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Pionierarbeit. Pioneering Work
Organic and Printed Electronics. Flexible Displays.

Organic and Printed Electronics - Technologies, Trends and Markets

Materials Valley e.V.
February 4, 2016



Stephan Kirchmeyer

- ▶ 1988 – 2002 Bayer AG: Lab- and Research Manager
- ▶ 2002 – 2010 H.C. Starck: Research Manager
Business Line Manager
- ▶ 2010 – 2015 Heraeus: Business Group Manager
Technical Service Manager
- ▶ Since 2009 Member of the OE-A Board
- ▶ 2011 – 2015 Chair of the OE-A Board
- ▶ Since 2015 Freelance

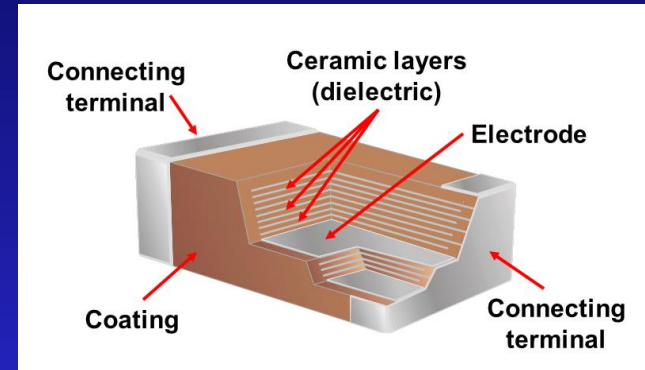
Outline

- ▶ Organic and Printed Electronics
- ▶ Technology
 - ▶ Printing Technologies
 - ▶ Functional Materials
 - ▶ Substrate Materials
- ▶ Applications
 - ▶ Automobile: antennas, self illuminated license plates and switches
 - ▶ Consumer Electronics: foldable smart phones, wearables and smart textiles
 - ▶ Energy: lighting elements and luminaires

What is unique about Organic and Printed Electronics ?

- ▶ Organics are omnipresent in electronics
 - ▶ Liquid crystals in LCD displays
 - ▶ Processing chemicals and functional layers (e.g. BARC) in semiconductor manufacturing
 - ▶ Polymer substrates
- ▶ Printing is a widely used process in electronics
 - ▶ “Printed wiring boards”
 - ▶ MLCC-capacitors
 - ▶ Antennae
 - ▶ touch sensors
 - ▶ EL-elements

Print chips via additive manufacturing !



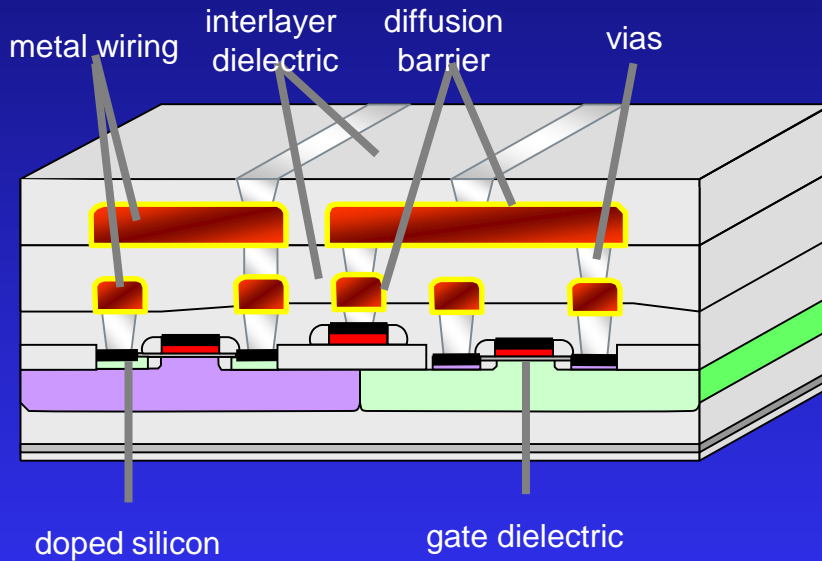
MLCC (multi layer ceramic capacitor)*



Printed conductive patterns used to create flexible Printed Circuit Boards (Source: ISORG)

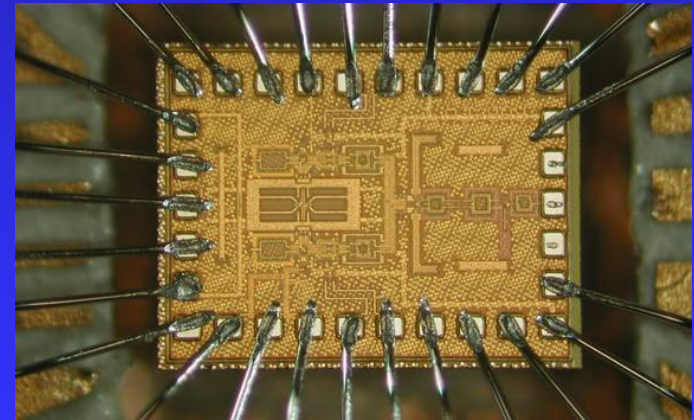
*) "MLCC-Construction" by Elcap - Own work. Licensed under CC0 via Commons - <https://commons.wikimedia.org/wiki/File:MLCC-Construction.png#/media/File:MLCC-Construction.png>

