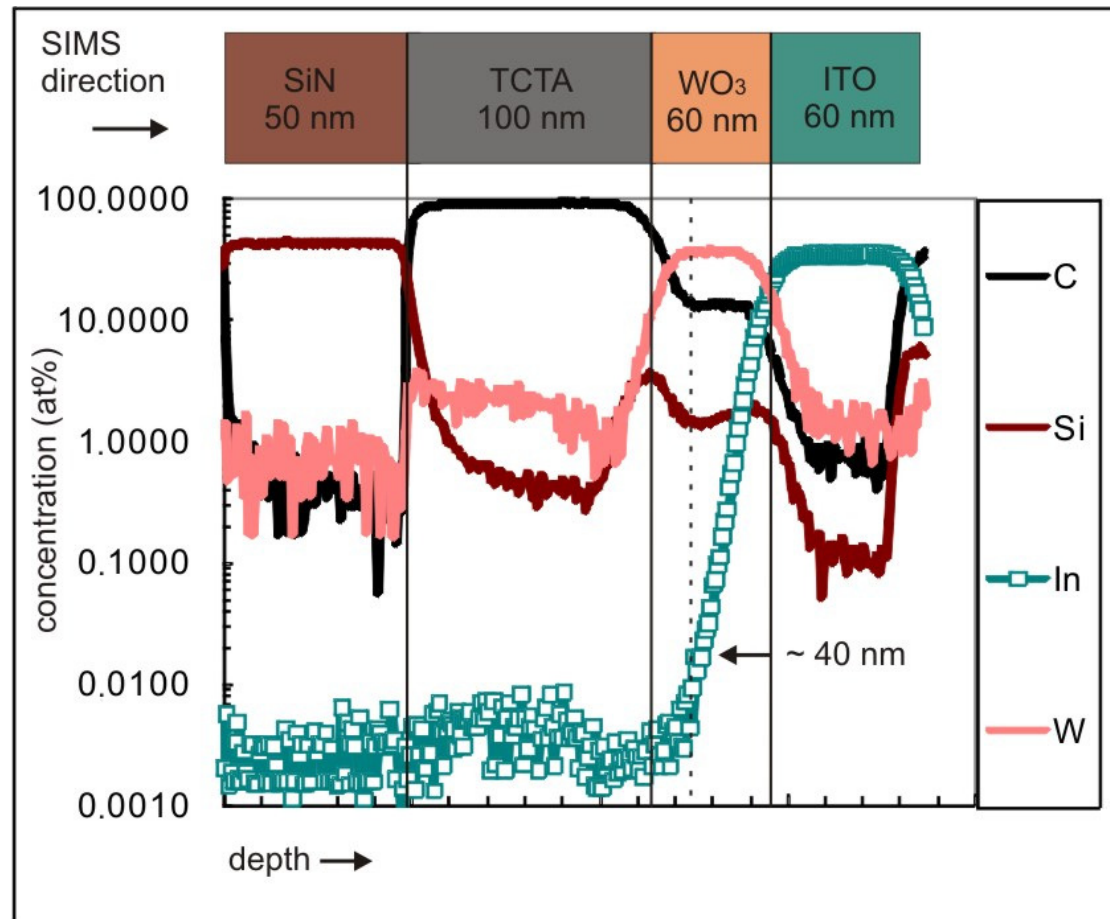
→ WO<sub>3</sub> transparent, ausreichend leitfähig

→ Rekord-Effizienz: **30 lm/W, 38 cd/A**

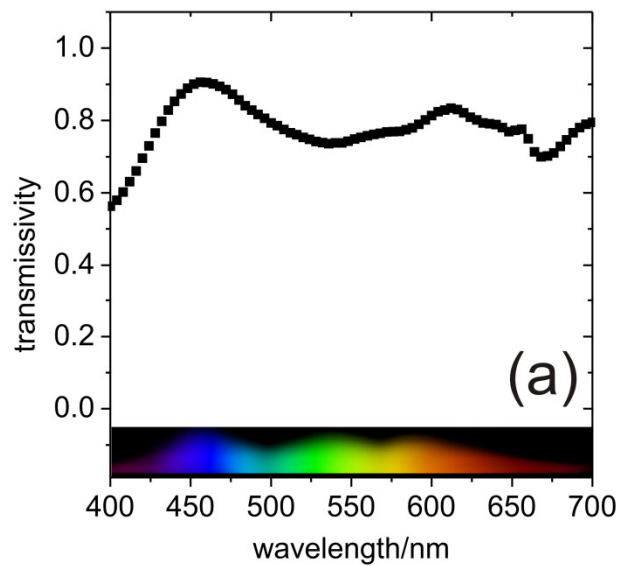
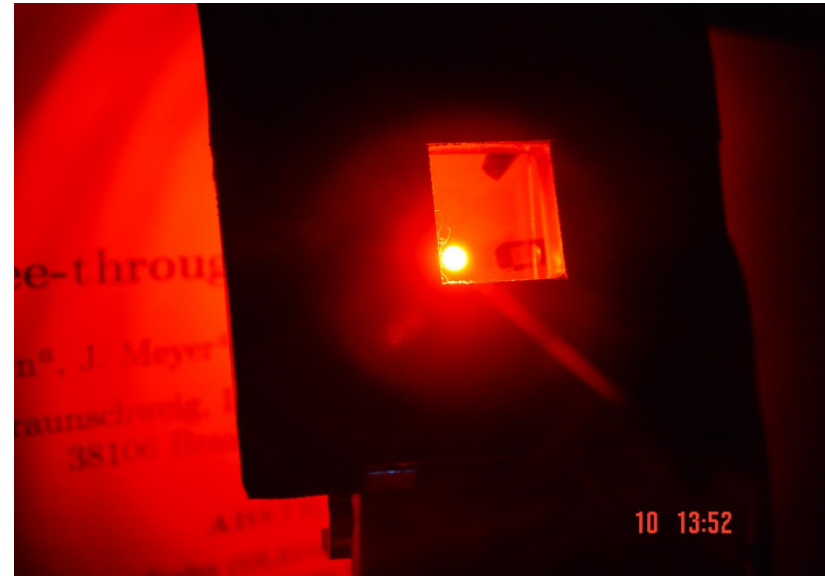
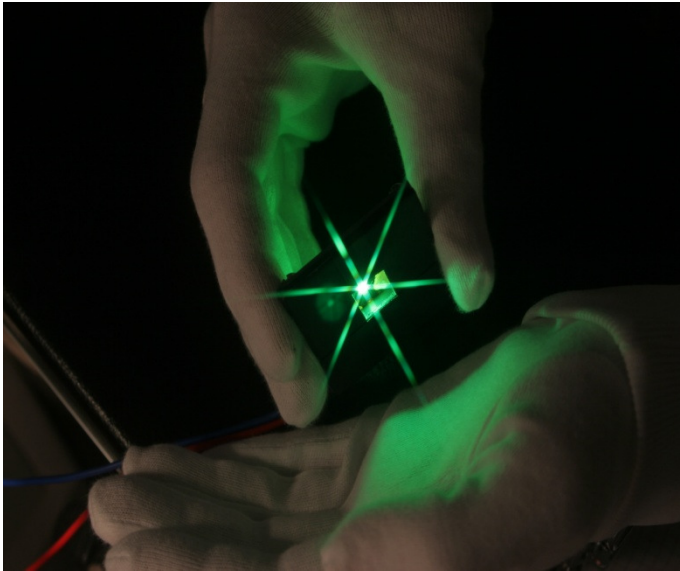
*Adv. Mater.* 20, 3839 (2008)

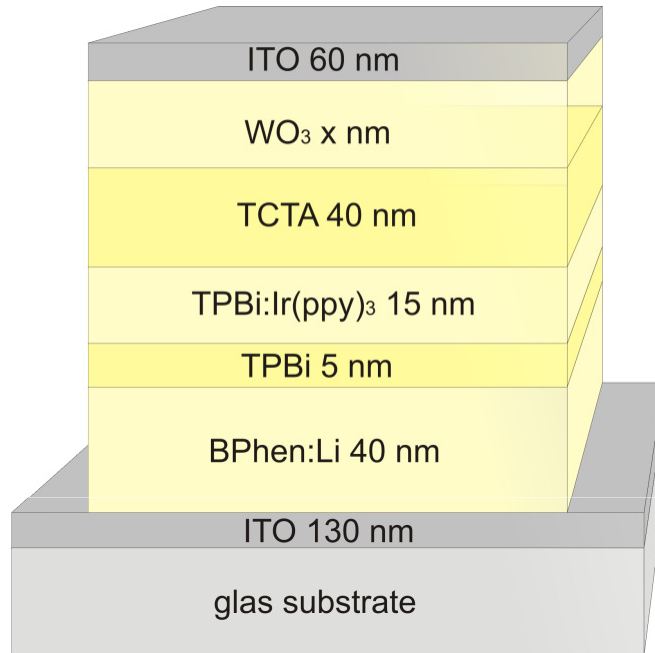


Analyse der Partikelpenetration → Sekundär-Ionen Massenspektroskopie



Sputterpartikel dringen ca. 40 nm tief in WO<sub>3</sub> ein → Schutz für Organik





*indium (metric tons)*

		2005	2006	2007	2008	2009
sources	Virgin	429	497	476	518	551
	Reclaim	357	503	650	802	961
uses	FPD	595	774	928	1114	1281
	Other	181	188	210	245	274
annual net*		10	38	-12	-39	-43
cumulative**		23	61	49	10	-33

\* annual net = sources and uses balance for that year  
\*\*cumulative = annual net plus prior year-end balance

13

source(s): Roskill Letter of Japan, press releases, Indium Corporation and partners



- Indium ist selten und teuer
- Ressourcen für noch ca. 20 Jahre  
(US geological survey 2006)

ZnO ist billig und verfügbar !

- ZnO:Al<sub>2</sub>O<sub>3</sub> (4 wt%)
- Pulsed Laser Deposition (KrF Excimer laser)
- Sputtern

„unser“ AZO auf Glas:

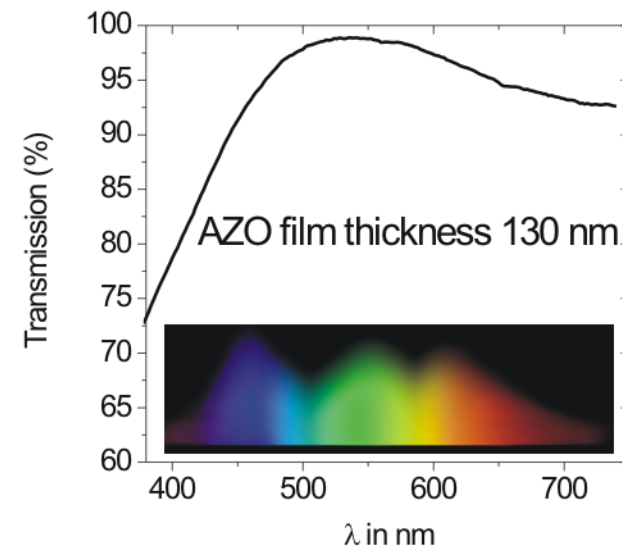
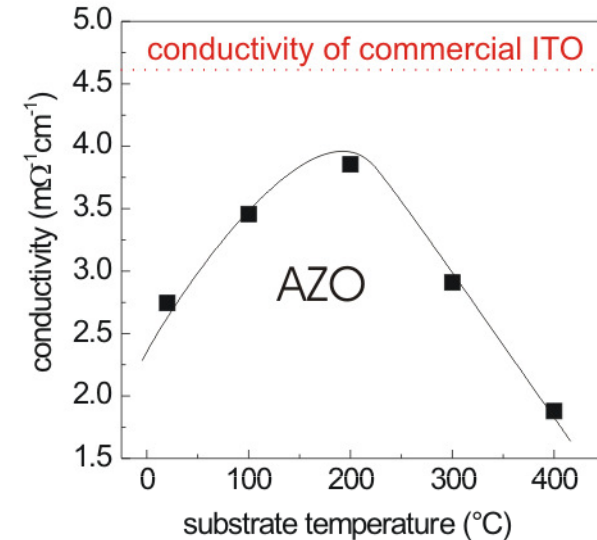
→ optimale Leitfähigkeit: 4000 S/cm  
(Hall:  $n = 6 \times 10^{20} \text{ cm}^{-3}$ ,  $\mu_n = 42 \text{ cm}^2/\text{Vs}$ )

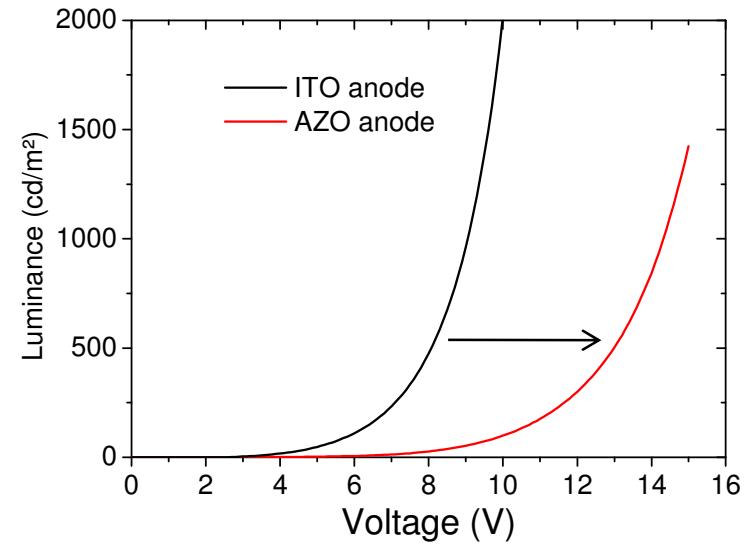
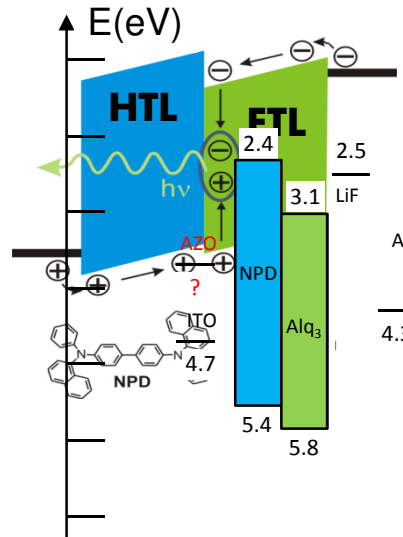
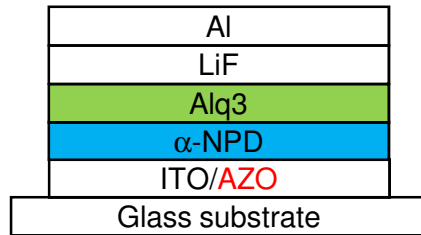
vergl. ITO (MERCK) 4700 S/cm

→ hohe Transparenz im sichtbaren Bereich

@ 550 nm:  $\alpha = 200 \text{ cm}^{-1} \rightarrow T = 98 \% \text{ (1 } \mu\text{m Film)}$   
 $\rightarrow R_{\text{sheet}} = 4 \Omega/\text{sq.}$

*Appl. Phys. Lett.* **91**, 041113 (2007)





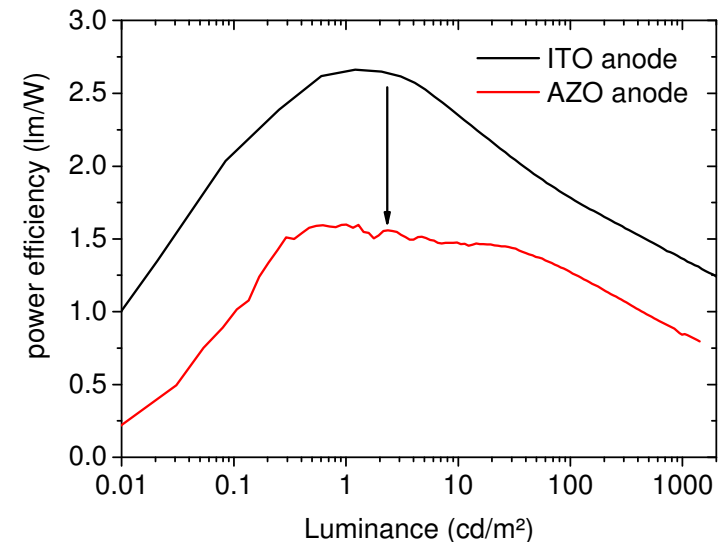
simple OLED Struktur

1:1 Austausch von ITO durch **AZO** als Anode

→ deutlich höhere Betriebsspannungen

→ drastisch reduzierte Effizienz

→ **Problem: Effiziente Injektion von Löchern !**



Ursache der limitierten Lochinjektion bei OLEDs mit AZO Anode:

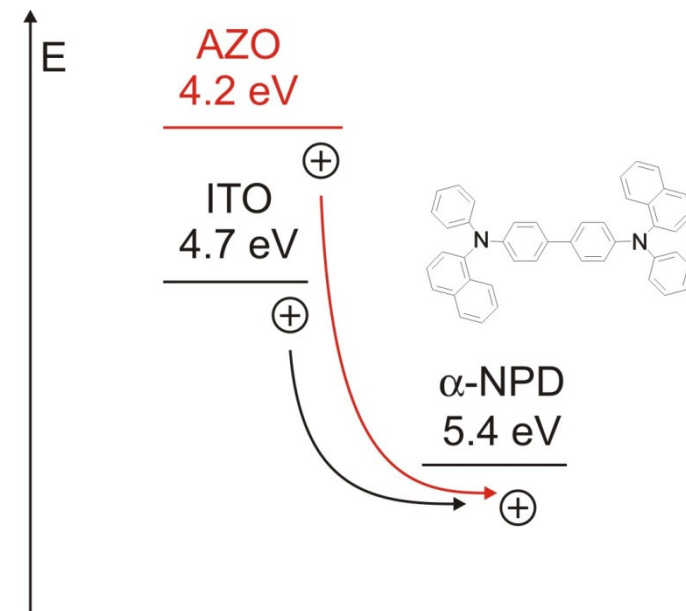
$$\Phi_{AZO} = 4.2 \text{ eV} < \Phi_{ITO} = 4.7 \text{ eV}$$

⇒ höhere Injektionsbarriere für Löcher

$$E_f(\text{AZO}) \rightarrow E_{\text{HOMO}}(\alpha\text{-NPD})$$

⇒ höhere Betriebsspannung

⇒ geringerer Luminanzwirkungsgrad





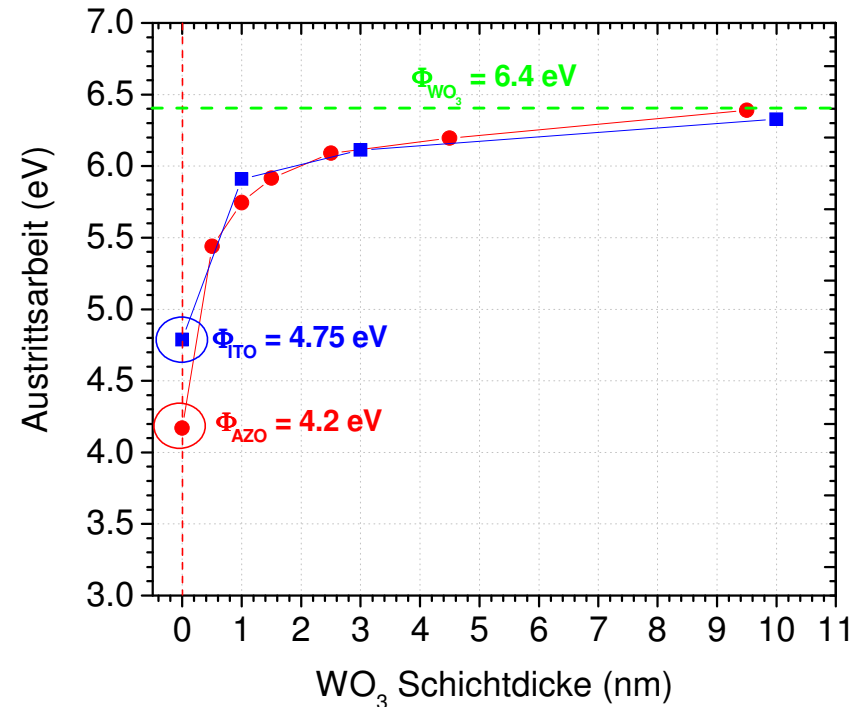
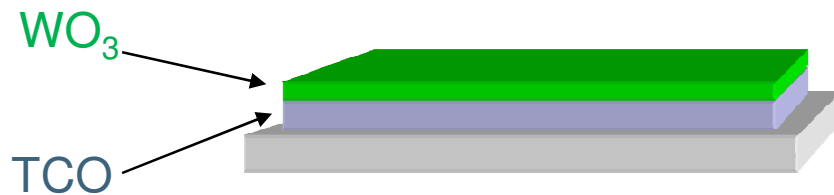
Metalloxide mit großer Austrittsarbeit

z.B. Wolframoxid WO<sub>3</sub> ( $\Phi_{\text{WO}_3} = 6.4\text{eV}$ )