The Challenge to Meet Technical Requirements: Silicon based Chips



Front end

- Photolithography
- Vapor Deposition
- Chemical Mechanical Polishing



Back end

- Bonding
- Encapsulation
- Mounting
- Integration

C. Schilling, Ruhr Universität Bochum
<http://www.ei.rub.de/fakultaet/banner/integriertesysteme/>

Visibility of Technologies

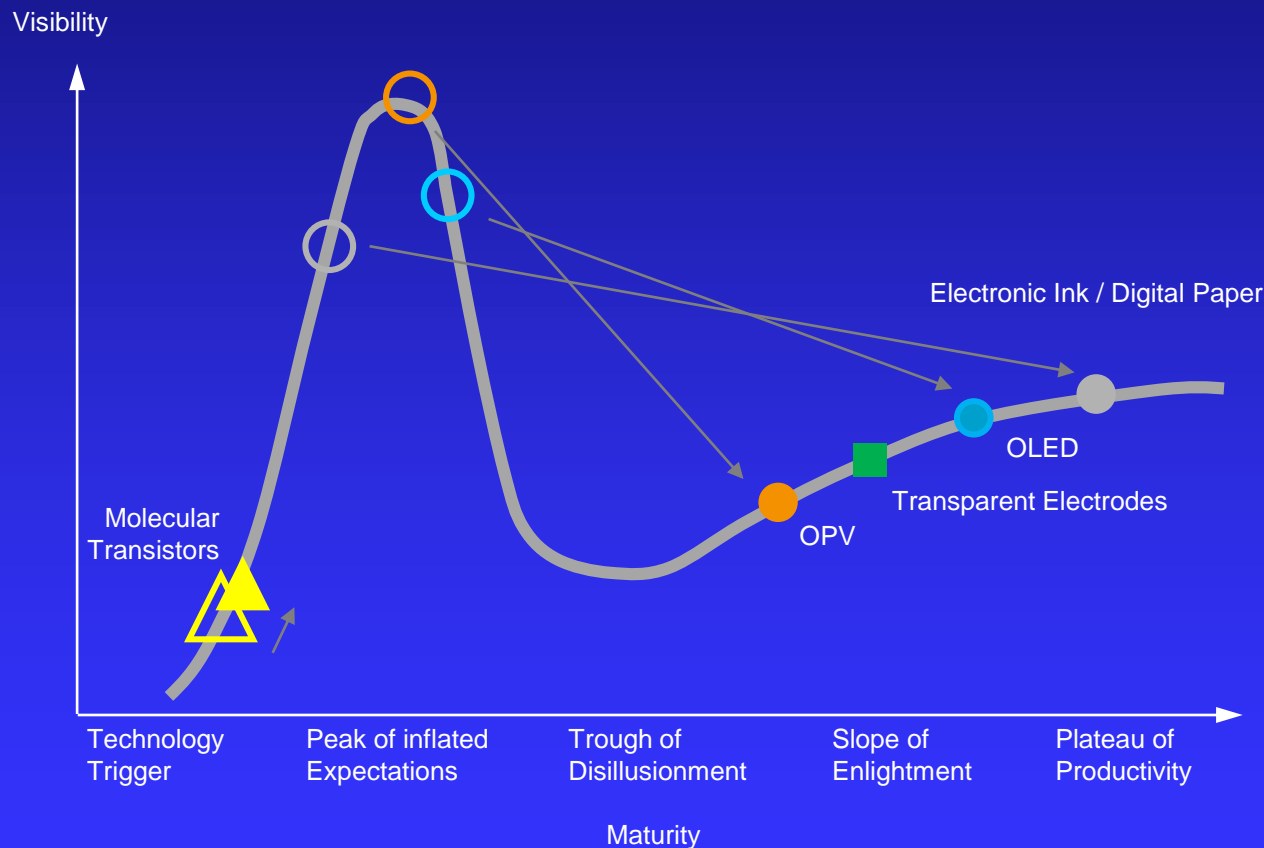


Figure adopted from Gartner



Pictures: Samsung, Plastic Logic, Heliatek

Target-Markets of Printed Electronics

Target Markets (from the OE-A Business Climate Survey)

6 major industries*):

- ▶ Packaging/Printing
- ▶ Consumer Electronics
- ▶ Automotive
- ▶ Lighting
- ▶ Pharmaceutical
- ▶ Energy



*) OE-A :Organic Electronics Association
source: OE-A Business Climate Survey, Semiannual Questionnaire to OE-A Members

The Market of Printed Electronics

The OE-A Roadmap*) predicts 5 Application Areas

- ▶ OLED Lighting
- ▶ Organic Photovoltaics
- ▶ Flexible and OLED Displays
- ▶ Electronics and Components Cluster
 - ▶ Printed Memory
 - ▶ Flexible Batteries
 - ▶ Active Devices
 - ▶ Passive Devices
- ▶ Integrated Smart Systems Cluster
 - ▶ Smart Objects and Printed RFID
 - ▶ Sensors
 - ▶ Smart Textiles

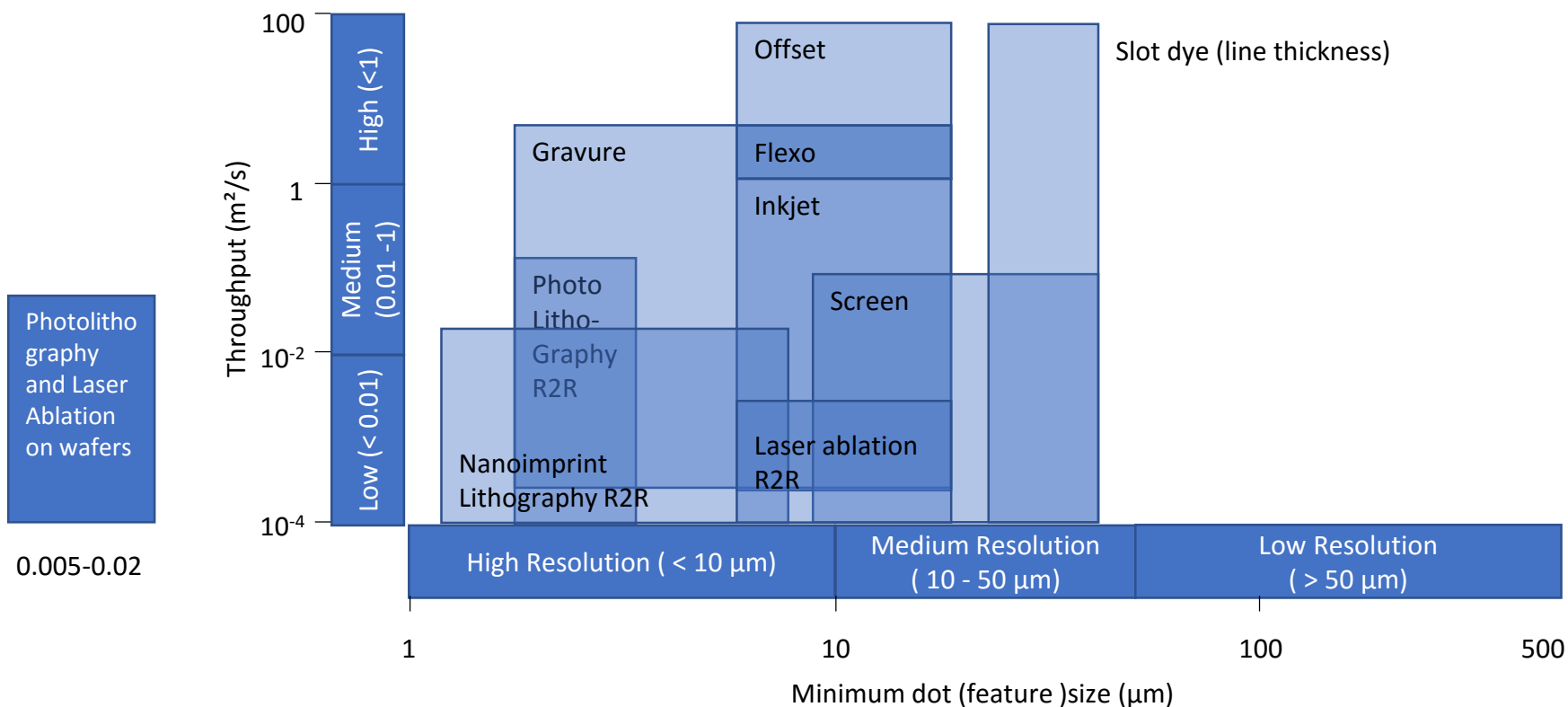


23-24 Bn USD*)
(18 Bn USD
OLED Displays)

*) Clemens W, Lupo D, Hecker K and Breitung S White Paper 2015 – OE-A Roadmap for Organic and Printed Electronics, 6th Edition

Technologies: Printing

Throughput vs. Feature Size for Premium Quality Production Processes*)