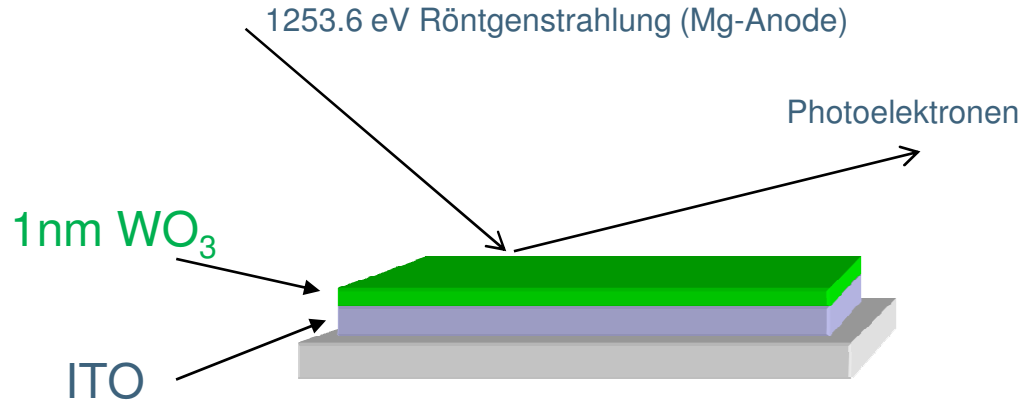
Leitfähigkeit sehr gering (Hopping W<sup>5+</sup> → W<sup>6+</sup>)

→ kein Ersatz für ITO/AZO als Elektrode

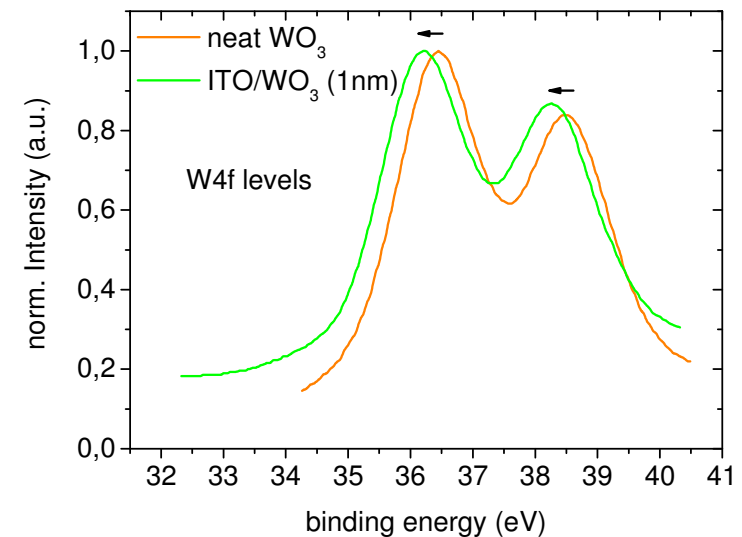
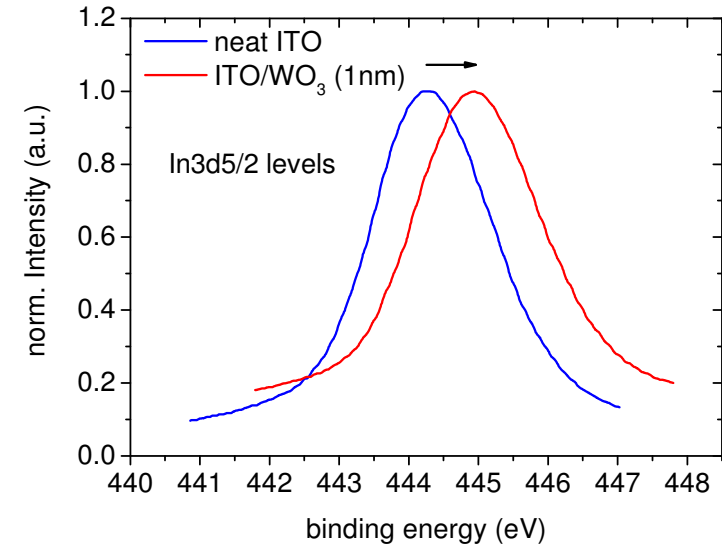
→ Verwendung als dünne Zwischenschicht

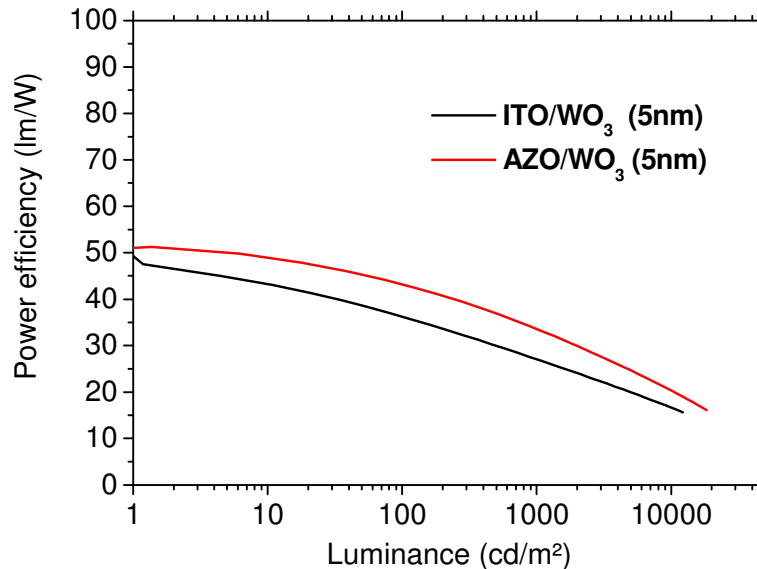
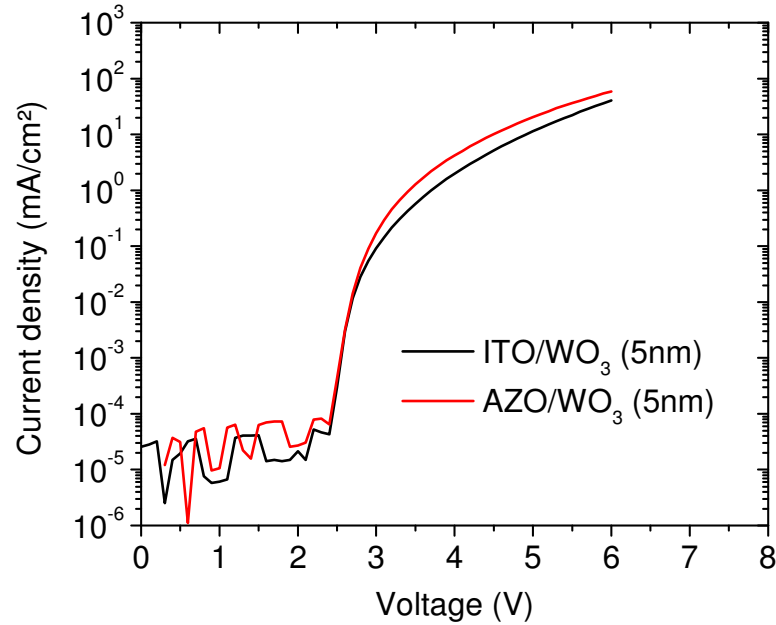


⇒ sukzessive Verschiebung der Austrittsarbeit durch dünne WO<sub>3</sub> Schicht  
 ⇒ was passiert an der TCO/WO<sub>3</sub> Grenzfläche ?

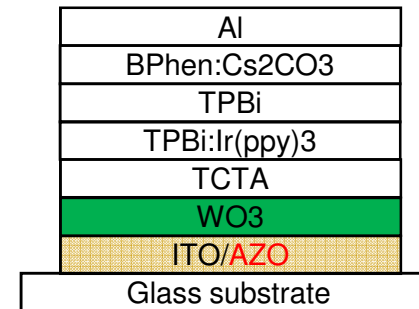


- Erhöhung der Bindungsenergie  $\text{In}3d_{5/2}$
- Verringerung der Bindungsenergie  $\text{W}4f$
- ⇒ Transfer von Elektronen  $\text{ITO} \rightarrow \text{WO}_3$
- ⇒ Ausbildung eines Grenzflächendipols
- ⇒ Absenkung der Energiebarriere ITO/Organik





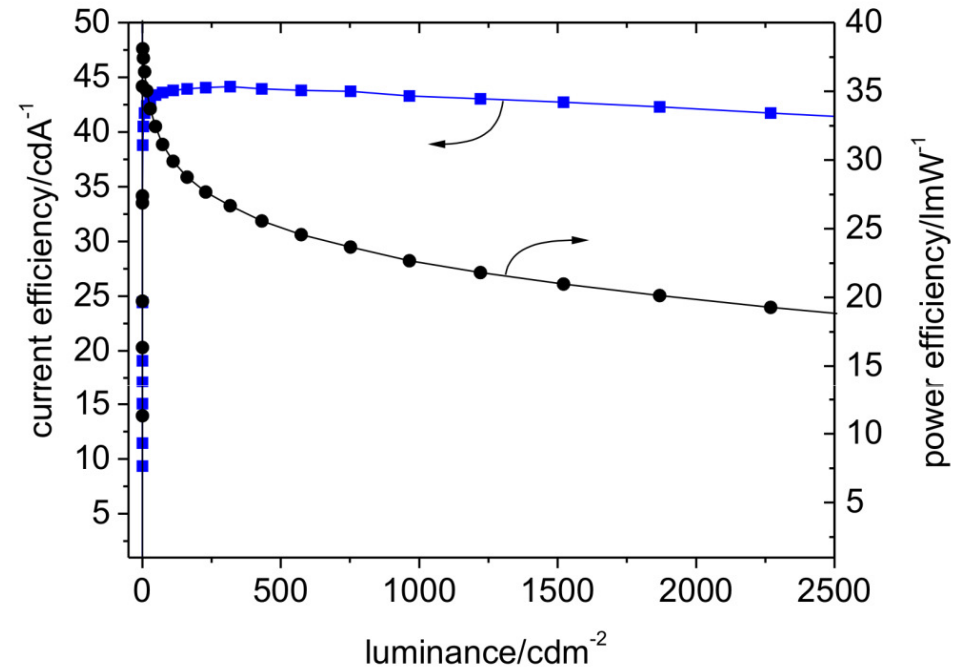
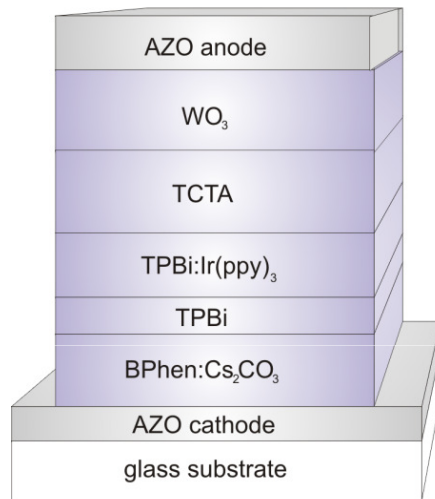
1:1 Austausch von ITO durch **AZO** als Anode



mit WO<sub>3</sub> Interlayer:

→ OLED-Effizienz unabhängig vom TCO

→ hohe Effizienzen (40 lm/W @ 100 cd/m<sup>2</sup>)  
auch für **AZO** Anoden !



→ Effizienz: 43  $\text{cd/A}$ , 30  $\text{lm/W}$  at 100  $\text{cd/m}^2$

→ vergleichbar zu transparenten OLEDs mit ITO Elektroden

→ Transparenz > 80 % im Sichtbaren

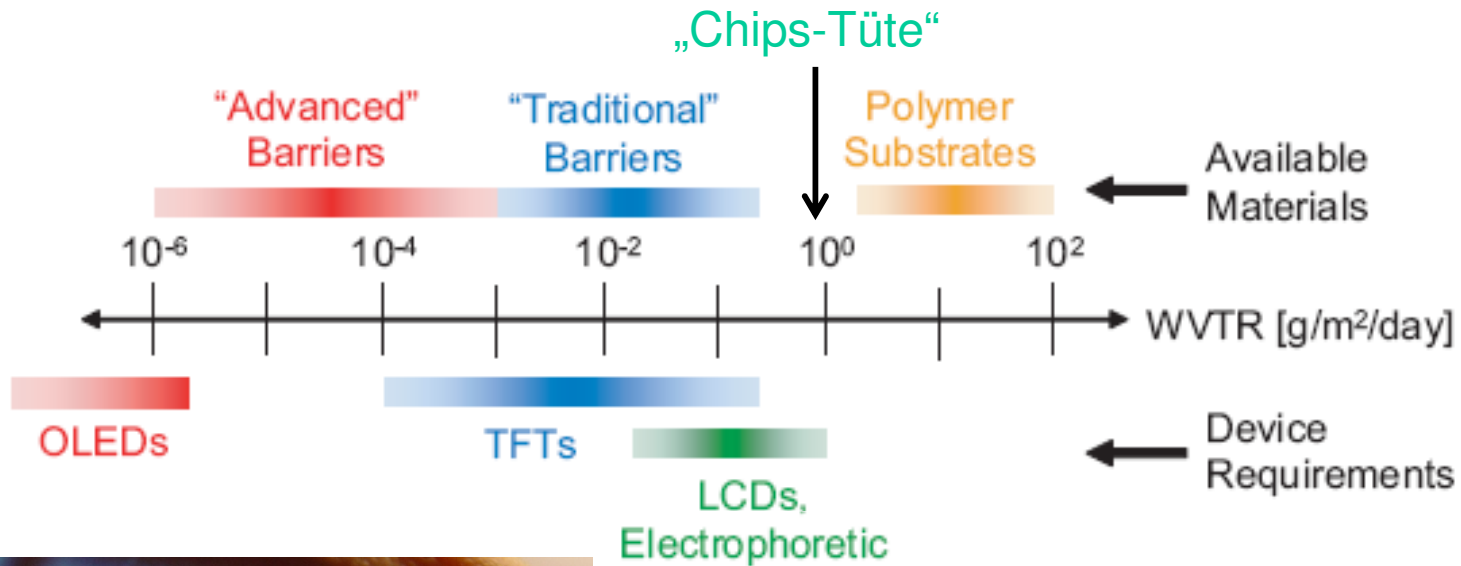
*Appl. Phys. Lett.* 93, 073308 (2008)



- transparente Elektroden für transparente OLEDs
- transparente Barrierschichten für organische Bauelemente
- transparente Dünnschichttransistoren für AMOLED



# Dünnschichtverkapselung für transparente OLEDs



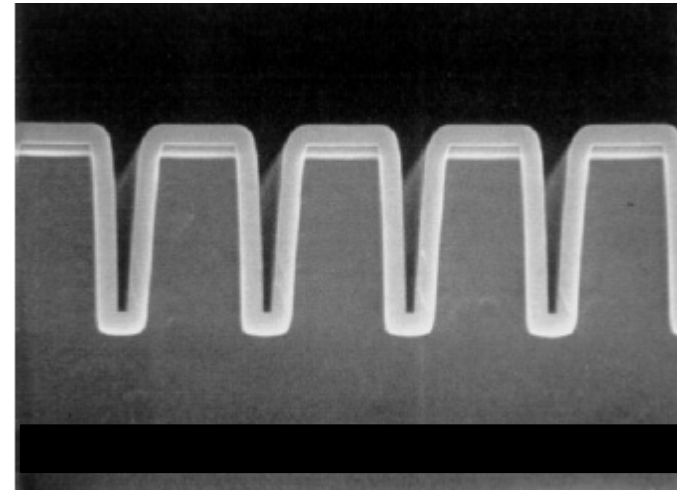
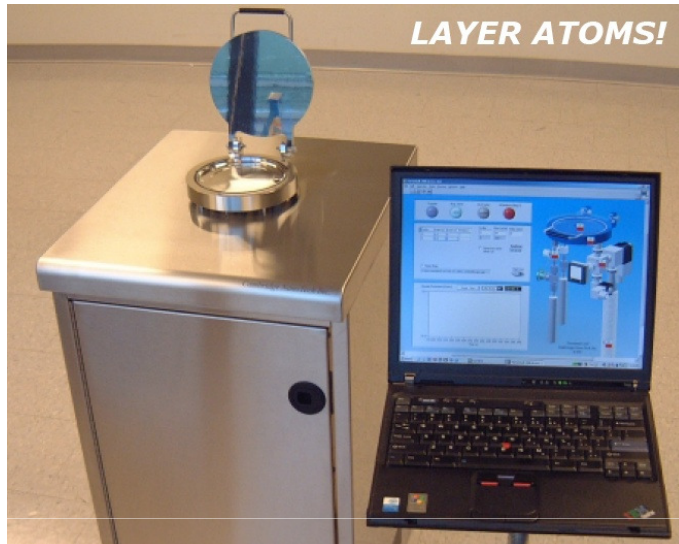
konventionelle Glasdeckel-Verkapselung:

→ nicht flexibel

→ teuer

→ problematisch für transparente OLEDs

⇒ **effiziente Dünnschichtverkapselung nötig**

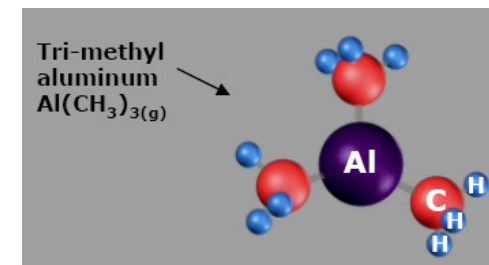


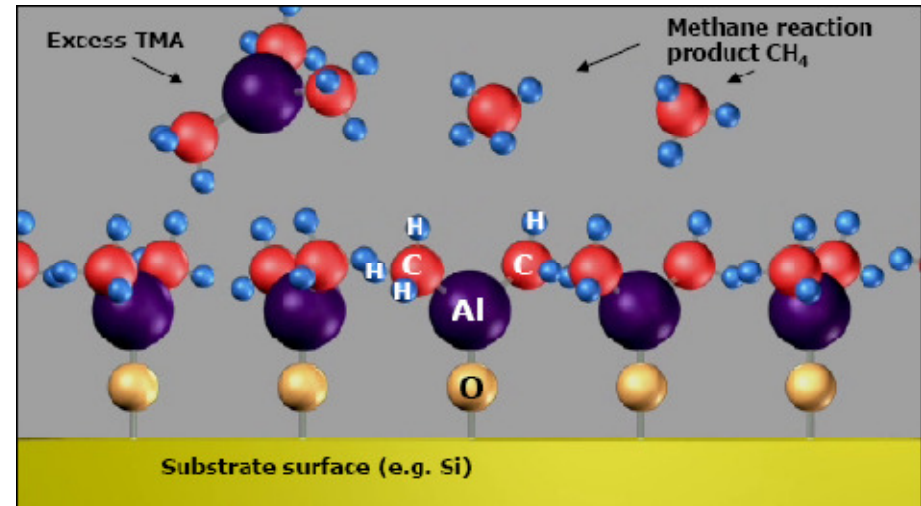
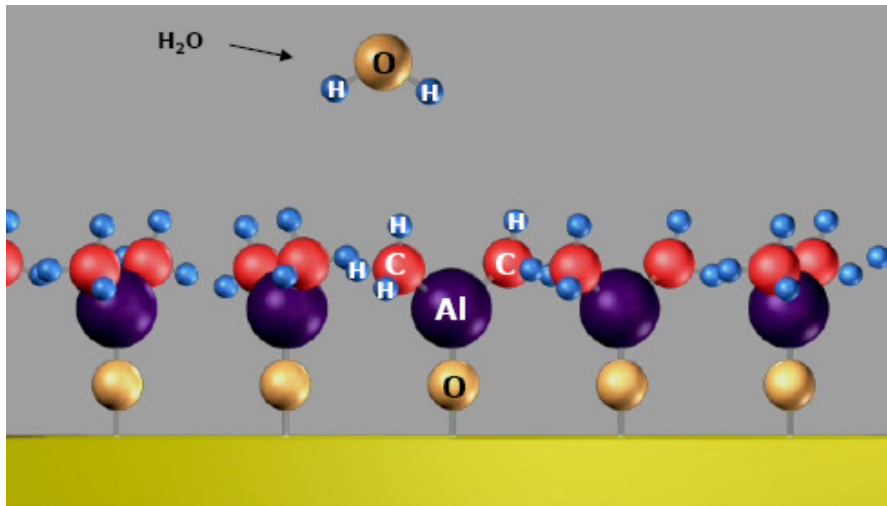
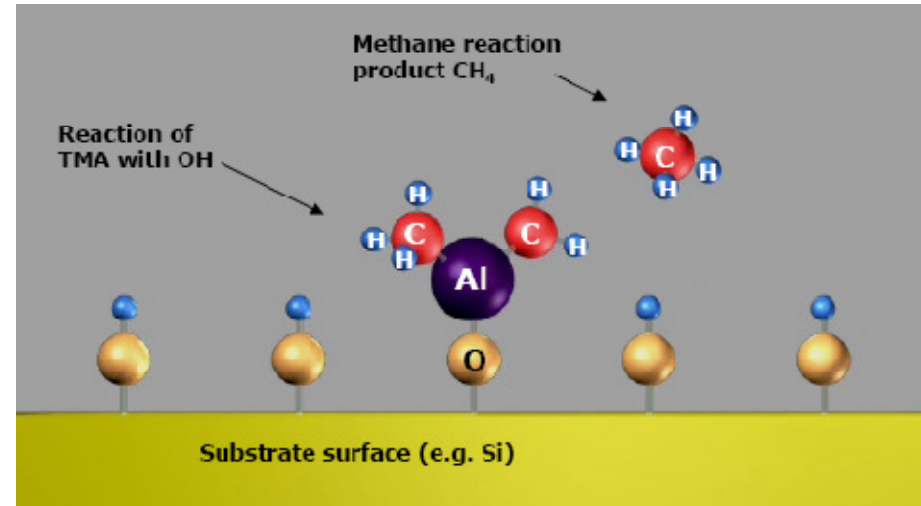
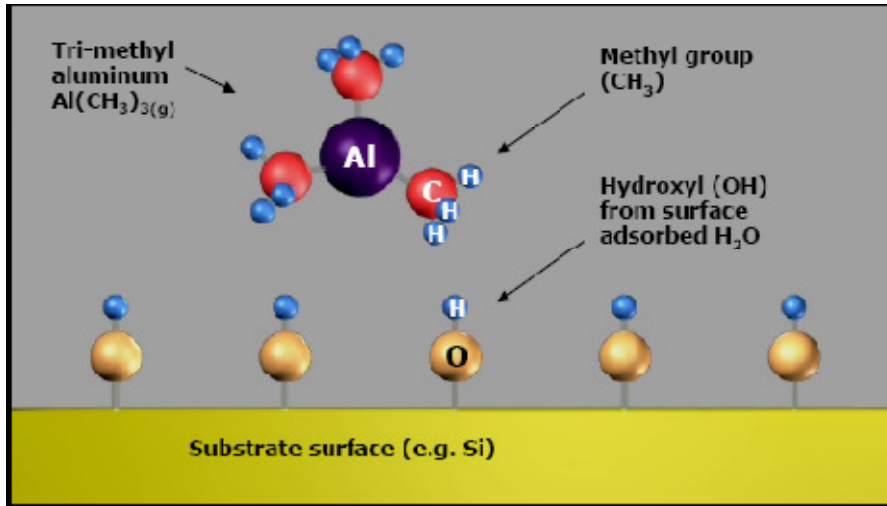
CVD Verfahren für extrem dichte und konforme dielektrische Schichten

Hochreaktive metallorganische Precursormoleküle  
z.B. für  $\text{Al}_2\text{O}_3$  Trimethylaluminium (TMA) mit  $\text{H}_2\text{O}$

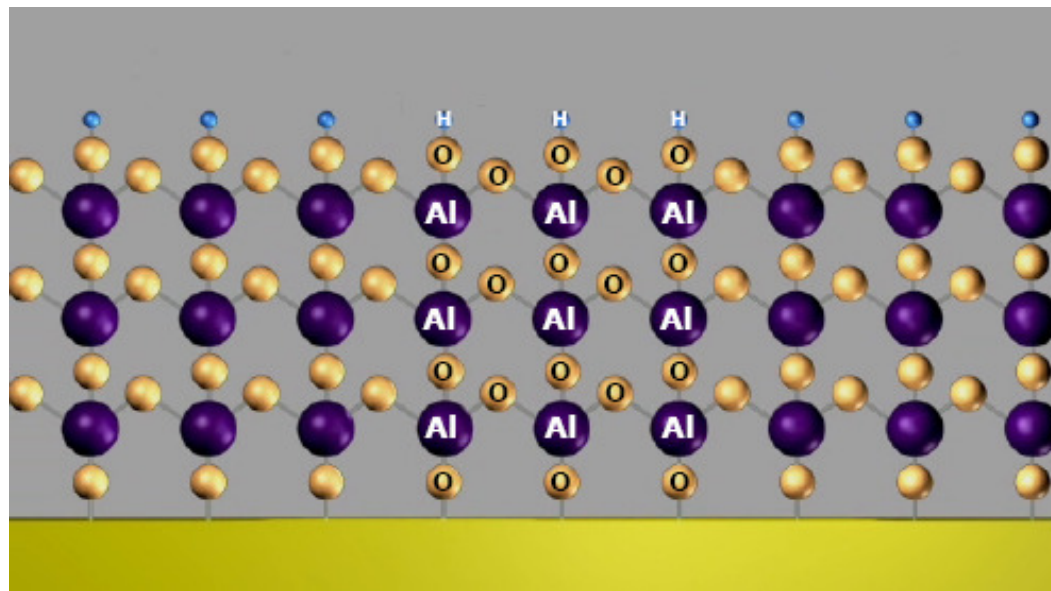
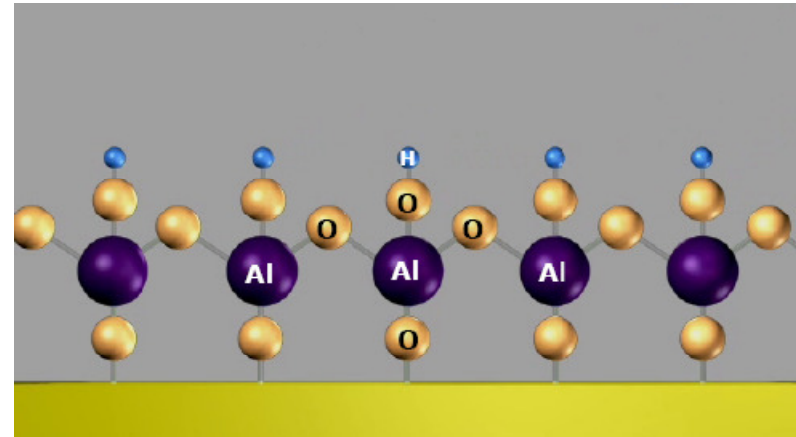
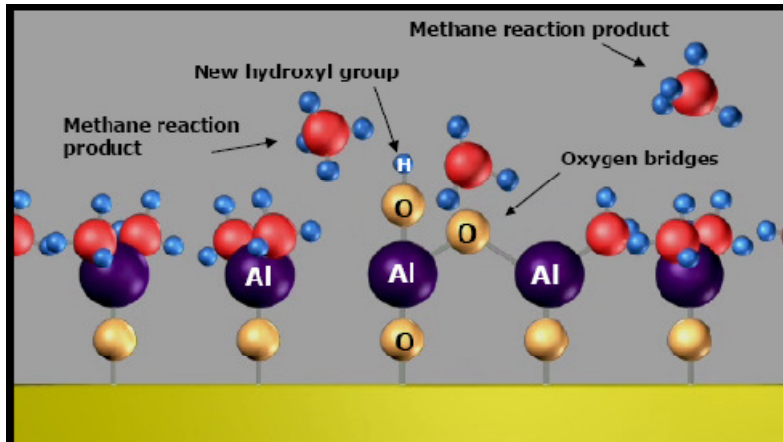
→ niedrige Prozesstemperaturen ( $< 100^\circ\text{C}$ )

→ aussichtsreiche Barrierschichten für organische Bauelemente



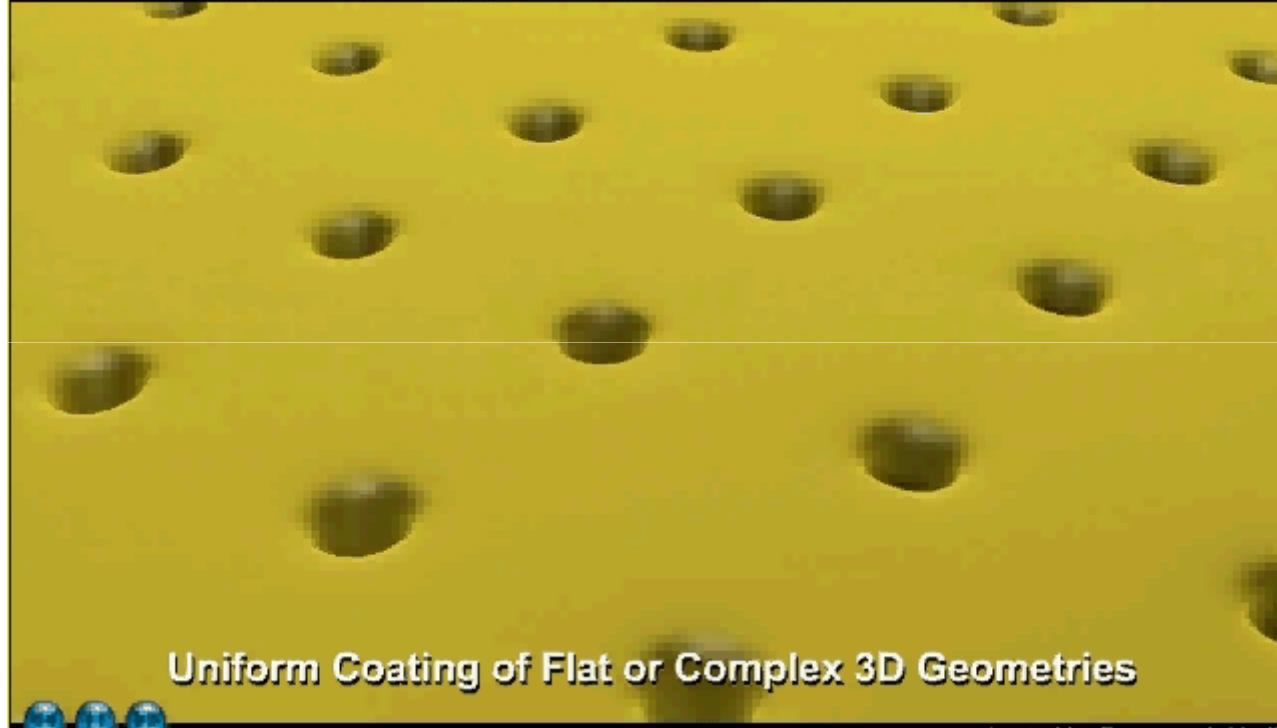








**Cambridge NanoTech: Atomic Layer Deposition Systems**



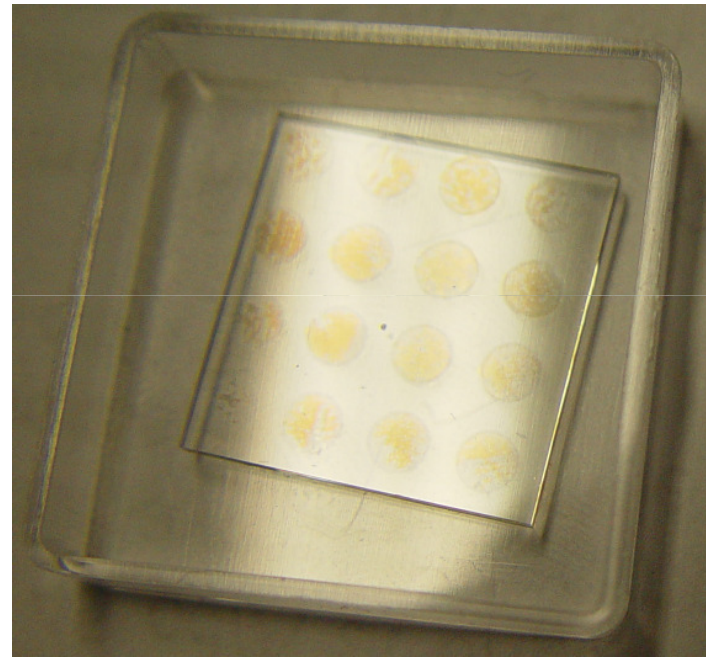
## Array aus Ca Pads

OLED Grenzwerte:

Permeationsraten für Wasser  
und Sauerstoff:

$$P_{H_2O}: 10^{-6} \frac{g}{m^2 day}$$

$$P_{O_2}: 10^{-3} \frac{cm^3}{m^2 day}$$



ohne Verkapselung → 100 nm Calcium komplett oxidiert (90 s in Luft)

Erwartung: Mit Verkapselung (WVTR=1x10<sup>-6</sup> g/m<sup>2</sup> d) → 700 Tage

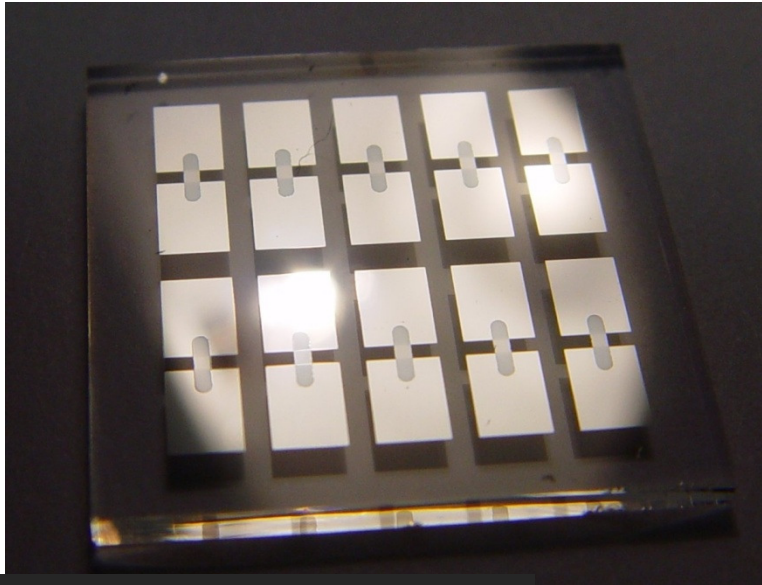


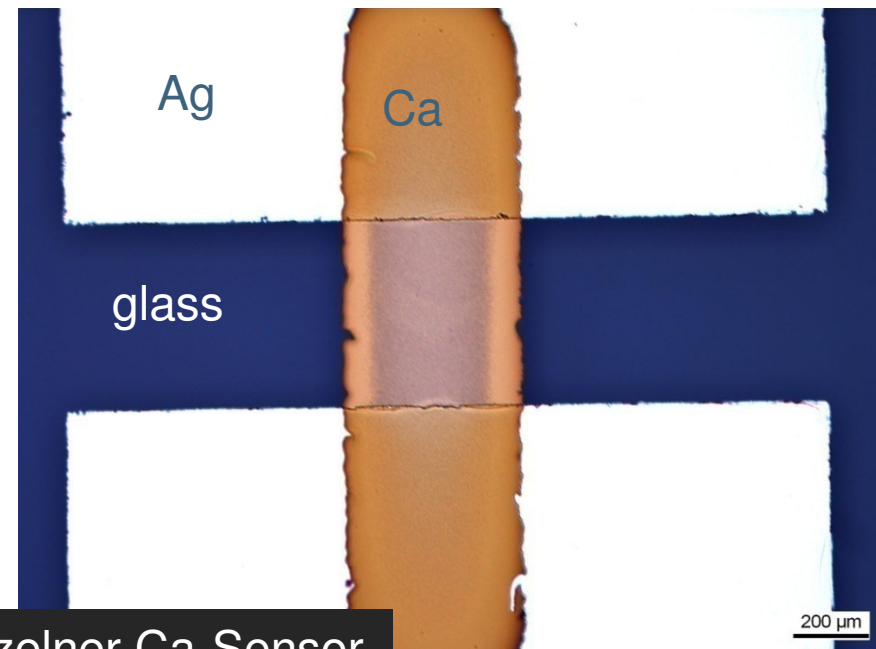
Foto des Sensorarrays

- lithographisch strukturierte Ag Elektroden
- strukturierte Ca Pads (Schattenmasken)
- Messgröße: Widerstandsänderung

Abmessung des Ca-Sensors:

Fläche : 0.5 mm x 0.5 mm

Dicke: 150 nm



Einzelner Ca-Sensor

## OLED Grenzwerte:

Permeationsraten für Wasser  
und Sauerstoff:

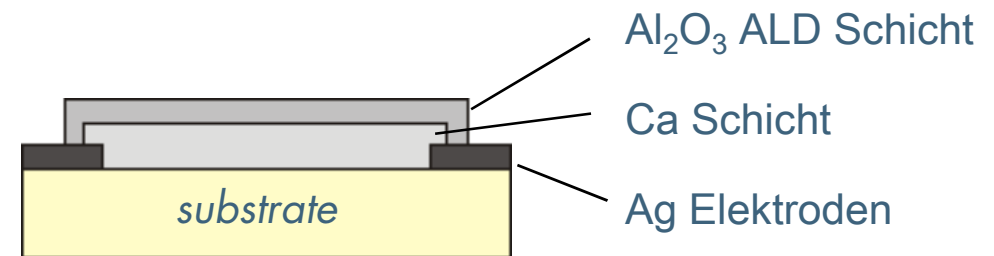
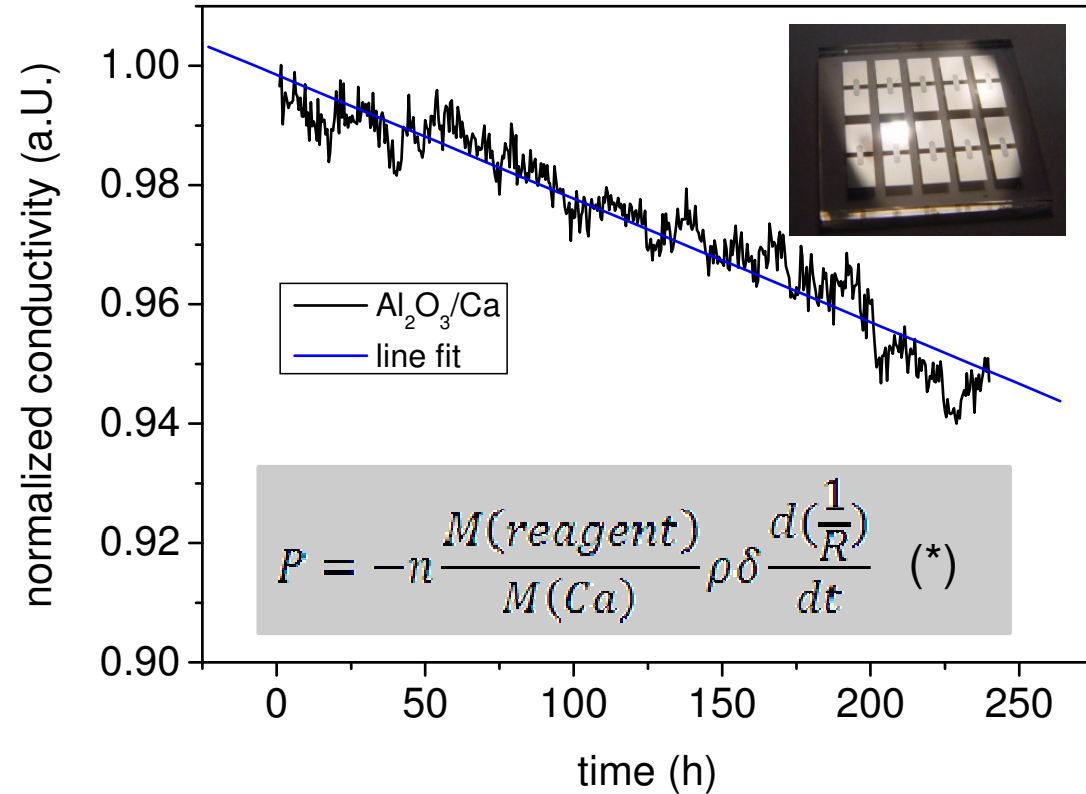
$$P_{H_2O}: 10^{-6} \frac{g}{m^2 day}$$

$$P_{O_2}: 10^{-3} \frac{cm^3}{m^2 day}$$

gemessene Werte für  $Al_2O_3$   
(100 nm, ALD: 80 °C, RT)

$$P_{H_2O}: 6.54 \times 10^{-6} \frac{g}{m^2 day}$$

$$P_{O_2}: 1.07 \times 10^{-3} \frac{cm^3}{m^2 day}$$



(\*) Rev. Sci. Instrum., Vol. 74, No. 12, 2003

Adv. Mater. 21, 1845 (2009)