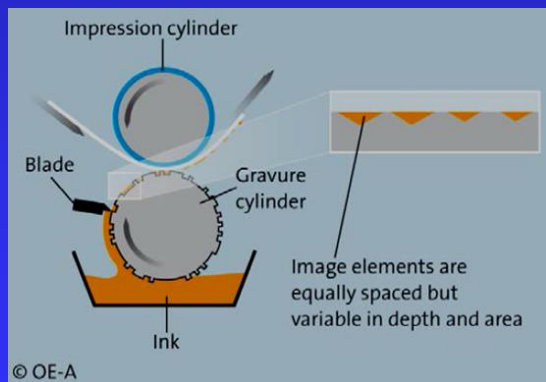
*) adopted from Clemens W, Lupo D, Hecker K and Breitung S White Paper 2015 – OE-A Roadmap for Organic and Printed Electronics, 6th Edition

Printing: Summary

No standard set of processes, individual decision for each projected product

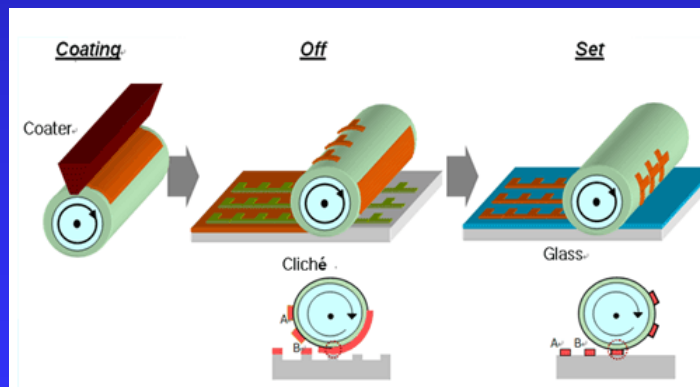
Key application parameters

- ▶ Thickness
- ▶ Resolution (line, space), registration
- ▶ Throughput
- ▶ Ink availability



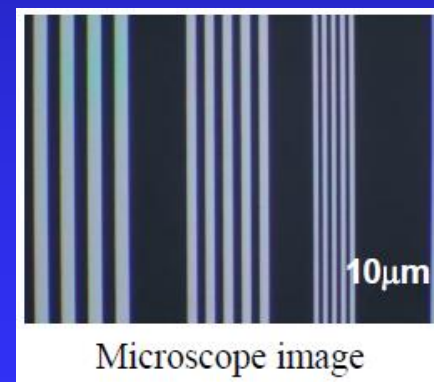
Gravure:

- ▶ High throughput
- ▶ Good resolution



reversed offset

- ▶ Widely used
- ▶ good resolution



T. Okubo, Printed Electronics Asia 2009

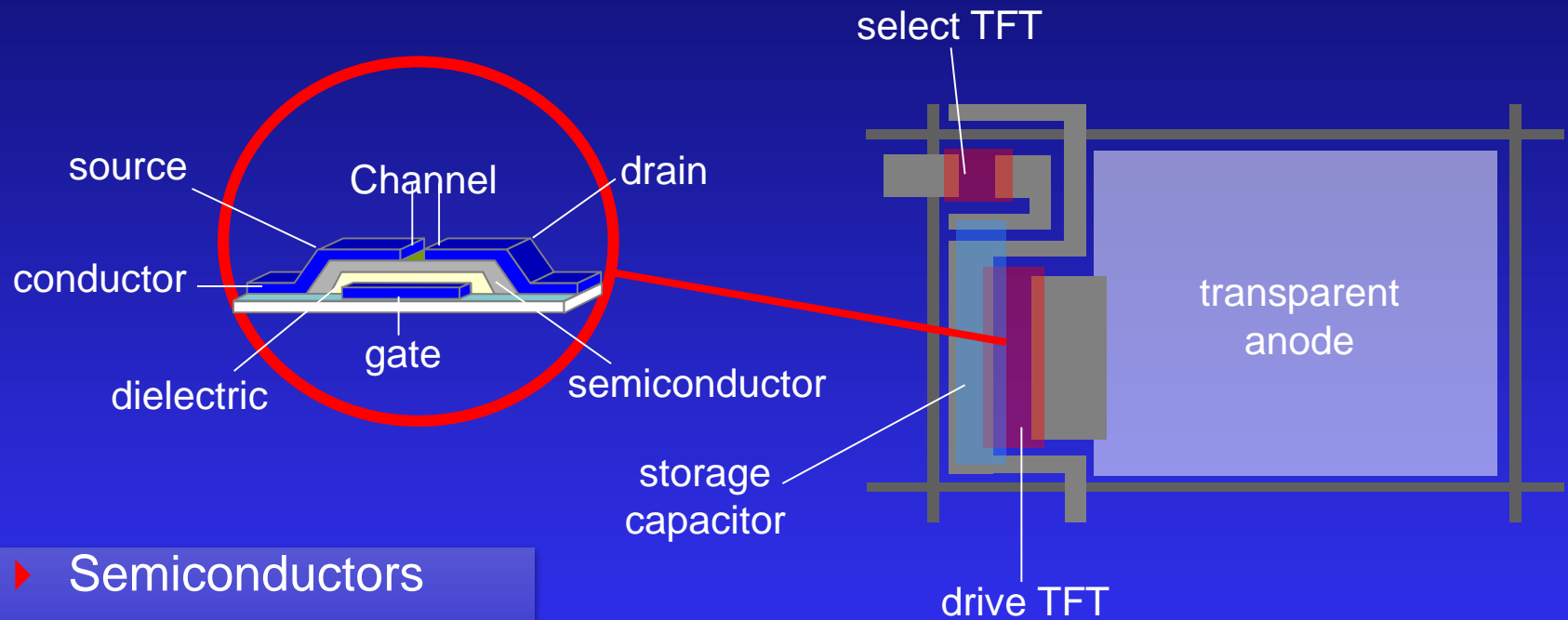
Substrates*)

		Glass	Metal	Paper	PET	PEN	PC	PI	PES	PEEK	Textiles
	OLED Lighting	++	+	(+)	+	+	(+)	X	X	X	(+)
	OPV	+	(+)	(+)	++	+	X	X	X	X	X
	Flexible Displays	+	+	(+)	+	+	X	++	X	X	X
Electronics and Components	Flexible Batteries	-	(+)	(+)	+	+	X	X	X	X	-
	Passive Devices	-	-	(+)	++	(+)	(+)	-/+	X	(0)	X
	Active Devices & Logics	-	-	(+)	++	(+)	(+)	-	X	(0)	X
	Printed Memory	-	-	X	++	+	(+)	X	X	X	X
Integrated Smart Systems	Smart Objects	-	-	++	++	+	X	X	X	X	+
	Sensors	-	-	(+)	++	(+)	(+)	-	X	(0)	(+)
	Smart Textiles	-	-	X	+	(+)	(+)	-	X	X	++

++ standard + suitable 0 option, not widely used
 - not suitable X not known () for special applications

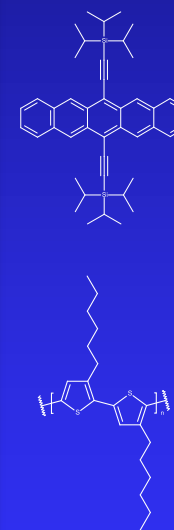
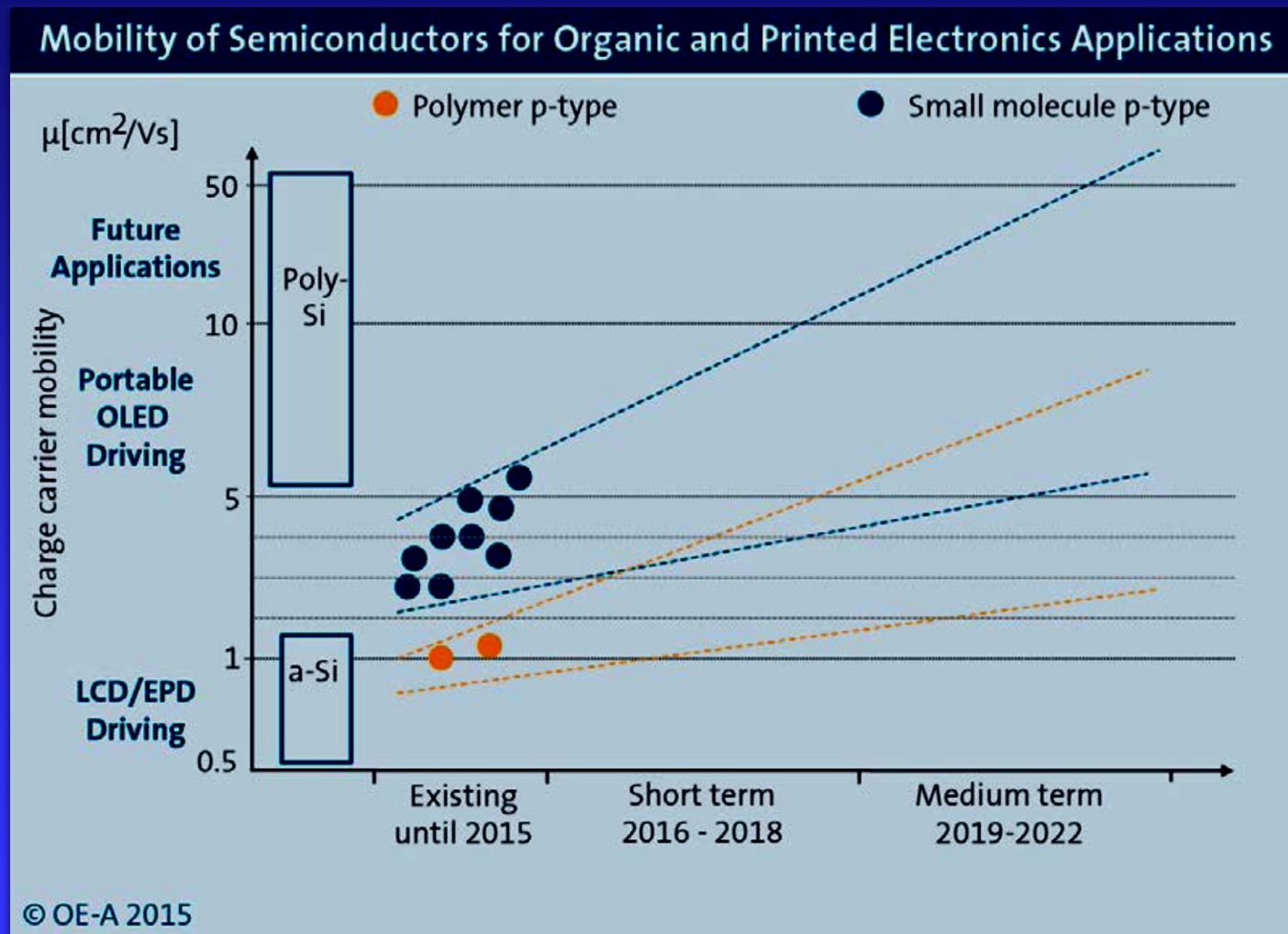
*) adopted from Clemens W, Lupo D, Hecker K and Breitung S White Paper 2015 – OE-A Roadmap for Organic and Printed Electronics, 6th Edition, S. Kirchmeyer