Dielectric properties  $\epsilon_r$ :

$\epsilon_r = 9$  @ 250 °C (1 Å / cycle)

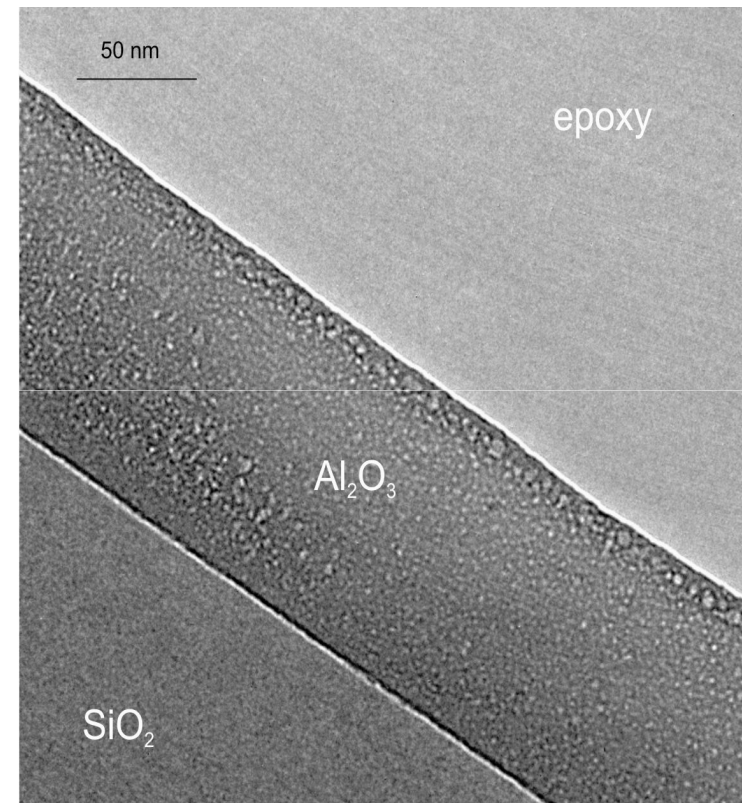
$\epsilon_r = 7.9$  @ 80 °C (1.3 Å / cycle)

Low-temp. growth:

- no sign of crystallization
- less dense structure at low temperatures
- increased formation of residual AlOH species

*Surf. Sci.* **322**, 230-242 (1995)

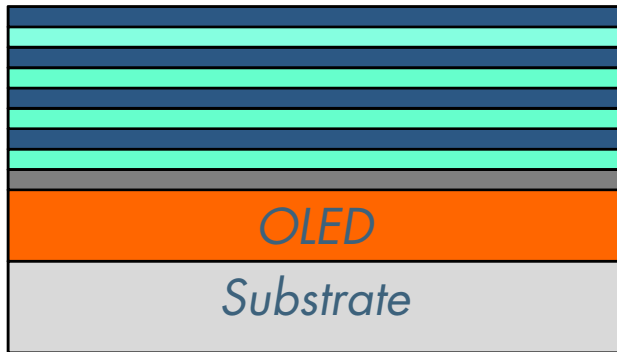
TEM cross section  $\text{Al}_2\text{O}_3$  (80 °C)



*Adv. Mater.* **21**, 1845 (2009)



Next-generation thin-film encapsulation → Nano-laminates

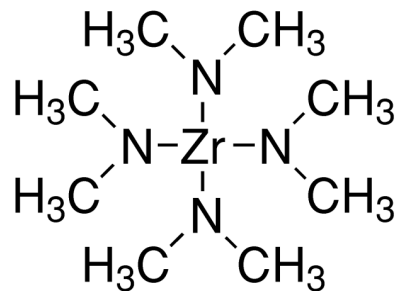


cyclic deposition of  $\text{Al}_2\text{O}_3$  and  $\text{ZrO}_2$

20 cycles  $\text{Al}_2\text{O}_3$  (2 nm)

20 cycles  $\text{ZrO}_2$  (3.8 nm)

Precursor for  $\text{ZrO}_2$  preparation



Tetrakis(dimethylamido)zirconium(IV)

TDMA(Zr) heated to 75 °C

Aim:

→ increased film density

→ forced amorphicity

→ avoid permeation channels



Test conditions (climate cabinet): 70 °C and 70 % RH

encapsulation	permeation rate for water (g/m <sup>2</sup> day)	permeation rate for oxygen (cm <sup>3</sup> /m <sup>2</sup> day)
Al <sub>2</sub> O <sub>3</sub> 100 nm @ 80 °C	3.4 x 10 <sup>-4</sup>	1.5 x 10 <sup>-1</sup>
Al <sub>2</sub> O <sub>3</sub> & ZrO <sub>2</sub> 100 nm @ 80 °C	6.6 x 10 <sup>-5</sup>	2.9 x 10 <sup>-2</sup>
Al <sub>2</sub> O <sub>3</sub> 130 nm @ 80 °C	8.8 x 10 <sup>-5</sup>	3.9 x 10 <sup>-2</sup>
Al <sub>2</sub> O <sub>3</sub> & ZrO <sub>2</sub> 130 nm @ 80 °C	4.7 x 10 <sup>-5</sup>	2.1 x 10 <sup>-2</sup>

with  $E_a = 92$  kJ/mol  $\rightarrow 5 \times 10^{-7}$  (at RT)

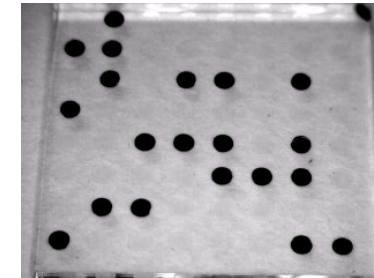
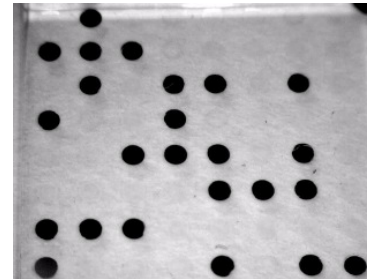
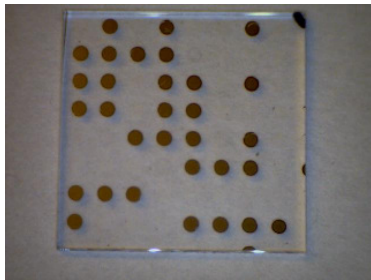
*Adv. Mater.* 21, 1845 (2009)



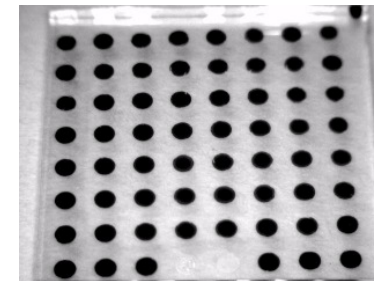
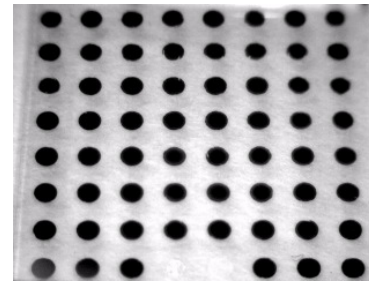
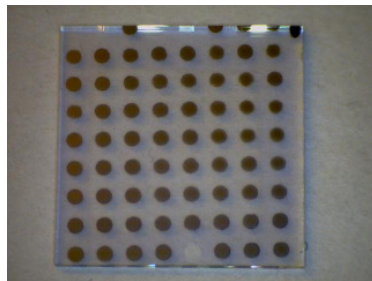


Large area encapsulation (70 °C, 70 % RH)

100 nm  $\text{Al}_2\text{O}_3$



100 nm  $\text{Al}_2\text{O}_3$  +  $\text{ZrO}_2$  Nanolaminate



20 h

60 h

160 h



TEM cross section of  $\text{ZrO}_2/\text{Al}_2\text{O}_3$  NL (80 °C)

→ No voids observable

→ No extended crystallites

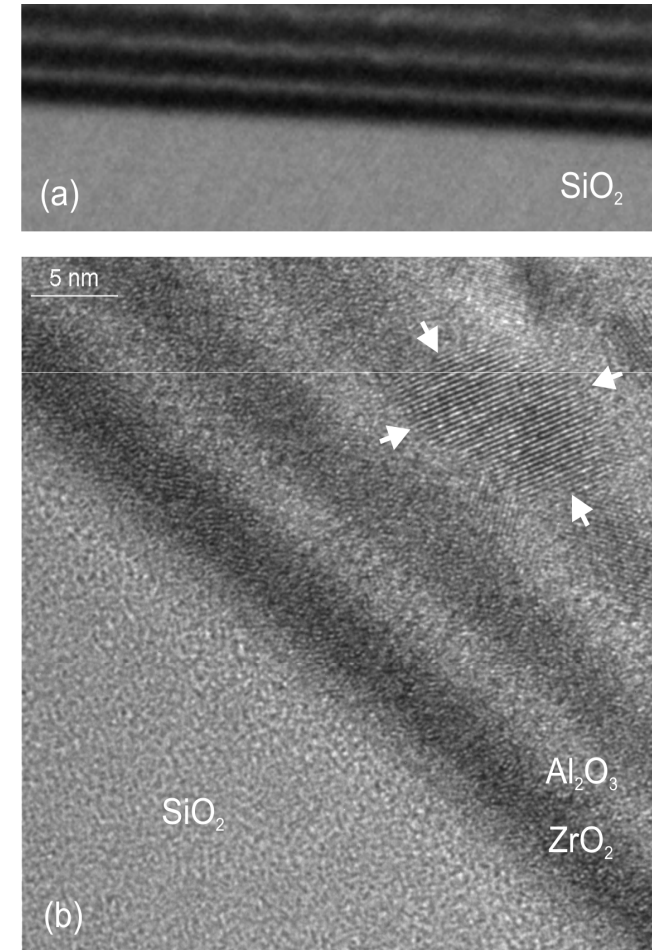
→ crystallites remain inside the sub-layers

$$\epsilon_r = 13.3 @ 80 \text{ °C}$$

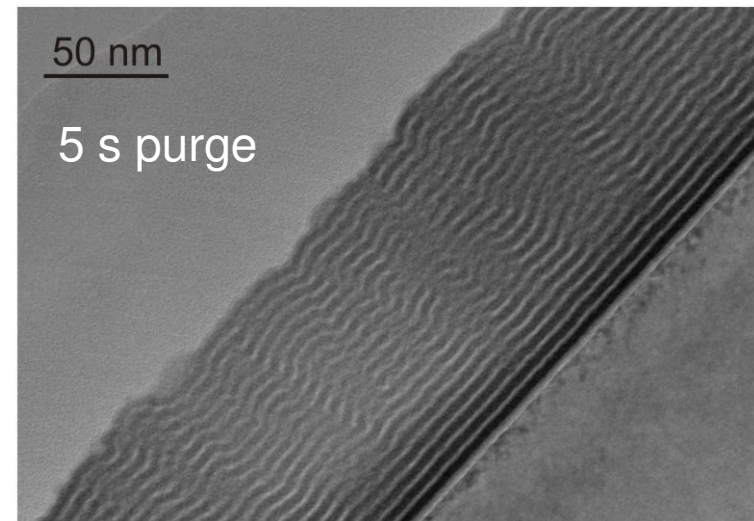
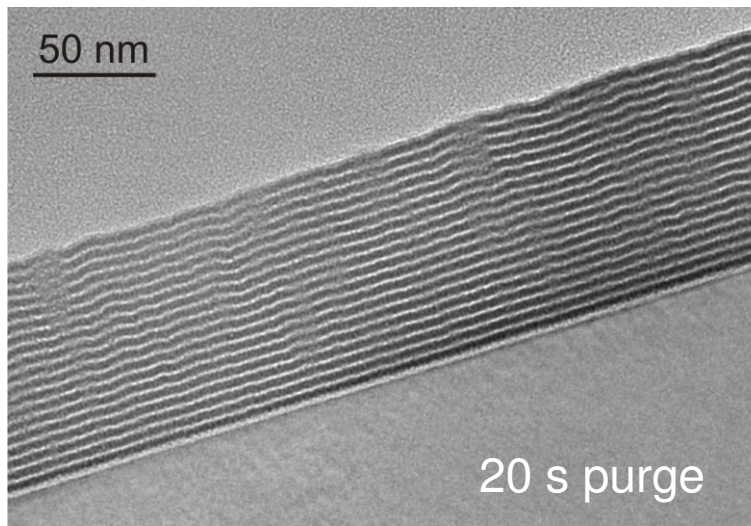
Preliminary result:

$$\epsilon_r (\text{Al}_2\text{O}_3 \text{ in NL}) > \epsilon_r (\text{neat Al}_2\text{O}_3 @ 80 \text{ °C})$$

$$\Rightarrow \text{density (Al}_2\text{O}_3 \text{ in NL)} > \text{density (neat Al}_2\text{O}_3 @ 80 \text{ °C)}$$



Variation of the purge time between precursor dosing (growth temperature: 80 °C)

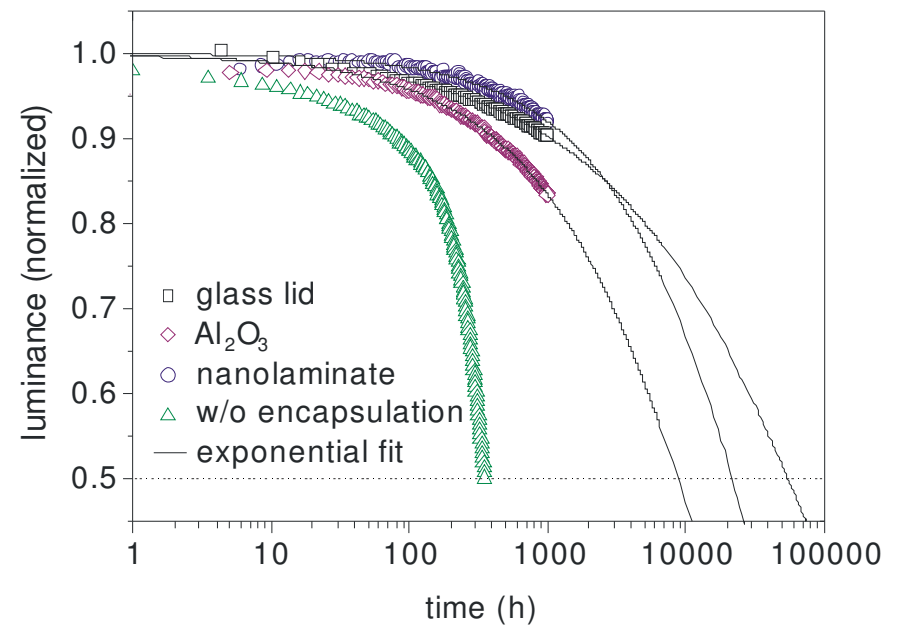
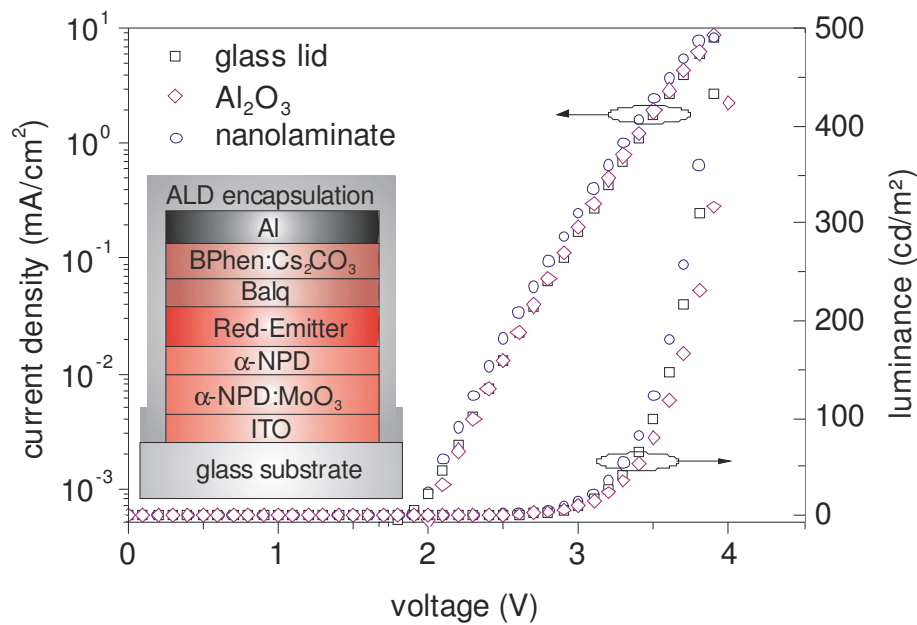


- growth starts smooth
- wavy features and onset of CVD-like growth for short purge times

*Appl. Phys. Lett.* 94, 233305 (2009)

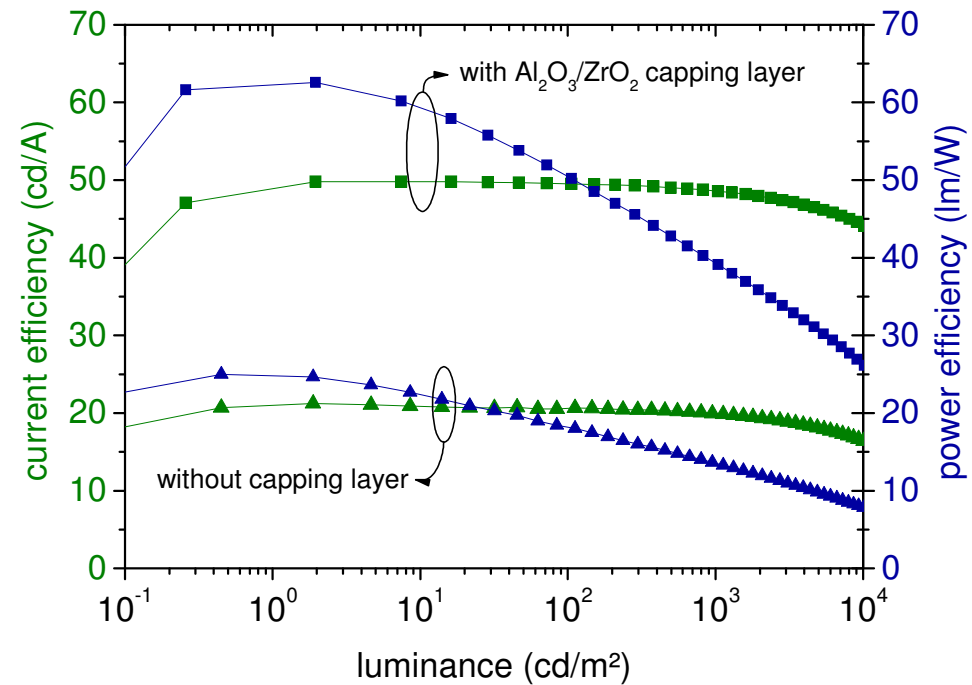
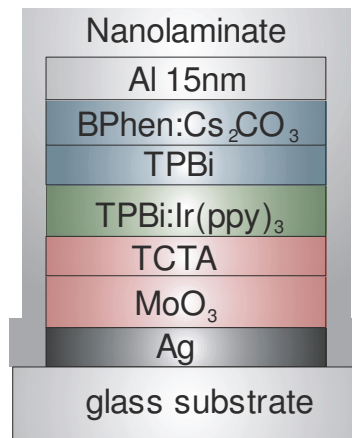