Functional Materials



- ▶ Semiconductors
- ▶ Conductors
 - ▶ Non-transparent
 - ▶ Transparent
- ▶ Dielectrics

OE-A Roadmap for Organic Semiconductors



Materials: Conductors



Silver Paste

- ▶ Silver flakes + binder + additives
- ▶ screen printing
- ▶ Limited resolution
- ▶ Sintering for high conductivity



Silver Precursor and Nano Inks

- ▶ Silver salt → Nano particles
- ▶ Low viscosity → ink jet printing
- ▶ Low sintering temperature



Silver Nano Wire Ink

- ▶ Silver salt + polymer → Nano wires
- ▶ Usually not easy to handle

Conductive Polymers

- ▶ Intrinsically conductive
- ▶ screen printing → ink jet printing
- ▶ Conductivity: ~ 1000 S/cm, ~ 0,5 % of silver

Carbon Nano Tubes

- ▶ Variety of different grades
- ▶ Conducting/semi-conducting
- ▶ Single wall/ multi wall
- ▶ Screen printing & ink jet printing

Graphene

- ▶ Variety of different grades and properties
- ▶ Relative new research are

Printed Antennas

Hirschmann Car Communication

- ▶ Screen printing of silver thick film pastes
- ▶ Printed antennas for
- ▶ AM/FM, TV, GPS, mobile phones...
- ▶ Hidden antennae in rear bumper, side, mirror, cover

- ▶ Specialized in building antennas
- ▶ 86 years of experience
- ▶ Worldwide active company located in southern Germany



- ▶ Realized in for the production of
Audi A 5 convertible
VW T5
MAN

Self-illuminated License Plates

Screen-printed thick film electroluminescent (EL) elements

- 2000 A. Sievers started to develop self illuminated license plates
- 2002 Lumitec (CH) and FER (D) start a similar development
- 2005 FER obtains a temporary license for its product, used for VW's Phaeton
- 2007 A.Sievers obtains a general license from German Federal Motor Transport Authority and sells G-elumic® license plates via internet as aftermarket brand



Electrical connection to the vehicles electrical system:

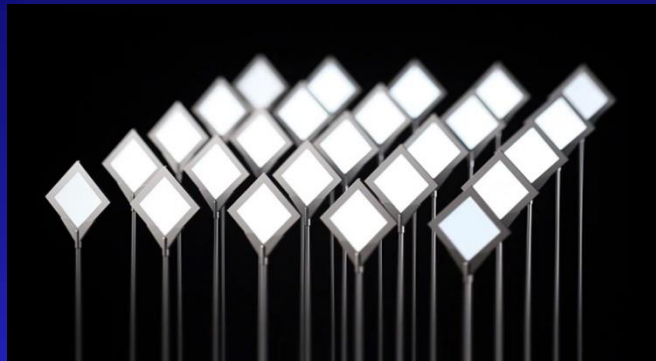


Operating conditions:

- ▶ $U = 100-300 \text{ V AC}$
- ▶ $F = 100-400 \text{ Hz}$

Photos: A. Sievers

Commercial Status of OLED General Lighting



Commercially available

- ▶ OLED lighting elements
- ▶ OLED luminaires (e.g. Ovisio, Winona, Actuity Brands)

	Production Scale	Commercialization	
Philips	Pilot	Lumiblade, sold via internet	Rigid
Osram	Pilot	Orbeos, product information upon request	Rigid
Konica Minolta	Pilot	Symfos, product information upon request, 83.3 Mn USD pilot line	Flexible
Sumitomo	Pilot, "Project-Status"	Polymer LED, Product information upon request	unclear
LG Chem	Pilot	Product catalogue available from web page	Rigid, flexible
GE	Konica Minolta as contract manufacturer	Commercialization started in 2011, case study (US embassy in Helsinki), no product specifications	Most likely flexible

OLED Lighting in Automobiles

Commercial Status:

- ▶ Lexus 2010: small OLED display in the dashboard
- ▶ Audi R18 (race car): AMOLED display as a digital rear-view mirror
- ▶ BMW plans to launch the BMW M4 GTS as first production vehicle with OLED rear lights in 2016
- ▶ Audi showed a concept car with OLED “Matrix Rear Lights” during the IAA 2015



Flexible OLED

Foldable Smart Phone

- ▶ Enlarge display area
- ▶ Commercial phone announced by Samsung for January 2016
- ▶ Bending radius 3 mm
- ▶ Critical component: barrier film

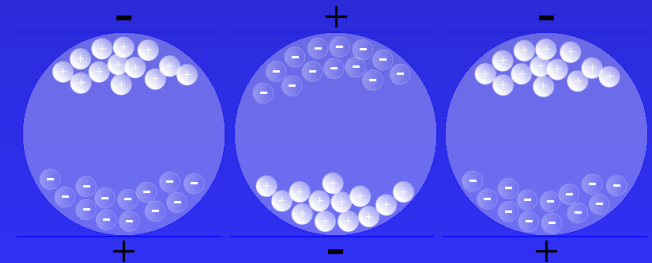
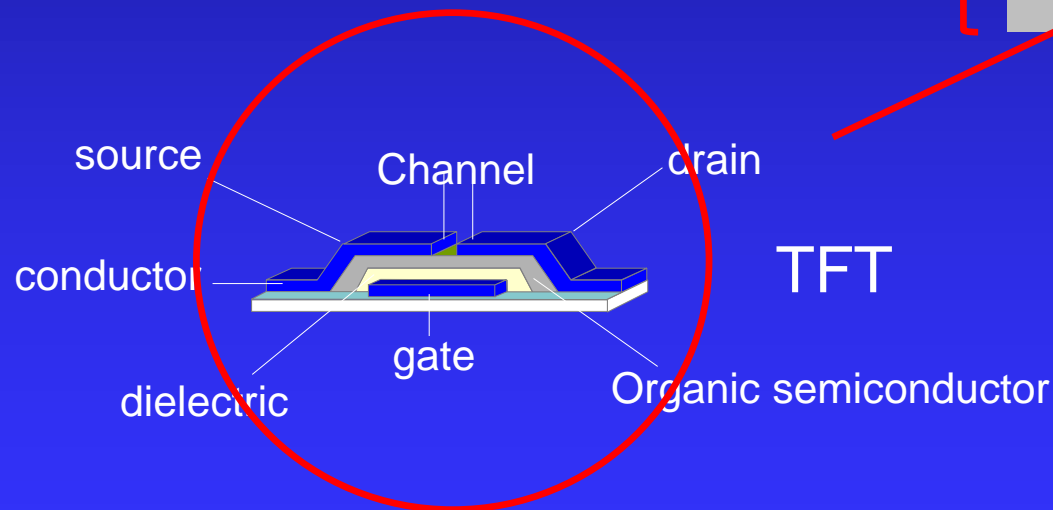
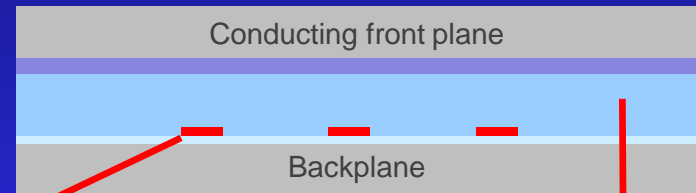


Flexible OLED

Video of LG's flexible OLED at the CES 2016 in Las Vegas



Fully Flexible Electrophoretic Display



Flexible Display Lectum™ of Plastic Logic (source: PlasticLogic)

Polyera's Wove

Polyera was founded 2005

- ▶ Development, production and marketing of organic semiconductors
- ▶ Changed strategy in 2012 to become device manufacturer

Wove

- ▶ Electronic bracelet, Wove announced for 2016
- ▶ Flexible electrophoretic display, Si-based processor, android operating system

Technology Challenges

- ▶ All components (display, processor ...) for Wove are readily available
- ▶ Challenges:
 - ▶ connection technology
 - ▶ Apps, software



Photo: Polyera

Shiftwear: Shoes with displays

Crow funding project

- ▶ 900 T USD supporting money (January 2016)
- ▶ Target: make demo shoes, 1 per supporter

Shiftwear Shoe Features

- ▶ Flexible electrophoretic (ED) display, Si-based processor/controller
- ▶ Battery with walk-n-charge charger
- ▶ Display controlled by app from smart phone