## encapsulation of bottom emitter



*Appl. Phys. Lett.* 94, 233305 (2009)

## encapsulation of top emitter

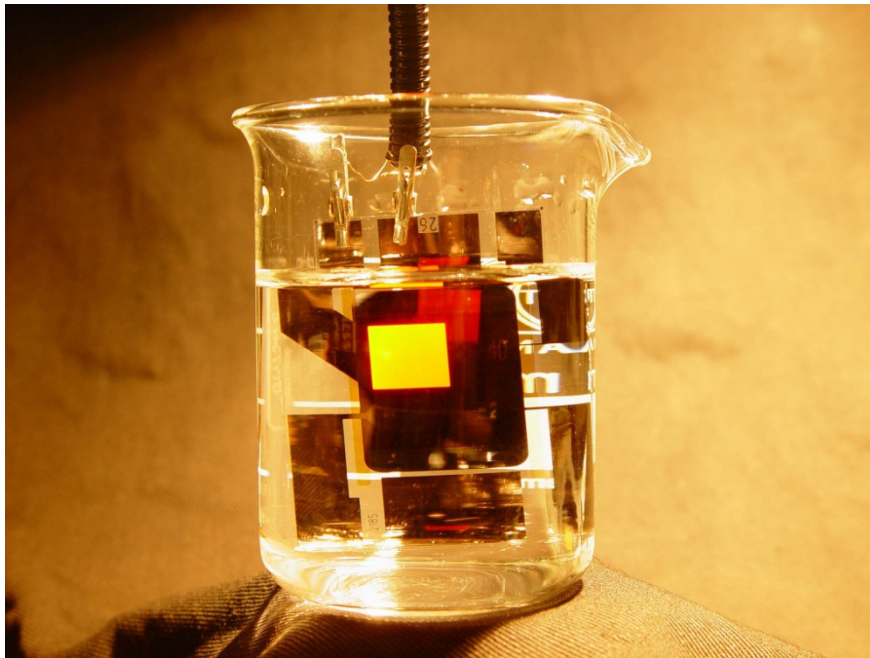


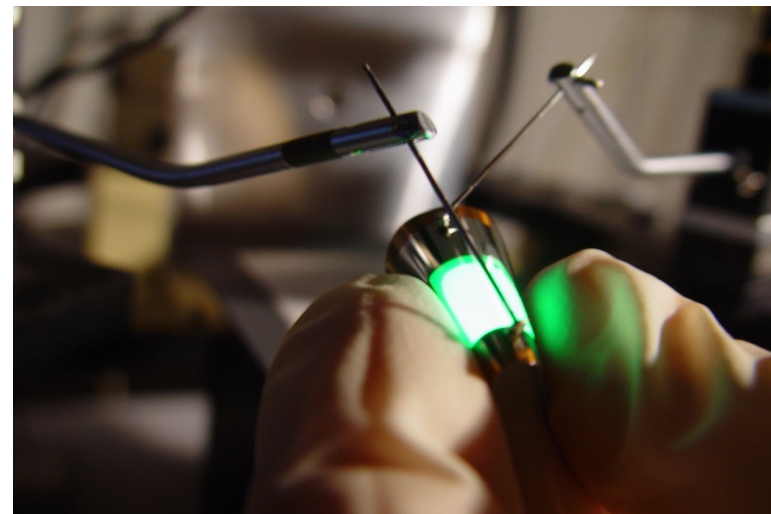
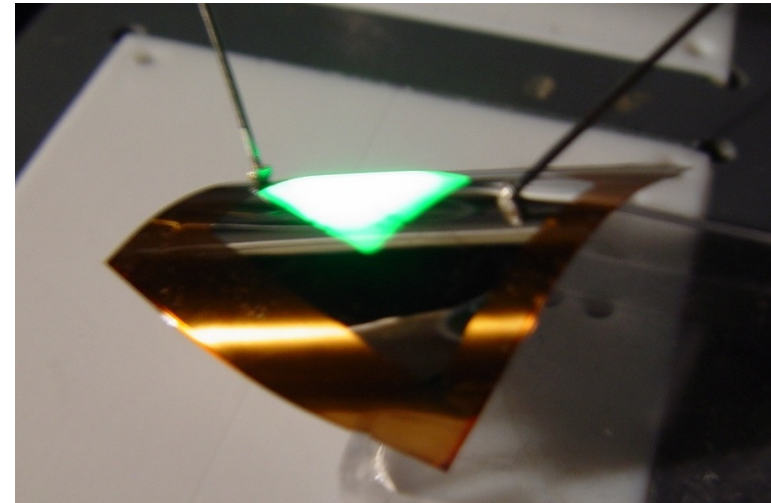
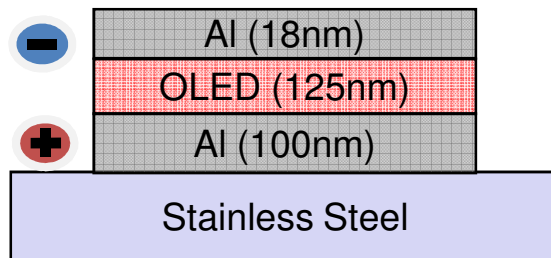
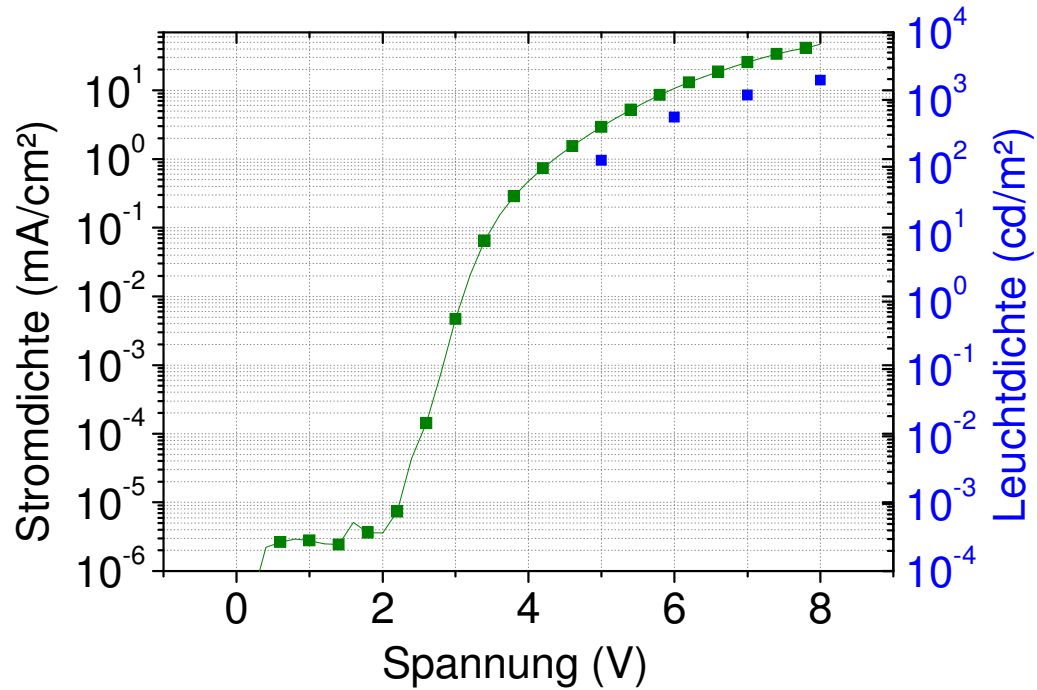
- gas diffusion barrier and capping layer simultaneously

⇒ enhancement of nearly 100 %



## Underwater OLED



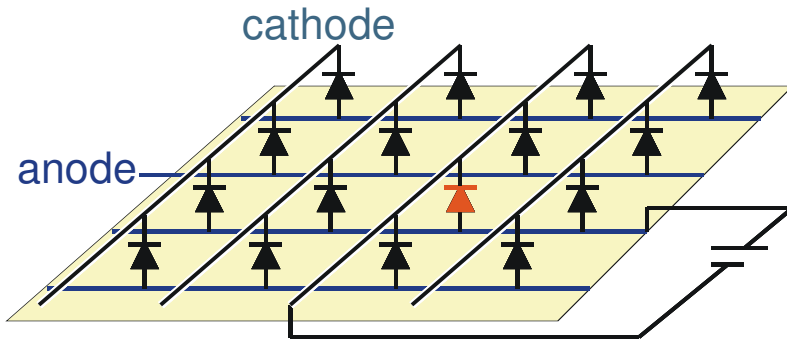


Thin film encapsulation of flex. OLEDs



- transparente Elektroden für transparente OLEDs
- transparente Barrierschichten für organische Bauelemente
- transparente Dünnschichttransistoren für AMOLED



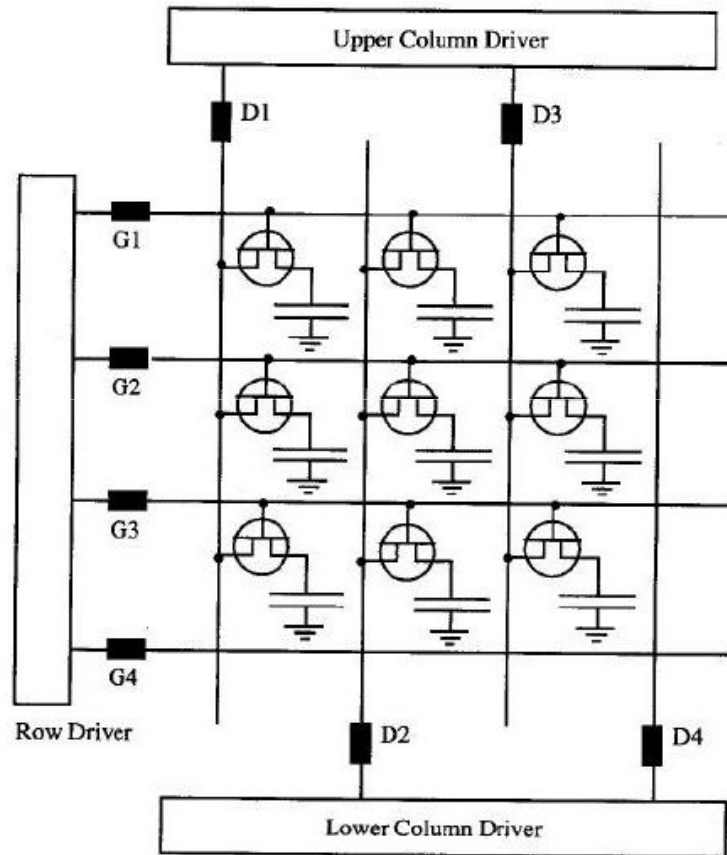


Passiv Matrix Display:

- zeilenweises Ansprechen der Pixel
- kleine Flächen/geringe Auflösung

- Pixelhelligkeit >> Displayhelligkeit
- z.B. VGA-Display (640 x 480 Pixel) 100 cd/m<sup>2</sup>
  - notwendige Pixelhelligkeit > 48.000 cd/m<sup>2</sup>
  - reduzierte Effizienz, reduzierte Lebensdauer

Lösung: Aktiv Matrix Ansteuerung



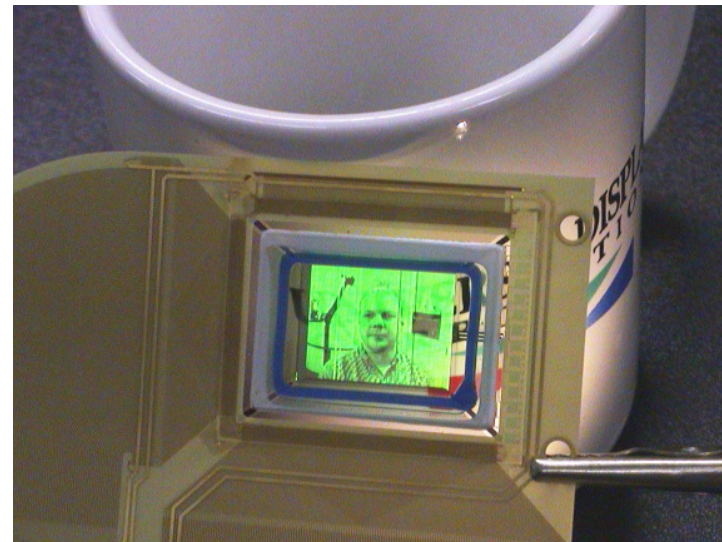
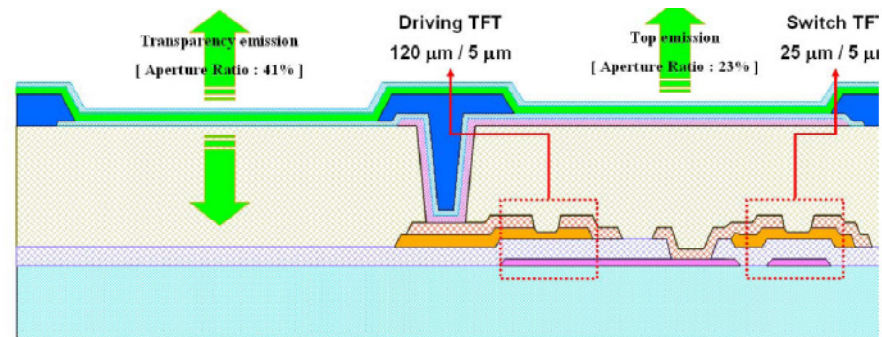
- Introduce non linear device that improves the selection.
- Storage of data values on capacitor so that pixel duty cycle is 100%
- Improve brightness of display by a factor of  $N$  (# of rows) over passive matrix drive
- Display element could be LC, EL, OLED, FED etc

Yeh & Gu



# Semi-Transparente Aktiv Matrix OLEDs

Silizium Elektronik nicht geeignet für transparente AMOLED Displays  
UDC: (semi-)transparentes Aktiv Matrix Display → Transparenz 20%





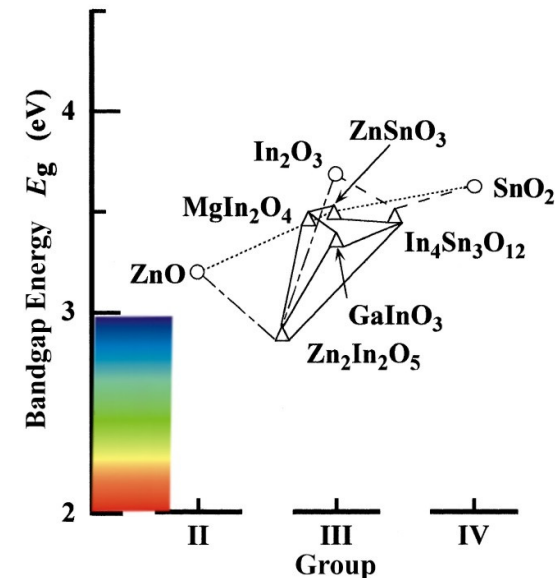
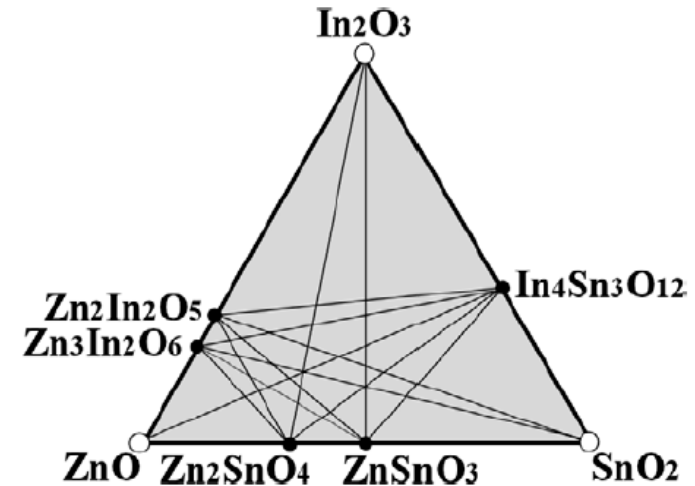
# Transparente Treiberelektronik für Transparente Aktiv Matrix Displays

Material	Dopant or compound
SnO <sub>2</sub>	Sb, F, As, Nb, Ta
In <sub>2</sub> O <sub>3</sub>	Sn, Ge, Mo, F, Ti, Zr, Hf, Nb, Ta, W, Te
ZnO	Al, Ga, B, In, Y, Sc, F, V, Si, Ge, Ti, Zr, Hf
CdO	In, Sn
ZnO–SnO <sub>2</sub>	Zn <sub>2</sub> SnO <sub>4</sub> , ZnSnO <sub>3</sub>
ZnO–In <sub>2</sub> O <sub>3</sub>	Zn <sub>2</sub> In <sub>2</sub> O <sub>5</sub> , Zn <sub>3</sub> In <sub>2</sub> O <sub>6</sub>
In <sub>2</sub> O <sub>3</sub> –SnO <sub>2</sub>	In <sub>4</sub> Sn <sub>3</sub> O <sub>12</sub>
CdO–SnO <sub>2</sub>	Cd <sub>2</sub> SnO <sub>4</sub> , CdSnO <sub>3</sub>
CdO–In <sub>2</sub> O <sub>3</sub>	CdIn <sub>2</sub> O <sub>4</sub>
MgIn <sub>2</sub> O <sub>4</sub>	
GaInO <sub>3</sub> , (Ga, In) <sub>2</sub> O <sub>3</sub>	Sn, Ge
CdSb <sub>2</sub> O <sub>6</sub>	Y
ZnO–In <sub>2</sub> O <sub>3</sub> –SnO <sub>2</sub>	Zn <sub>2</sub> In <sub>2</sub> O <sub>5</sub> –In <sub>4</sub> Sn <sub>3</sub> O <sub>12</sub>
CdO–In <sub>2</sub> O <sub>3</sub> –SnO <sub>2</sub>	CdIn <sub>2</sub> O <sub>4</sub> –Cd <sub>2</sub> SnO <sub>4</sub>
ZnO–CdO–In <sub>2</sub> O <sub>3</sub> –SnO <sub>2</sub>	