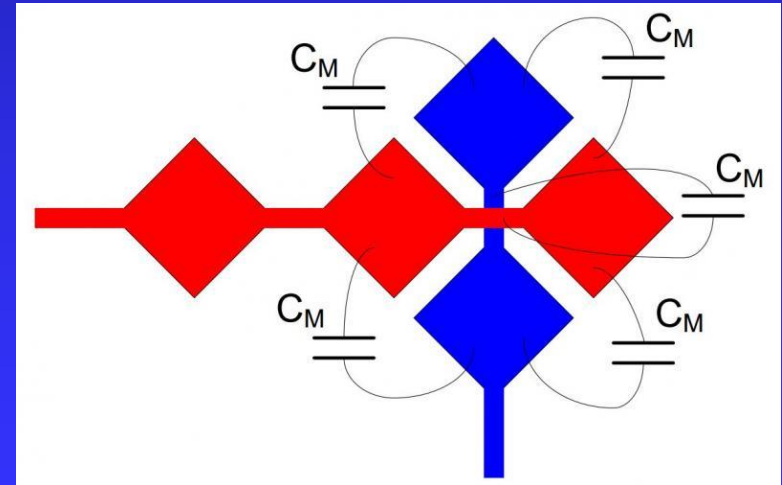
Technology Challenges

- ▶ All components (display, processor ...) are readily available
- ▶ Challenges:
 - ▶ connection technology
 - ▶ robustness
 - ▶ sizes, colors



Touch Sensors

- ▶ Market size ~ 26 Mio. m²/year (2015) ~ 13-14 Bn USD*)
- ▶ Capacitive Touch Sensors > 90 % of the market, dominated by smart phones & tablets
- ▶ Printing opportunities
 - ▶ Contact lines
 - ▶ ITO patterning process (e.g. diamond pattern)
 - ▶ Transparent electrode



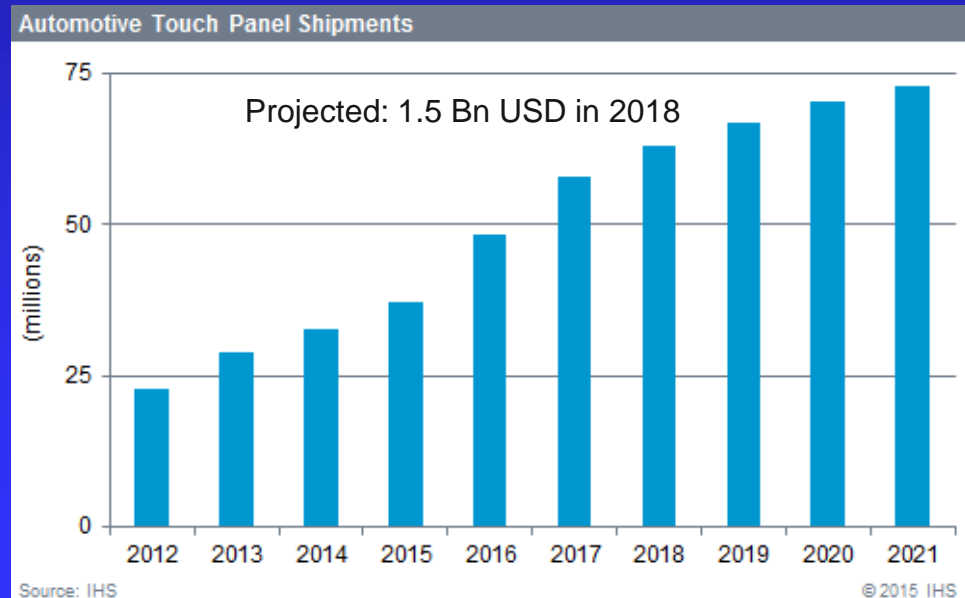
*) IHS, MarketsandMarkets, Touch Display Research

Touch Sensors and Automobiles

- ▶ Touch panel become an integral part of the automobile
- ▶ Capacitive touch switches and touch panels will substitute mechanical switches step-by-step
- ▶ Cost efficiency
- ▶ Freedom of design
- ▶ Integration into injection molded plastic parts



Photo: Toppan Printing



Source: IHS

Summary and Conclusions

- ▶ Both, organics and printing, serve multibillion USD markets today.
- ▶ According to the OE-A Business Climate Survey, enterprises active in Organic and Printed Electronics focus on the markets:
 - ▶ Packaging/Printing
 - ▶ Consumer Electronics
 - ▶ Automotive
 - ▶ Lighting
 - ▶ Pharmaceutical
 - ▶ Energy
- ▶ Materials and manufacturing process steps have to be optimized individually for each targeted product.
- ▶ New products are projected for the near future:
 - ▶ Touch switches replace mechanical switches in cars
 - ▶ Cars with OLED lights
 - ▶ Foldable smart phones
 - ▶ More electronic wearables and textiles

Thank you for your attention