ZnO-SnO<sub>2</sub> : billig, ungiftig

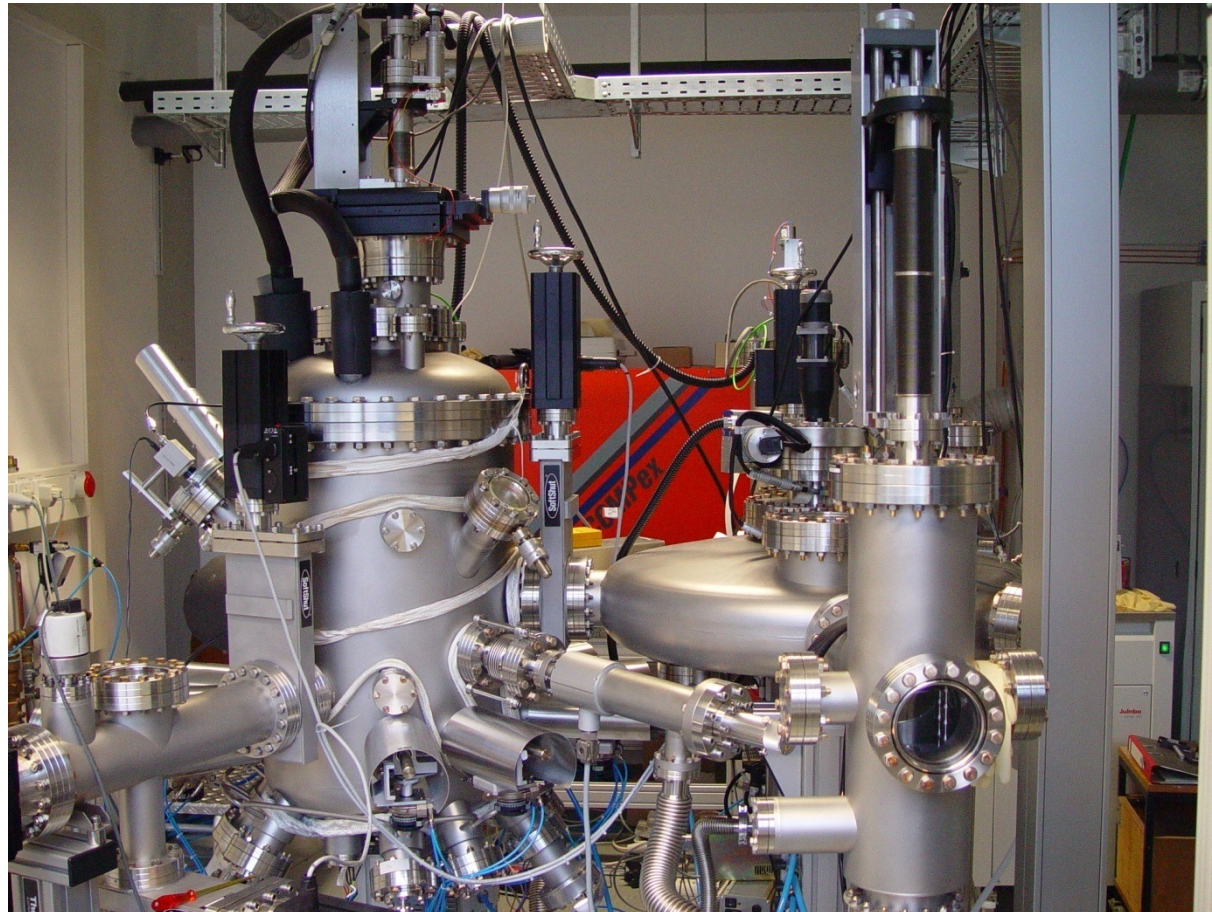
große Bandlücke (~ 3eV) → durchsichtig

Abscheidung mittels PLD bzw. Sputtern



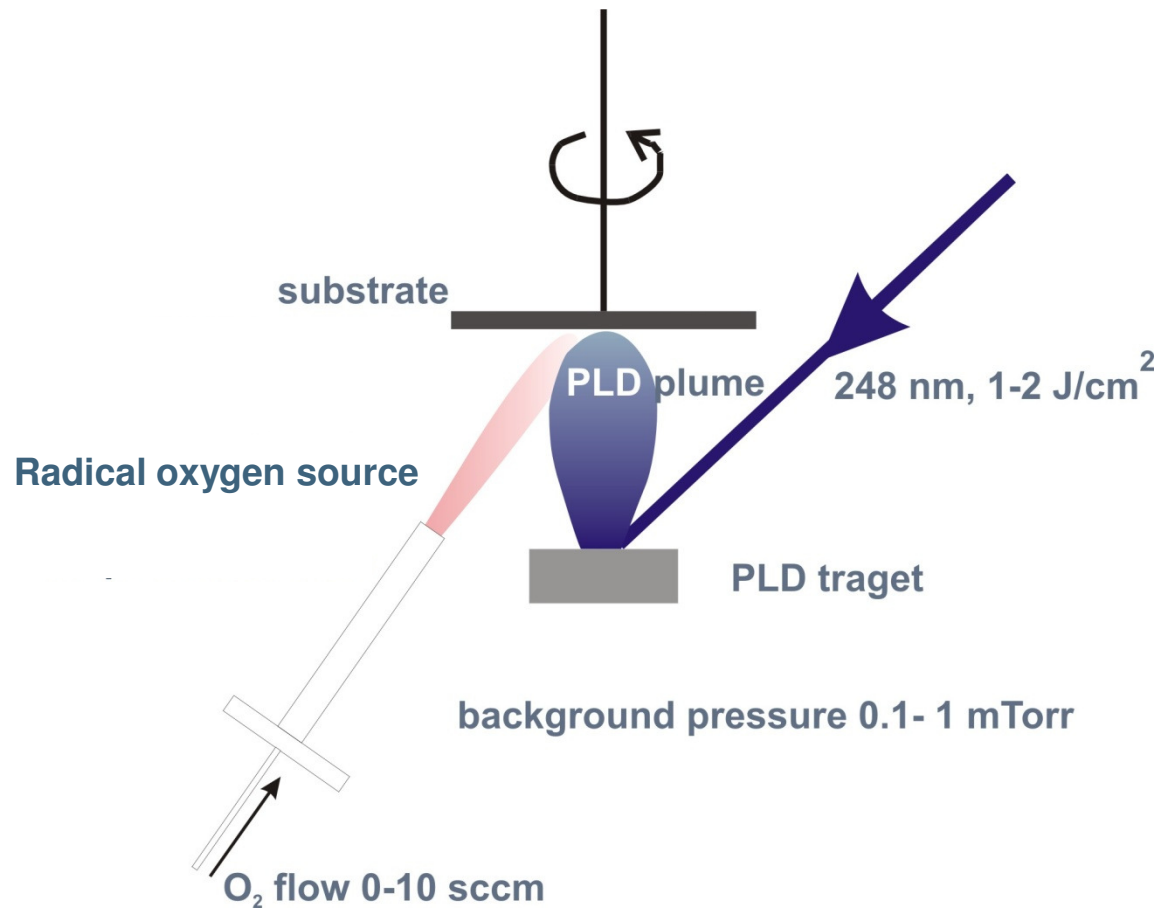


## Clusteranlage für die gepulste Laser-Deposition von Metall-Oxid basierten Halbleitern und Bauelementen (TFTs)

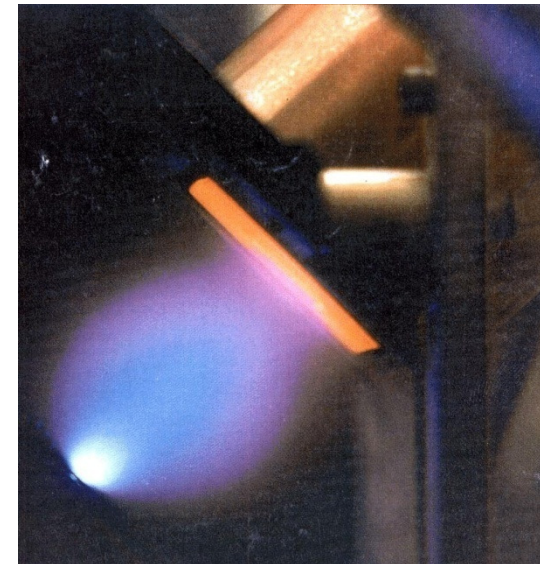




## Pulsed Laser Deposition (PLD)

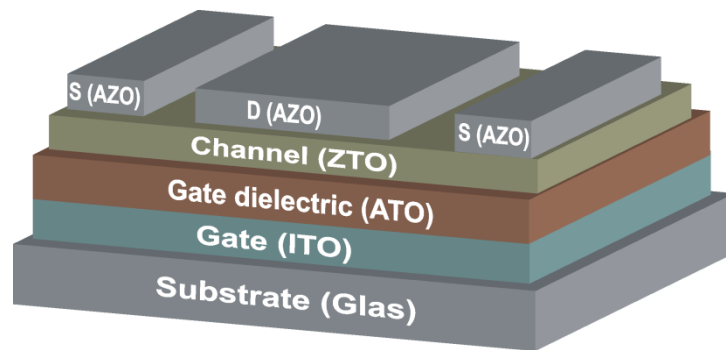


## PLD Plume



## PLD Target





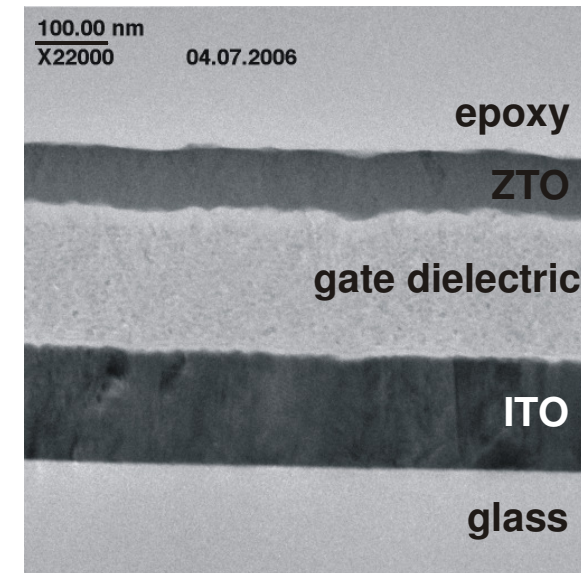
Bottom-Gate Struktur

Kanal: 30 nm  $(\text{ZnO})_x(\text{SnO}_2)_{1-x}$  (ZTO)

Drain-Source Elektroden: **ZnO:Al** (AZO)

- TEM: ZTO amorphe Struktur
- Transparenz > 80 %

TEM Querschnitt



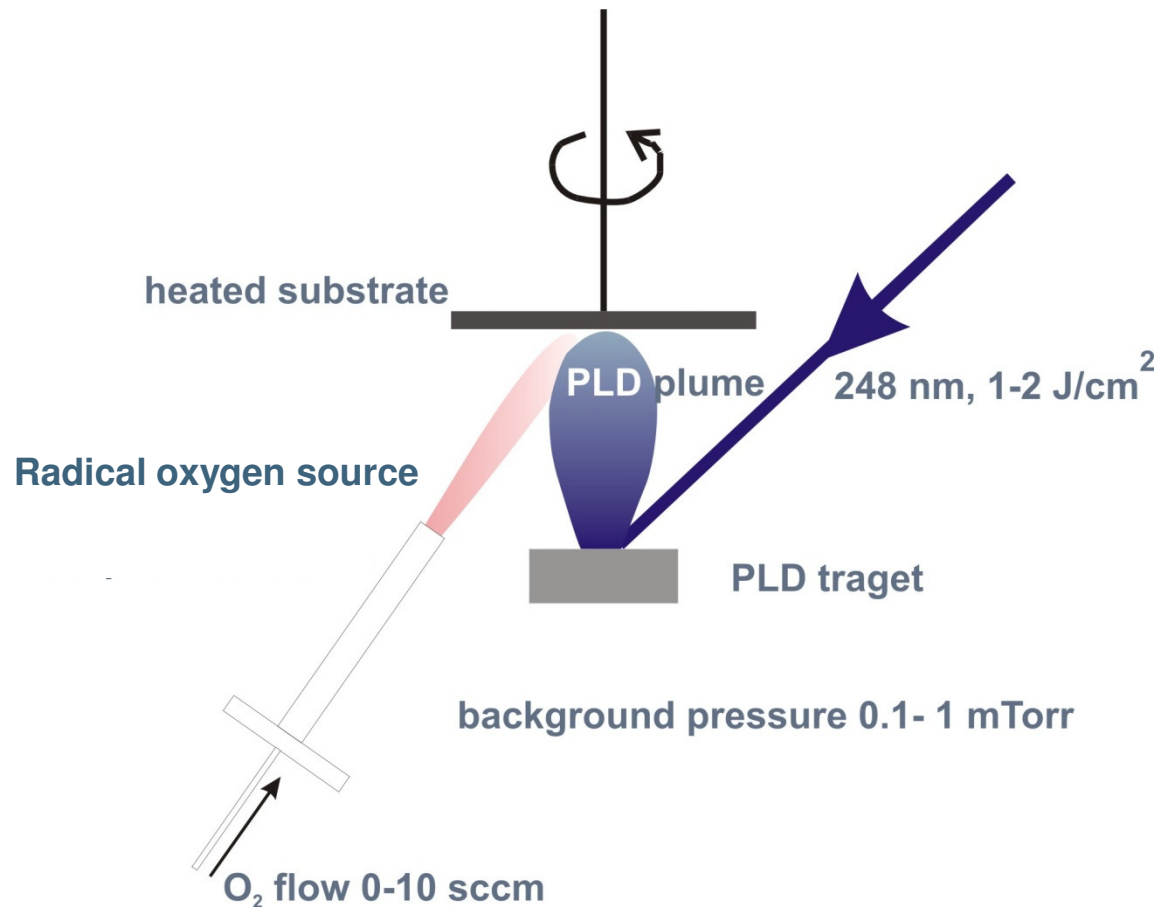
TEM Aufnahmen:  
Dr. Thomas Weimann  
Peter Hinze



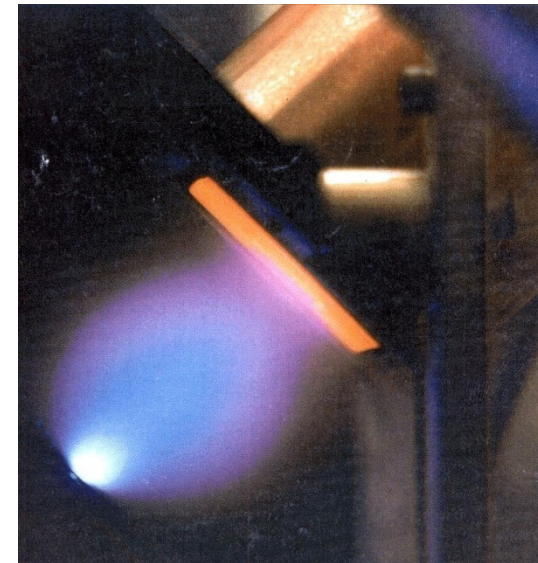




## Radical Oxygen assisted PLD



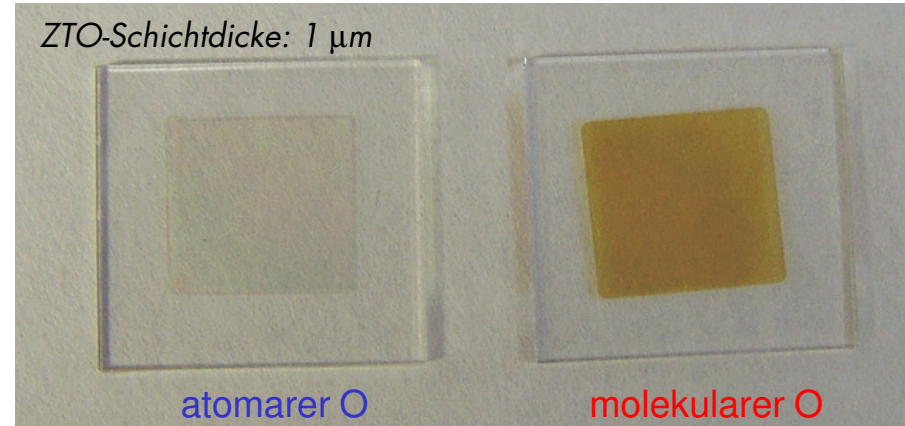
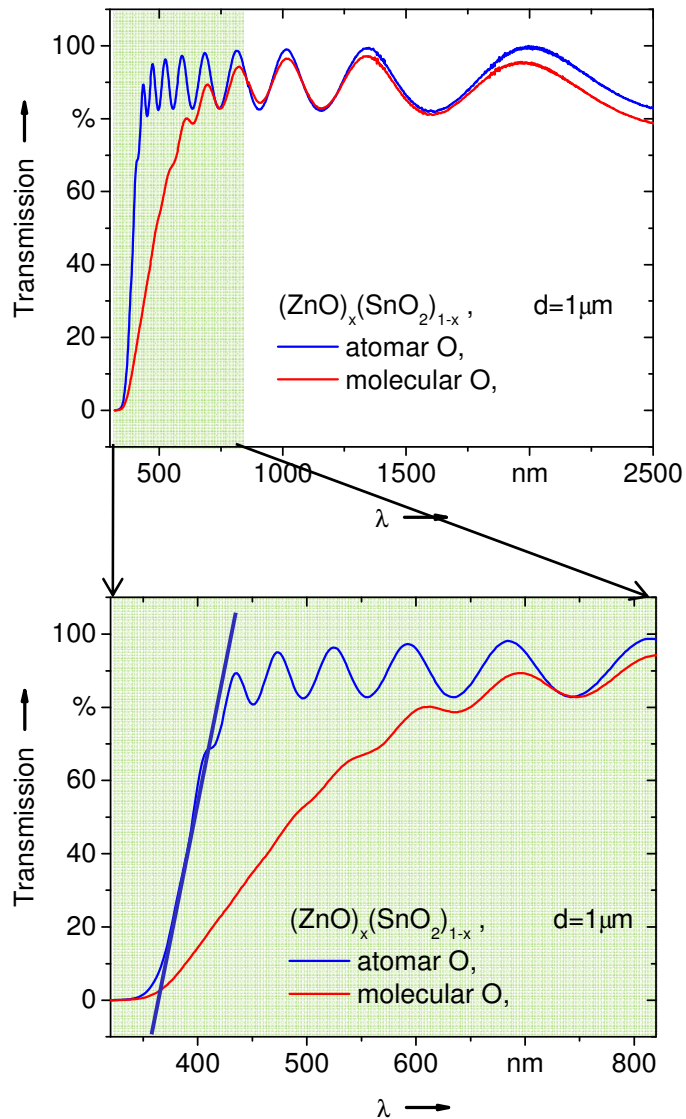
PLD Plum



Zufuhr von **atomarem** vs. **molekularem** Sauerstoff



# Analyse der Optischen Absorption



- viele „sub-bandgap“ Zustände
- „sub-bandgap“ Zustände als flache Donatoren

→ ZTO Ladungsträgerdichten (Hall-Messung):

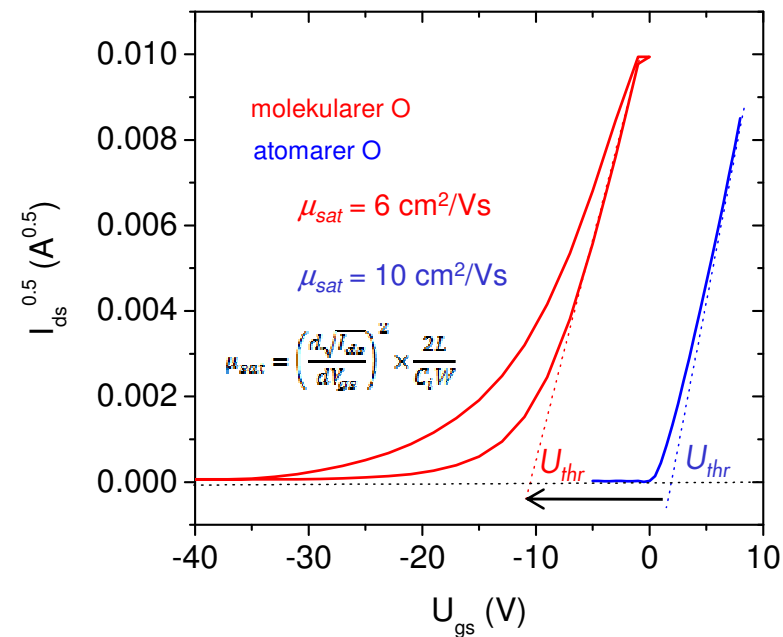
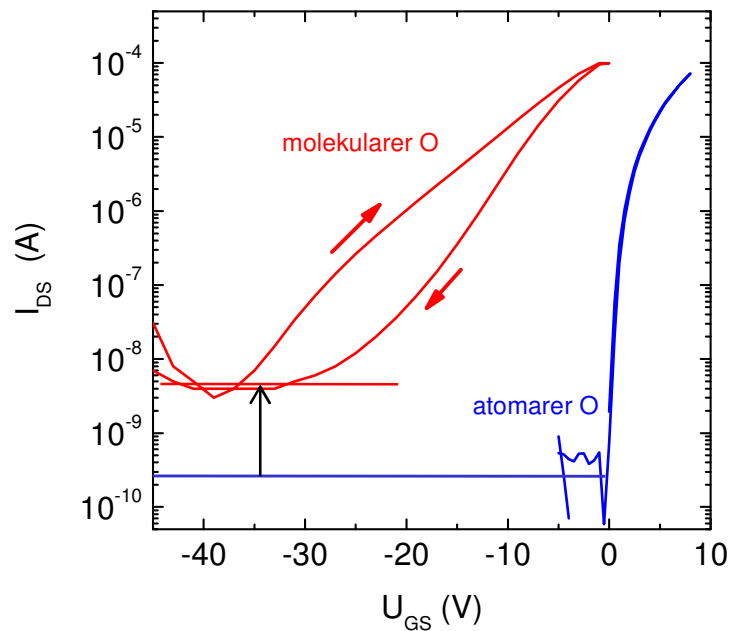
molekularer O :  $n = 10^{19} \text{ cm}^{-3}$

atomarer O :  $n = 2 \times 10^{16} \text{ cm}^{-3}$

Natur der Defektzustände → Sauerstofffehlstellen

Sauerstoffpartialdruck beim Prozess:  $2 \times 10^{-4}$  mbar

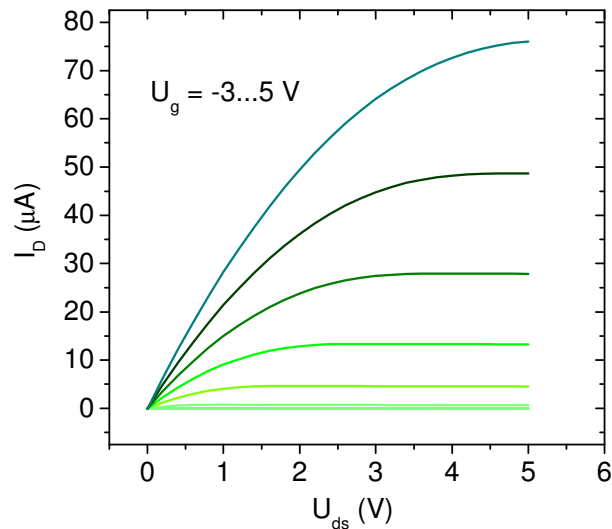
ZnO-SnO<sub>2</sub> Abscheidung mit **molekularem** und **atomarem** Sauerstoff



→ massive Hysterese bei TFTs → Defektzustände

→ erhöhter „aus“-Strom

→ zu negativen  $U_{gs}$  verschobene Schwelle  $U_{thr}$  → erhöhte Ladungsträgerdichte



TTFT Ausgangs-Charakteristik

TTFT Transfer-Charakteristik

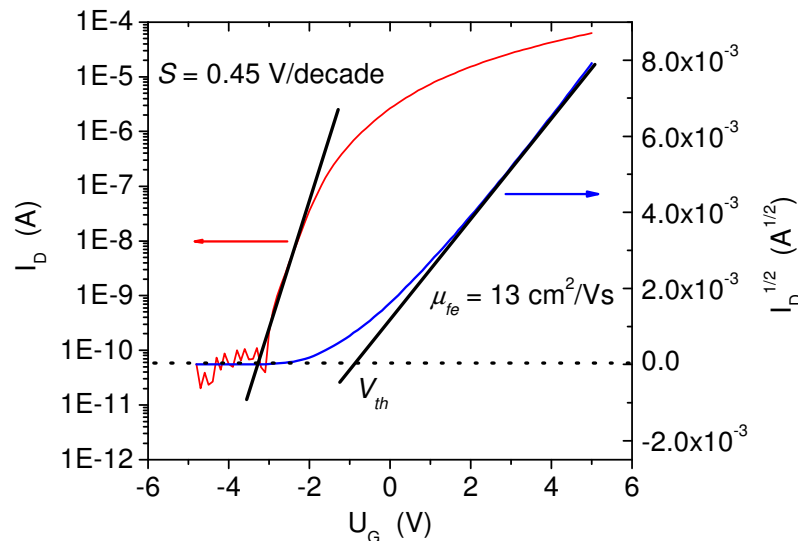
$$I_{\text{on}}/I_{\text{off}} = 10^6$$

$$\mu_{\text{FE,SAT}} = 13 \text{ cm}^2/\text{Vs}$$

(vergl.  $\alpha$ -Si:  $\mu_{\text{FE,SAT}} = 1 \text{ cm}^2/\text{Vs}$ )

$$U_{\text{th}} = -1..1 \text{ V}$$

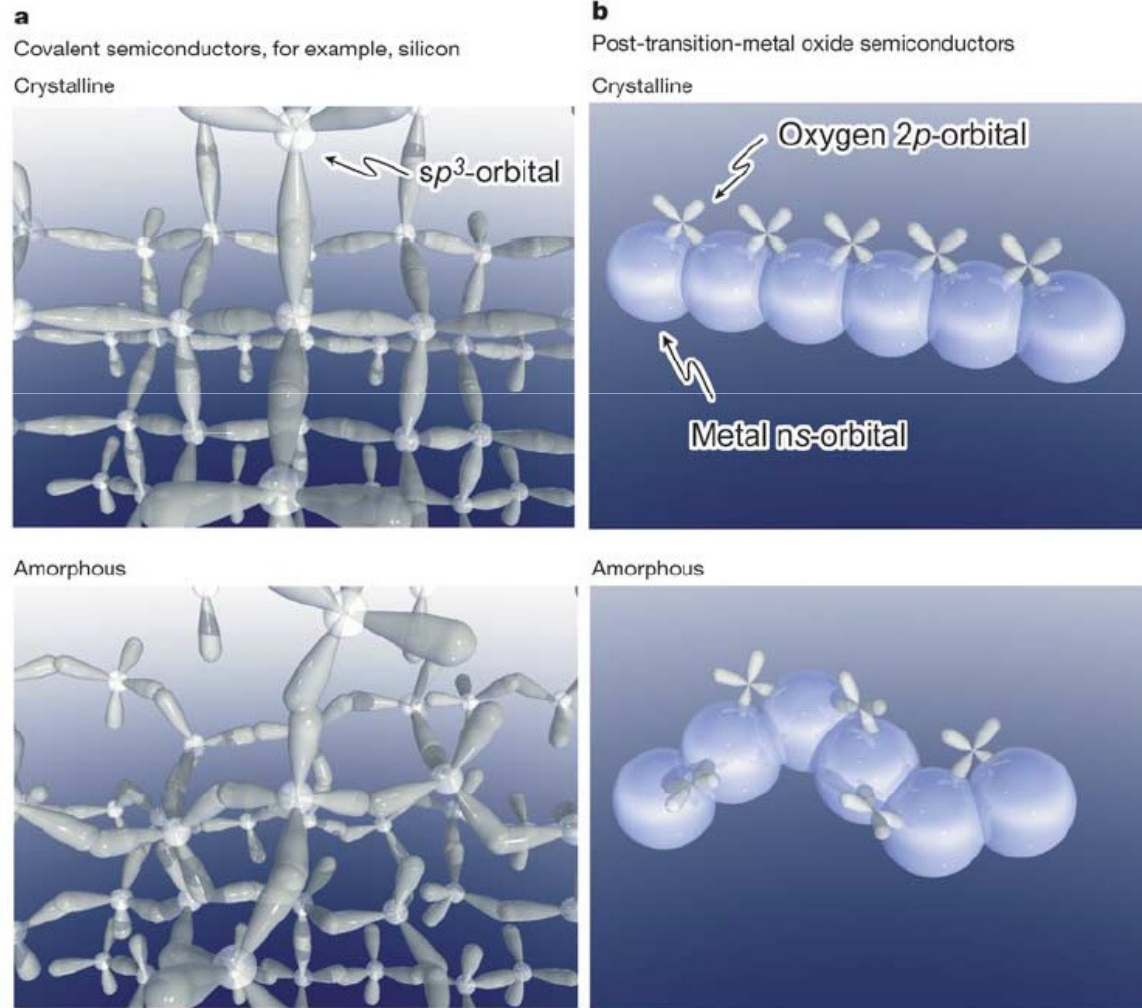
- keine Hysterese messbar
- unempfindlich gegen sichtbares Licht
- extrem stabil !



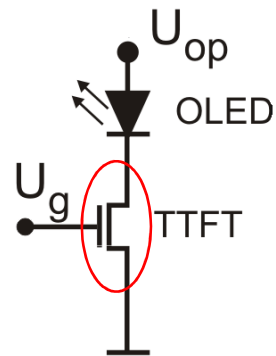
*Appl. Phys. Lett.* **90**, 063502 (2007)  
*Appl. Phys. Lett.* **91**, 193504 (2007)  
*phys. stat. sol. (rrl)* **1**, 175 (2007)



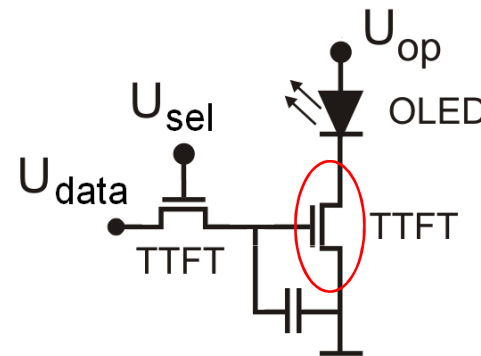
Überlapp ausgedehnter  $ns$  Orbitale  $\Rightarrow$  hohe Beweglichkeit in amorphen Schichten



smart pixel



active pixel



Stabilität des **analogen Treiber-TFTs**:

Verschiebung der TFT Charakteristika  $\Rightarrow$  Drift der Pixelhelligkeit



## AMOLED Display mit Si TFT backplane



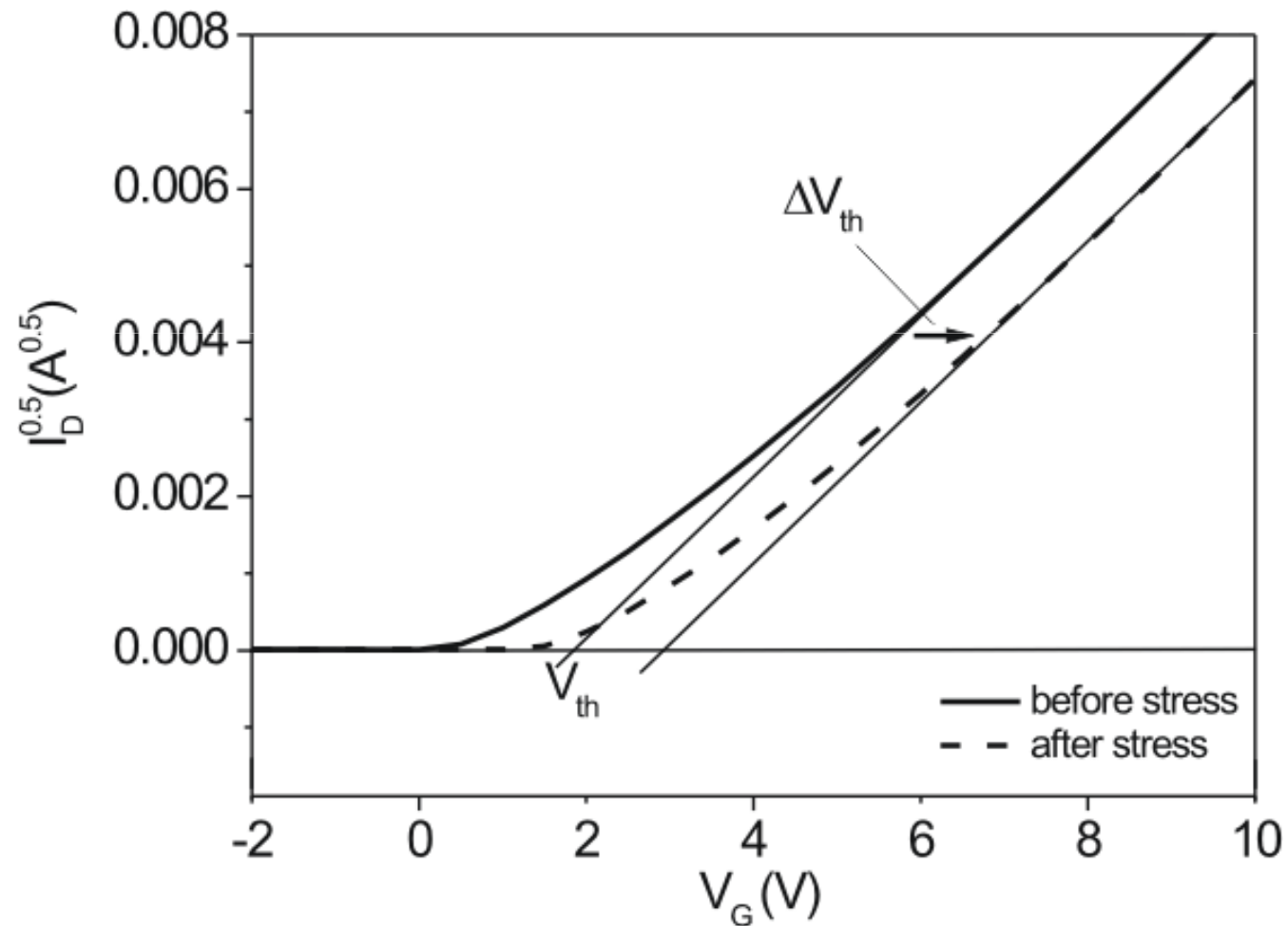
Originalbild (Stress der TFTs)



Homogenes Graubild mit  
„Ghost image“



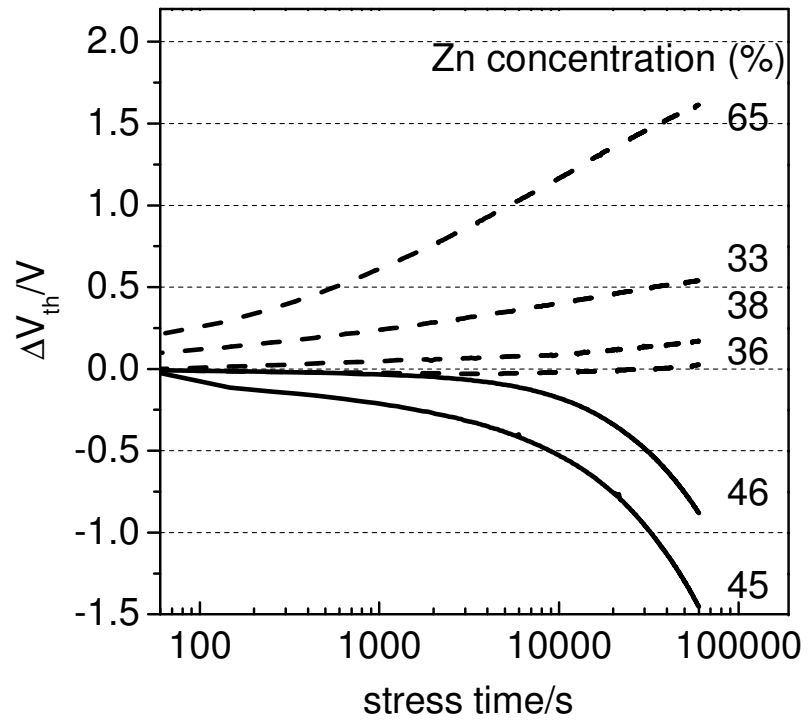
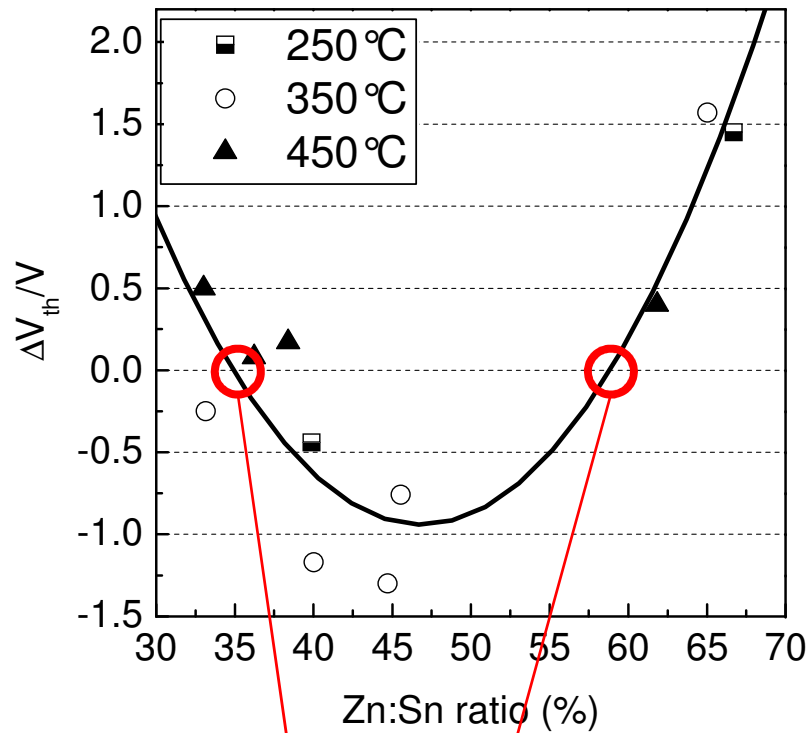
## Verschiebung der Schwellspannung nach 10 h Gate-bias Stress ( $U_g=10$ V)





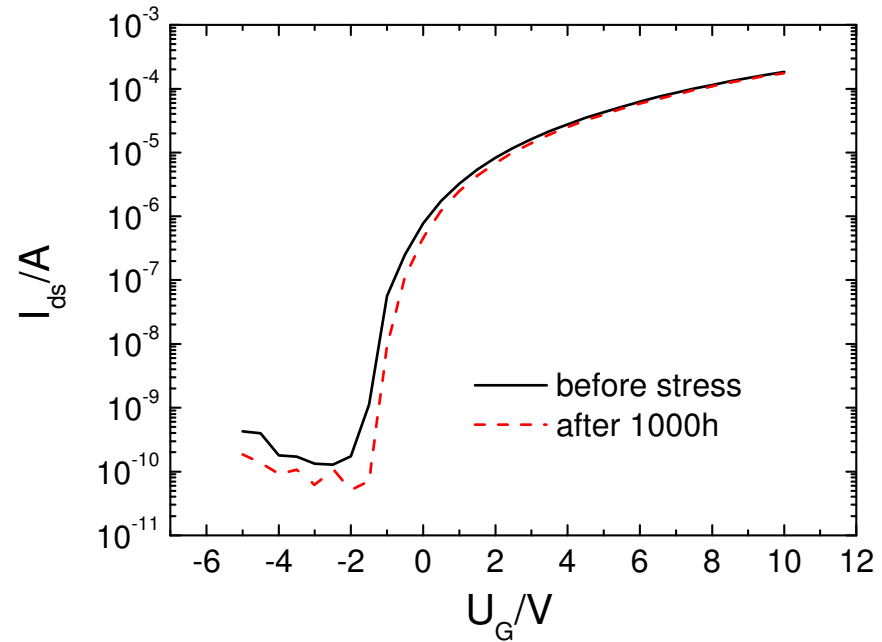
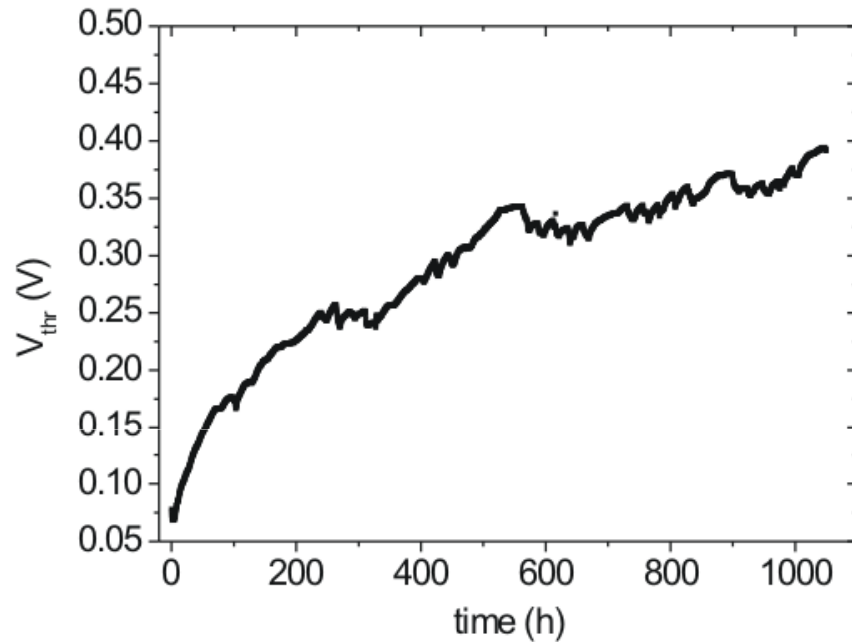


Verschiebung der Schwelle  $V_{thr}$  nach 10 h Gate-Bias-Stress  $V_g = 10$  V



**[Zn]:[Sn] Kompositionen mit hoher Stabilität der TFTs**

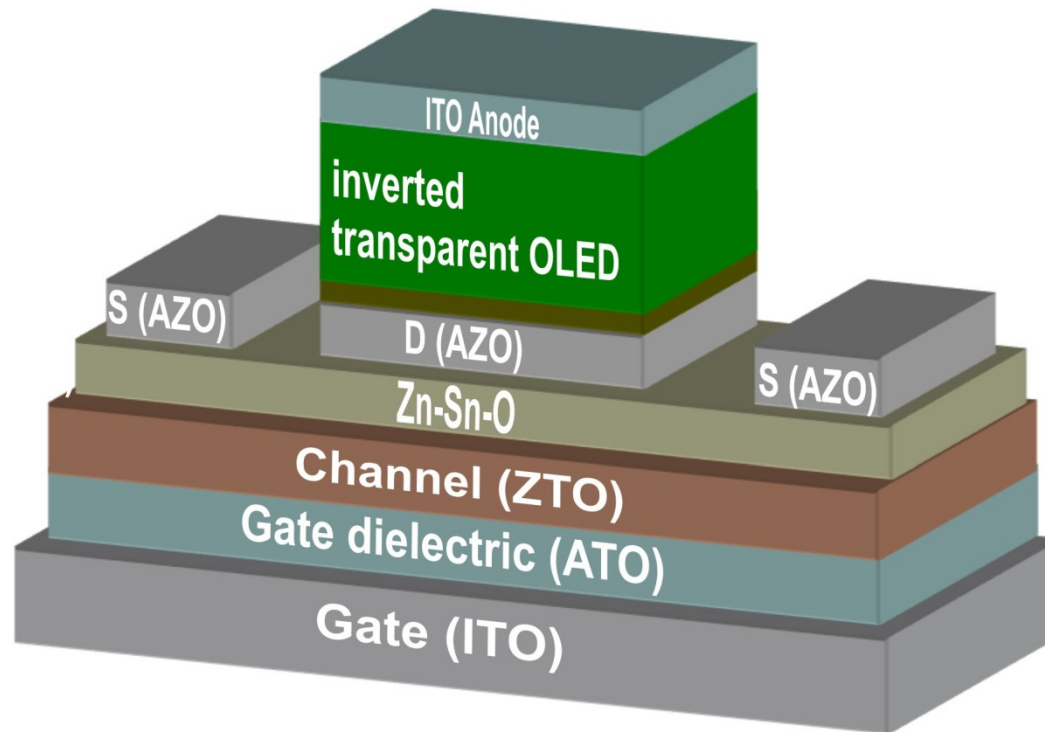
DC bias stress:  $U_{ds} = 10 \text{ V}$ ,  $U_{gs} = 10 \text{ V}$ ,  $I_{ds} = 188 \mu\text{A}$



nach 1000 h:  $DV_{th} = 320 \text{ mV}$  bei Strombelastung  $100 \times I_{OLED}$

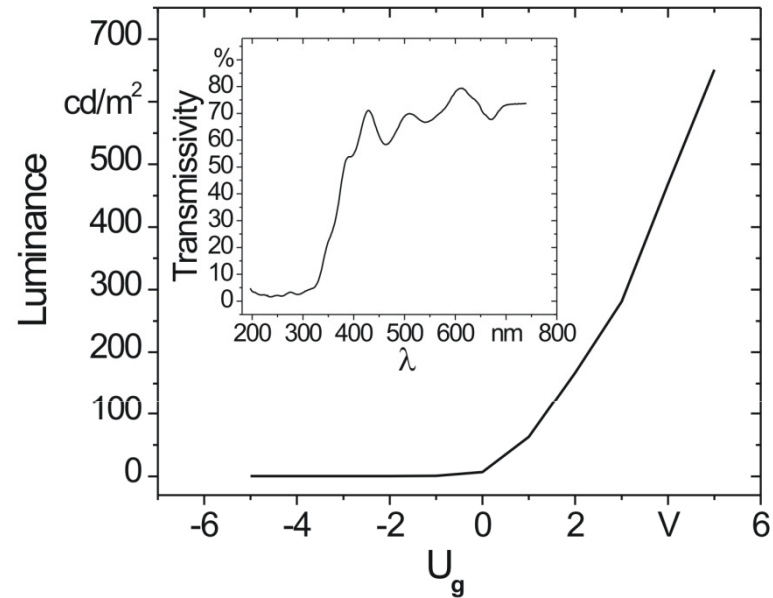
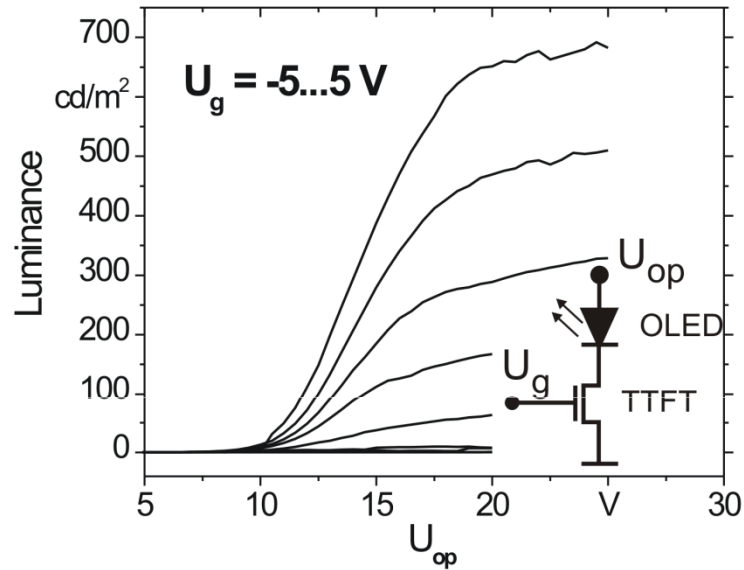
Vergl.  $\alpha$ -Si TFT  $DV_{th} = 2 \text{ V}$  schon nach 5 h

⇒ bislang weltweit **stabilste** TFTs mit amorphem Kanalmaterial



Aktives OLED Pixel, getrieben durch einen TTFT

Drain AZO Kontakt → OLED Kathode



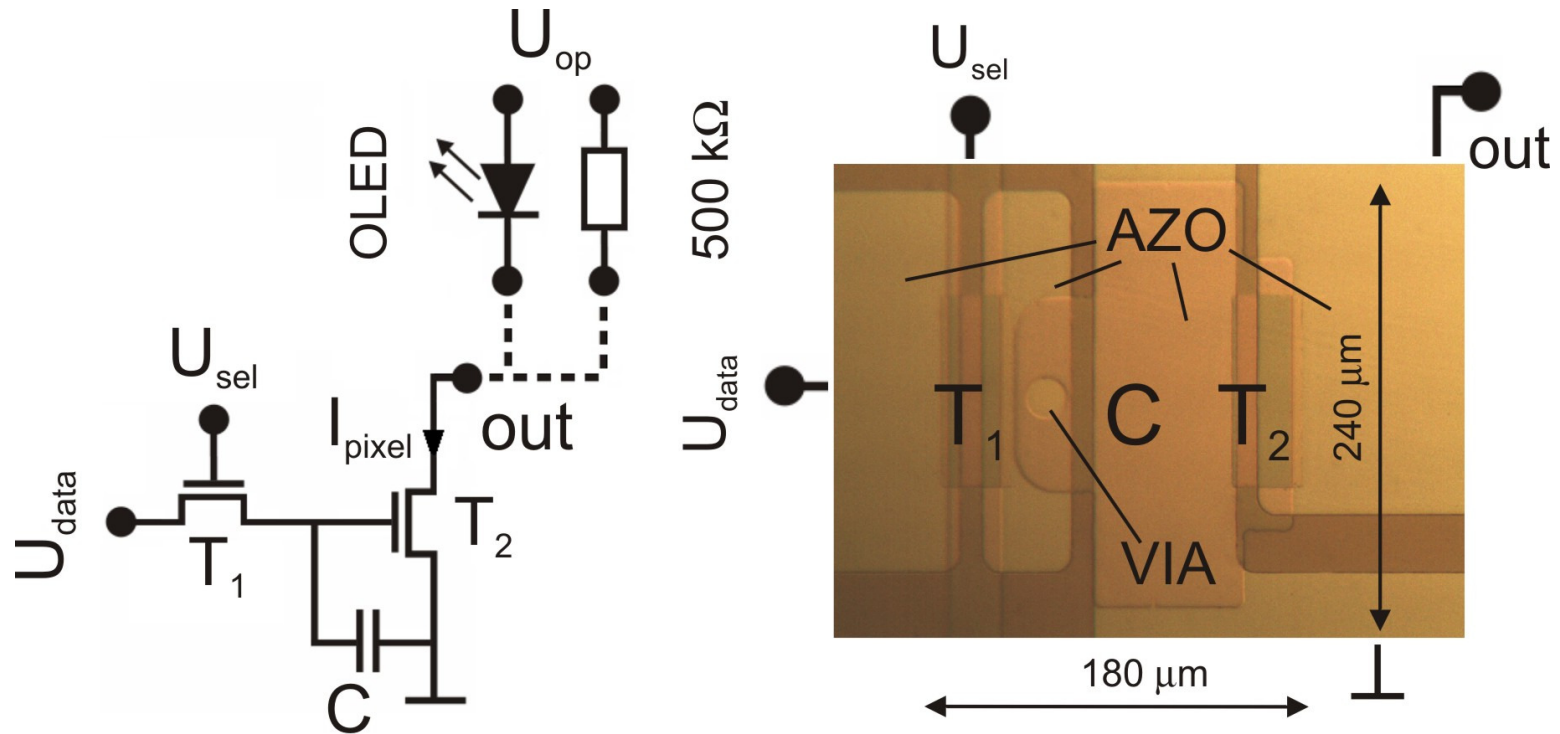
Transmission 70 % im sichtbaren Spektralbereich (OLED+TFT)

OLED „aus“:  $U_g < 0 \text{ V}$ ,  $U_g = 5 \text{ V} \rightarrow 600 \text{ cd/m}^2$



## Baustein transparenter AMOLED Displays

P. Görrn et al., *Adv. Mater.* **18**, 738 (2006)

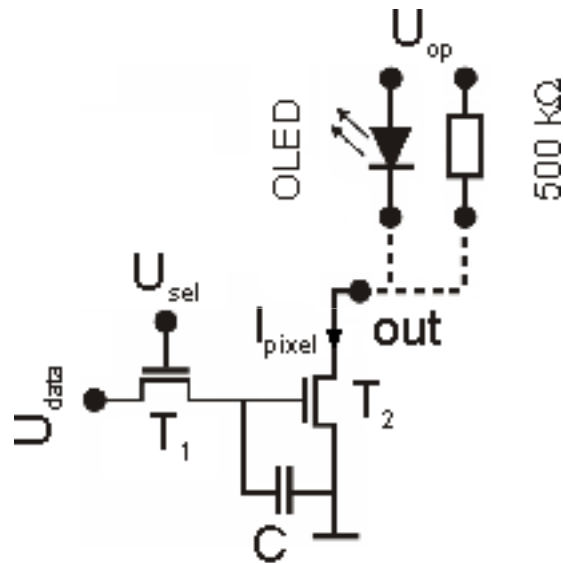


$$C = 12.3 \text{ pF}$$

$$W/L = 100 \text{ } \mu\text{m}/10 \text{ } \mu\text{m}$$

$$\text{pixel area: } 180 \times 240 \text{ } \mu\text{m}^2$$

transmissivity 80 %



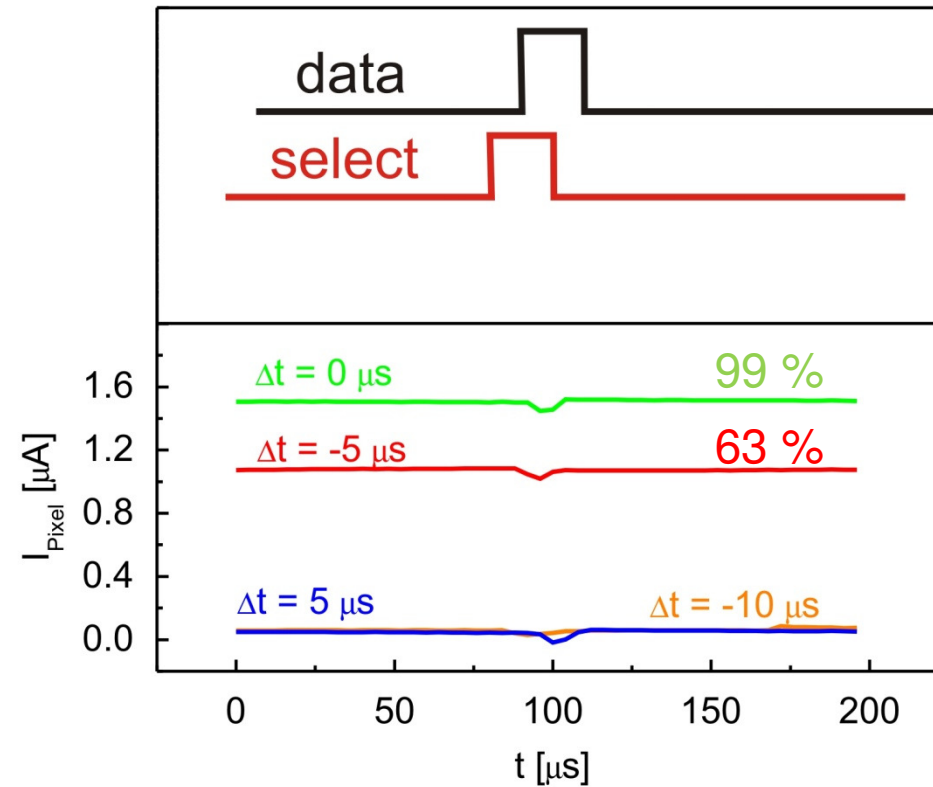
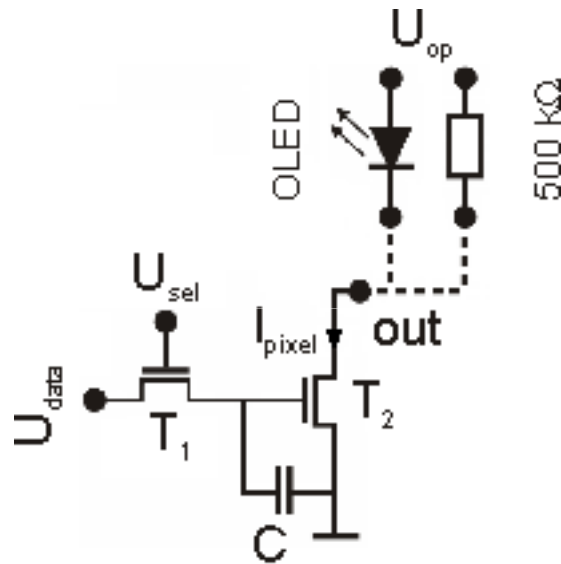
Requirement:

full HD (1,920x1,080 pixels) + 100 Hz refresh

frame-time 10 ms

max. pixel charging time  $\sim 10 \mu\text{s}$

Pulsewidth of data and select pulses 10  $\mu\text{s}$



$$U_c(t) = U_{c,\text{max}}(1 - \exp(-t/\tau))$$

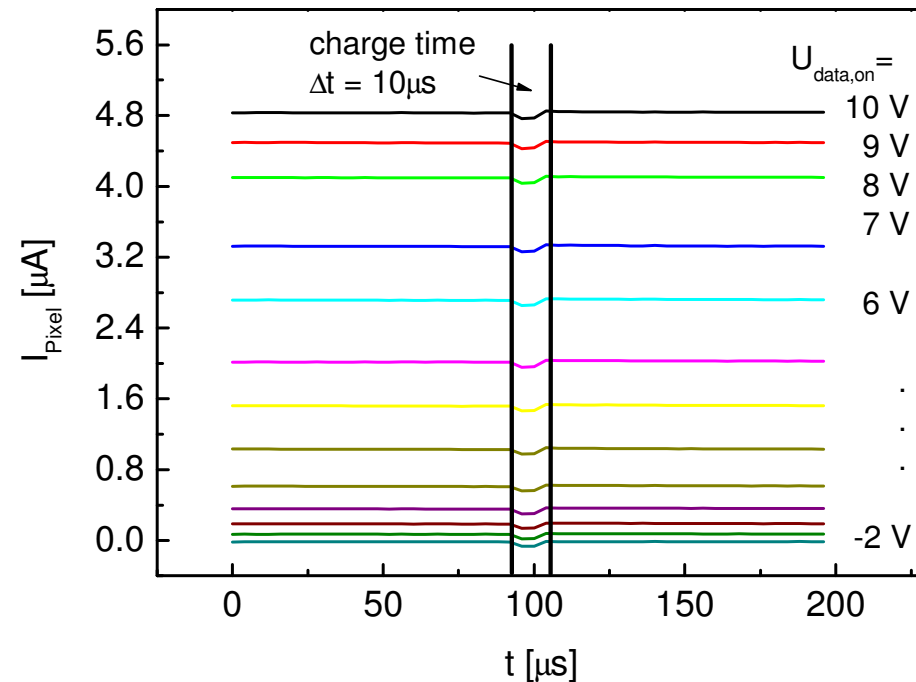
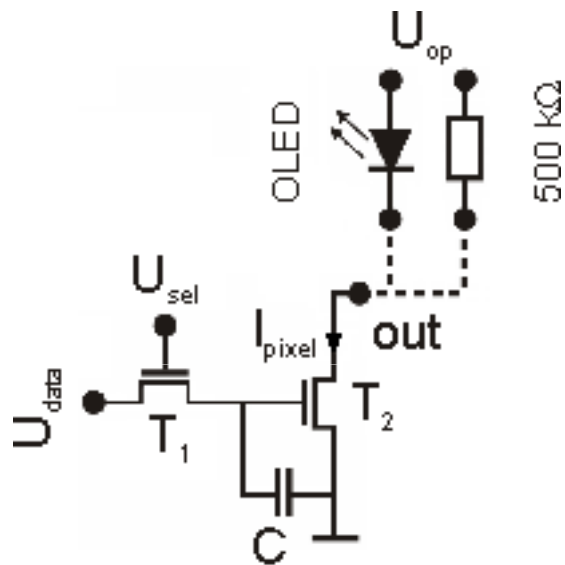
at  $t = \tau$ : C is charged to 63 %

Time constant  $\tau$  for the charging of  $C$ : 5  $\mu\text{s}$

$$I_{\text{pixel}} = 1 \mu\text{A} \rightarrow 880 \text{ cd/m}^2 \text{ (@ } 38 \text{ cd/A)}$$



US-DOD specs.: day-light perception of see-through displays: 5,000 cd/m<sup>2</sup>



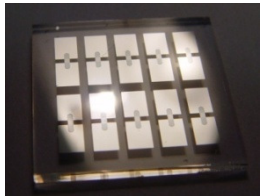
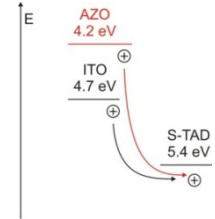
charging time 10 μs:

$I_{pixel}$  up to 4.8 μA → 4,224 cd/m<sup>2</sup> (@ 38 cd/A OLED efficiency)

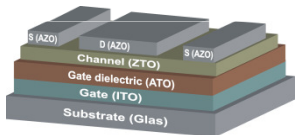
within 10 ms: 1,700 cd/m<sup>2</sup> → 1,676 cd/m<sup>2</sup> (1.4 %)



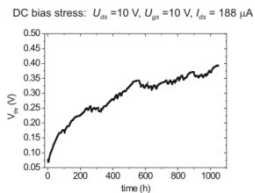
## Transparente Elektroden für transparente OLEDs



## Transparente Dünnschichtverkapselung mittels ALD



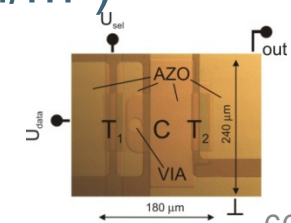
## ZnO-basierte transparente Dünnschichttransistoren



## Exzellente Stabilität unter Stress (1000 h)



## Transparente Treiber (100 Hz, full HD, >4,000 cd/m<sup>2</sup>)



## Partner im Bereich: Transparente OLEDs+Displays:

