Plastic electronics

<u>General information:</u>

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Lecture notes and additional information can be downloaded from

LTI homepage (protected by a password)

Examination : oral (English or German)

Prerequisite: Quantum mechanics/Semiconductor devices/
Passive components helpful

Outline of the course

What is plastic electronics ?

..we most likely know what electronics is so what is plastics ??

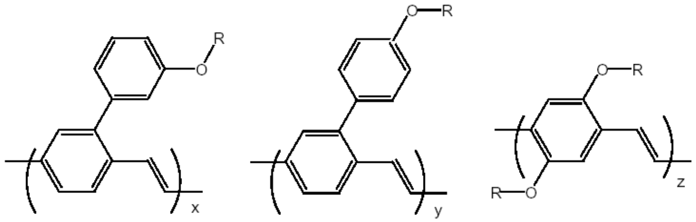
www.wordreference.com:
....any one of a large number of synthetic usually organic materials that have a polymeric structure.

→ it's organic ..

organic chemistry
www.wordreference.com:
… the branch of chemistry concerned with the compounds of carbon: originally confined to compounds produced by living organisms but now extended to include man-made substances based on carbon, such as plastics.

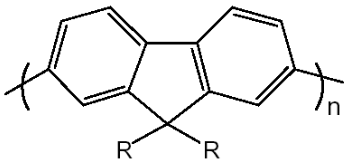
Materials

Conjugated polymers



R = $(CH_2)_3CH(Me)(CH_2)_2CHMe_2$

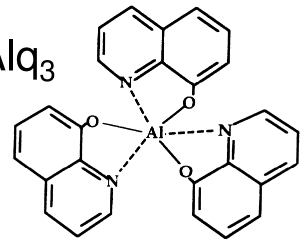
Covion PPV co-polymers

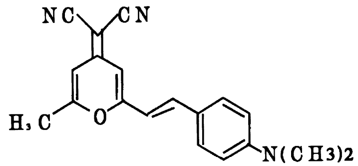


Polyfluorene (Dow)

Small evaporated molecules

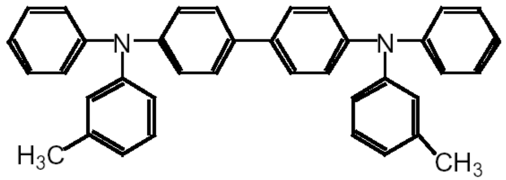
Alq_3



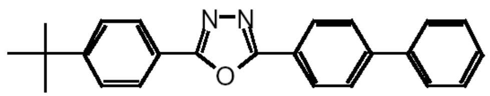


(DCM)

TPD

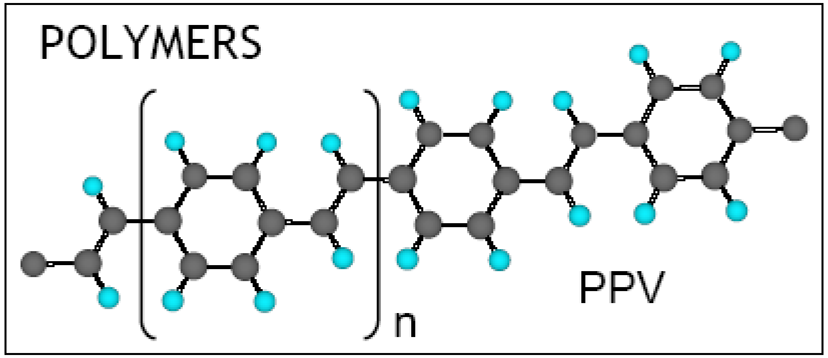


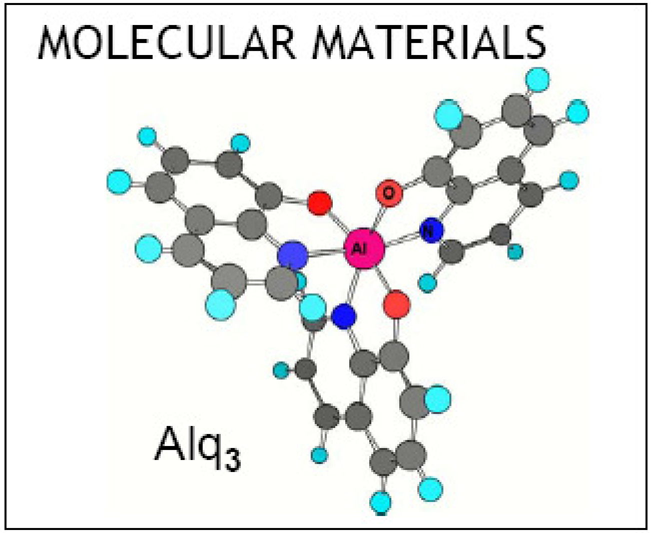
PBD



The preparation of the semiconductor film is very different. The electronic properties, however, are very similar.

What is plastic electronics ?



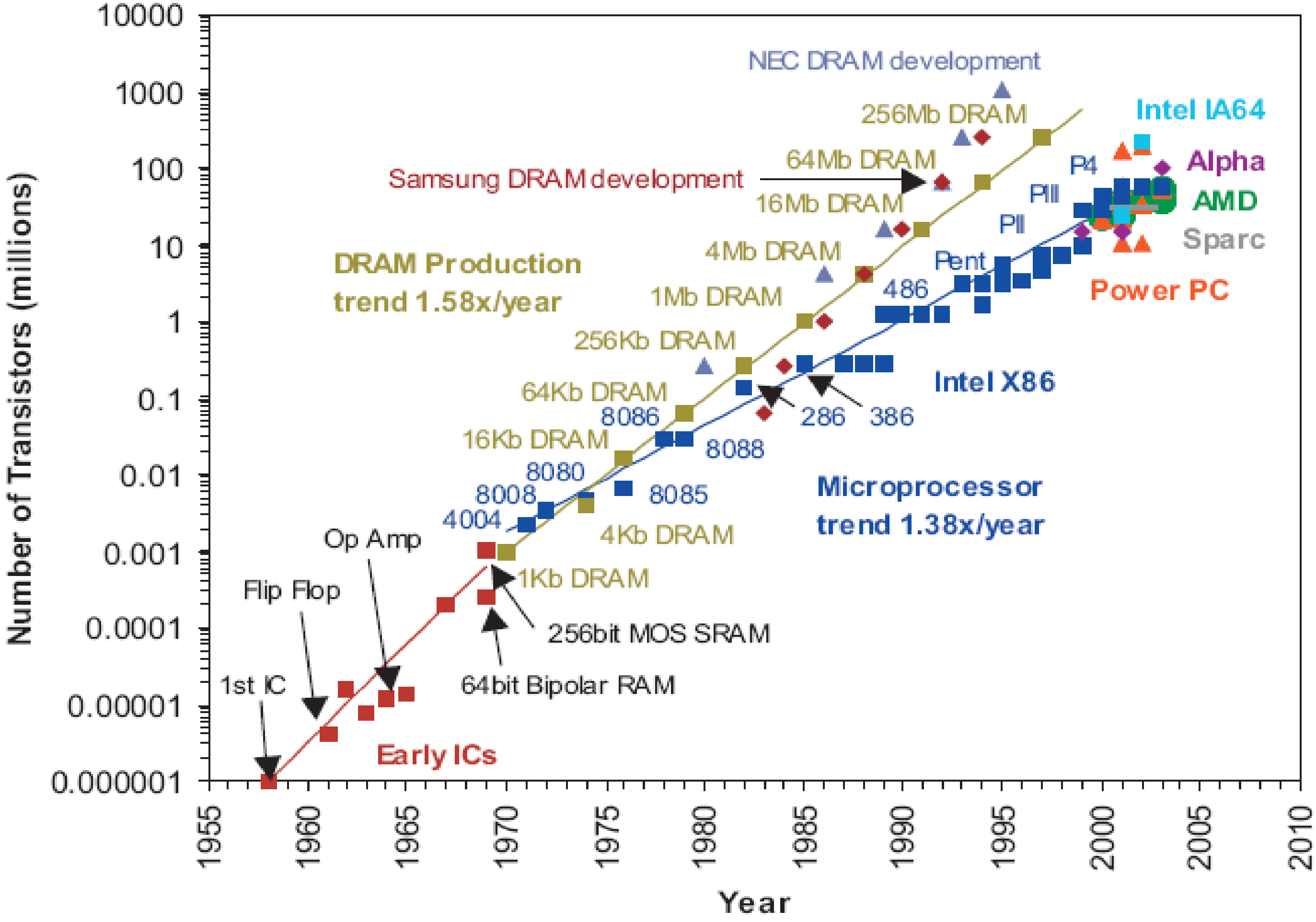


... this is real plastic electronics material

... this is an organic compound that can be deposited onto a plastic material

Why plastic electronics ?

Silicon electronics works quite well and improves rapidly



Source: IcKnowledge

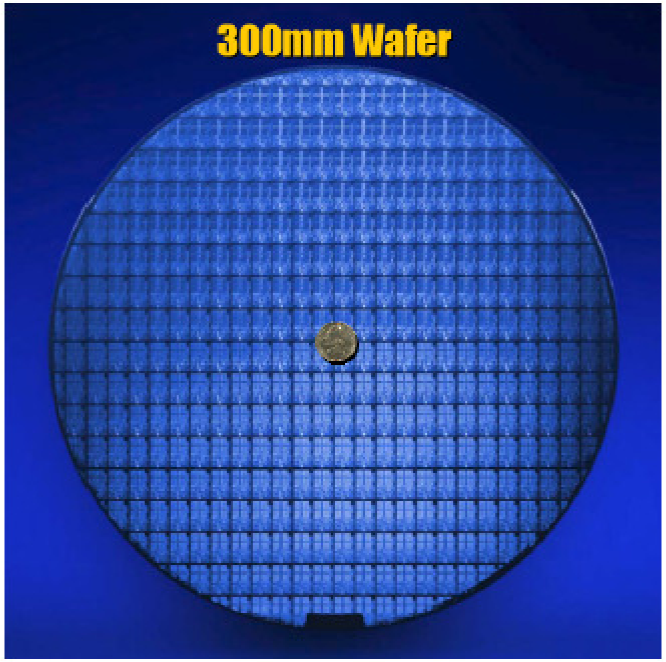
Why plastic electronics ?

... Si-ICs are not produced at low cost
(Case study #1)

... c-Si-fabrication is not large area (≤ 300 mm)

... c-Si is pretty fragile

... Si does not emit light

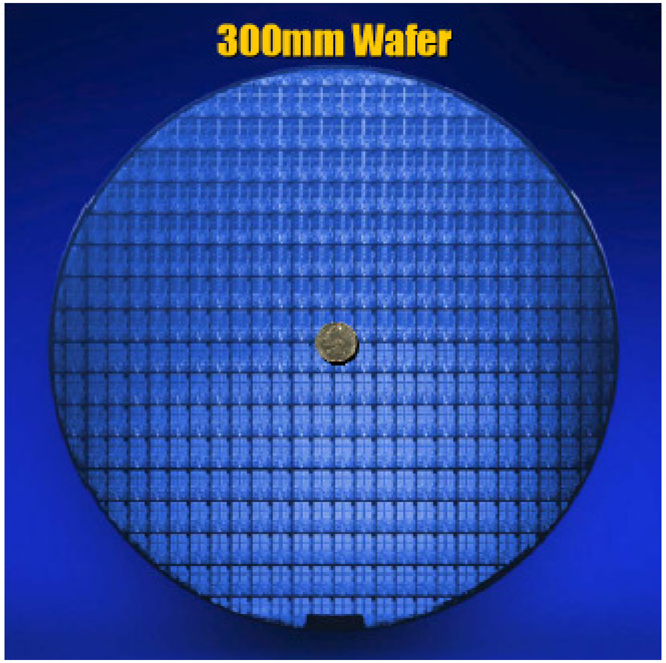


...hey, but how about III-V-semiconductors ??

...well, that‘s right, they do emit light
but they are even more expensive and less large area than Si.

Case study #1

How much costs one transistor in CMOS-Technology ?



Why plastic electronics ?

Some good reasons:

- large area (opto)electronic applications

- low cost applications

- mechanical flexibility

- it can emit light in all colors

- organic chemistry offers many, many compounds (> two millions)

- plastic electronics is currently generating jobs in Germany

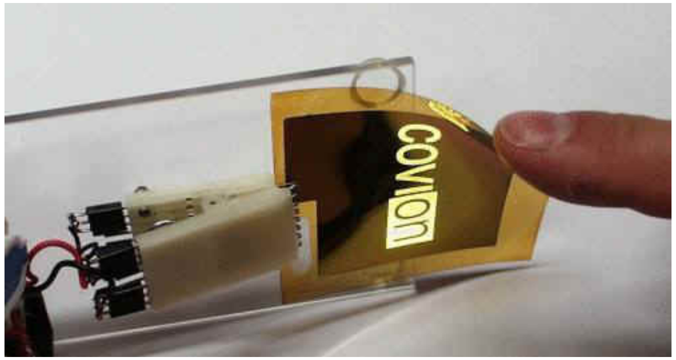
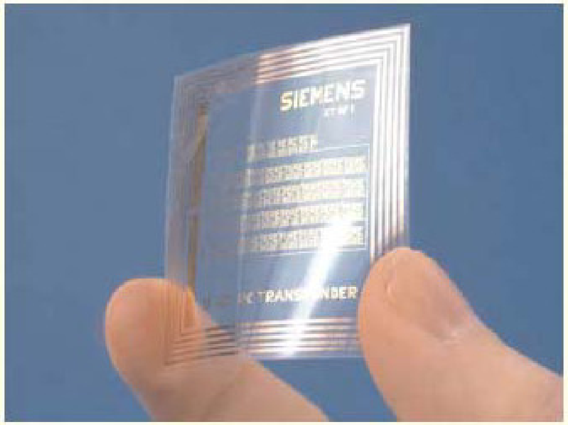


Bild einer OLED (Fa. Covion)



ID-Transponder auf flexiblem Substrat
(Quelle: Siemens)

WWW.merck-oled.de

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Organische Leuchtdioden revolutionieren Lichtmarkt

Taschenlampen im Scheckkartenformat oder Fenster, die bei Nacht als Lichtquellen dienen: Das ist die Technologie der Zukunft. BASF lässt diese Visionen aus sogenannten OLEDs (Organic Light Emitting Devices) in der gemeinsamen Forschung mit Partnern aus Industrie und Wissenschaft Realität werden.

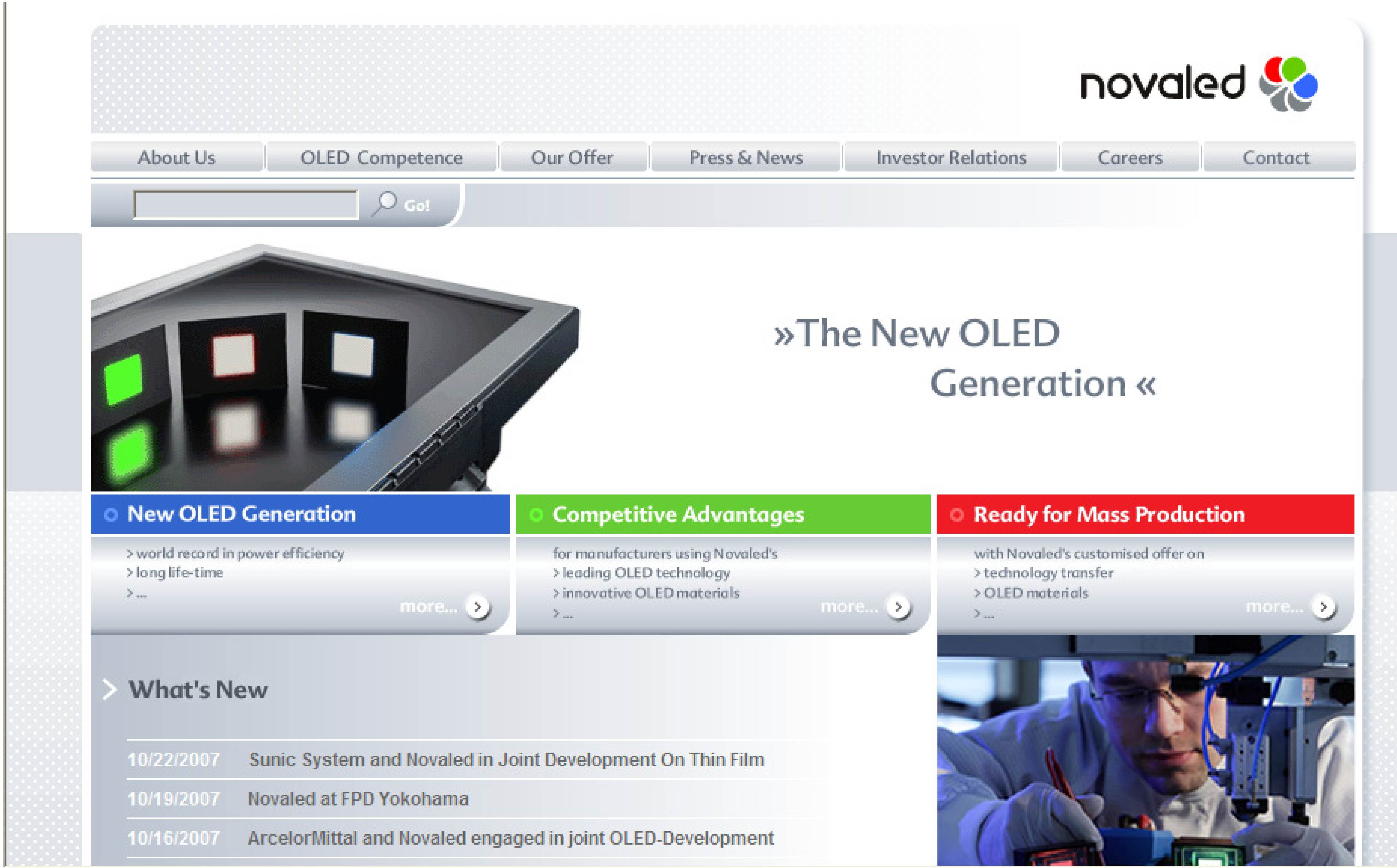
Bei OLEDs handelt es sich um dünne, leuchtende Bauelemente aus organischen, halbleitenden Materialien. Trotz aller Technologie, die in ihnen steckt, sind sie nicht dicker als eine Plastikfolie und können biegsam gestaltet werden. Dadurch bieten sie völlig neue Möglichkeiten für Beleuchtungssysteme: So können die organischen Leuchtdioden als durchsichtige Lichtkacheln an Stelle von Fensterscheiben platziert und Vorhänge zum Leuchten gebracht werden.

OLEDs bieten aber noch handfestere Vorteile. Sie werden voraussichtlich nur halb so viel Strom wie konventionelle Energiesparlampen benötigen und eine längere Lebensdauer haben. Zurzeit sind OLEDs bereits in Displays von Autoradios und Handys eingesetzt. OLED-Lichtkacheln, die herkömmliche Lampen ersetzen können, werden voraussichtlich ab 2011 erhältlich sein.

BASF-Experten forschen gemeinsam mit Partnern aus Hochschule und Industrie im Joint Innovation Lab (JIL), das 2006 in Ludwigshafen eröffnet wurde, an Materialien für organische Elektronik. Mit den Projekten im JIL tragen wir dazu bei, die Position Deutschlands im Wachstumsmarkt "Organische Elektronik" zu stärken. Gemeinsam mit den BASF-Mitarbeitern bilden die Partner ein interdisziplinär zusammengesetztes Team aus Physikern, Ingenieuren und Chemikern.

Diese Seite drucken | Fenster schließen

www.novaled.com



www.microemissive.com

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Our Company's manufacturing facility is
located in Dresden, Germany, in a purpose

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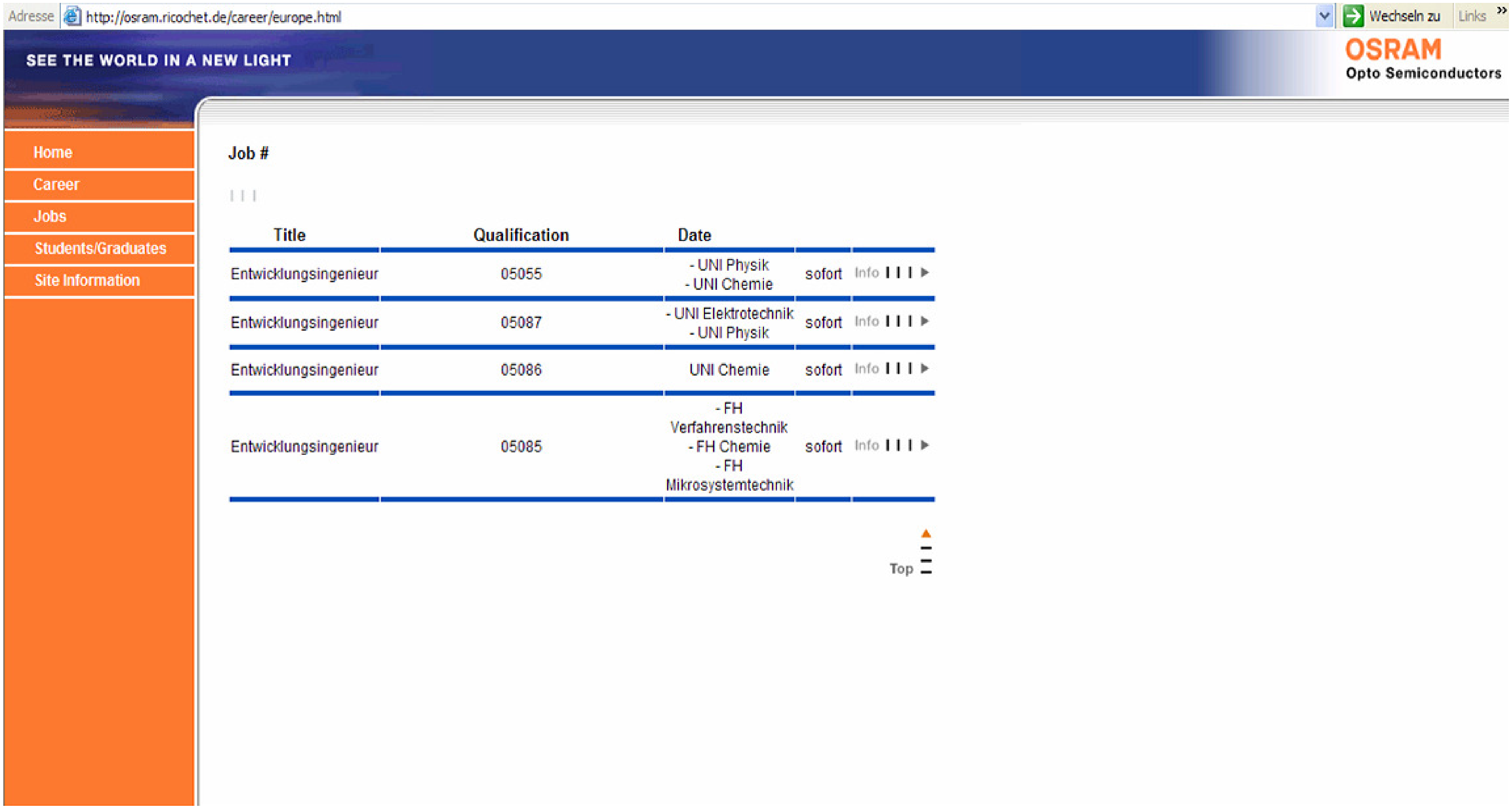
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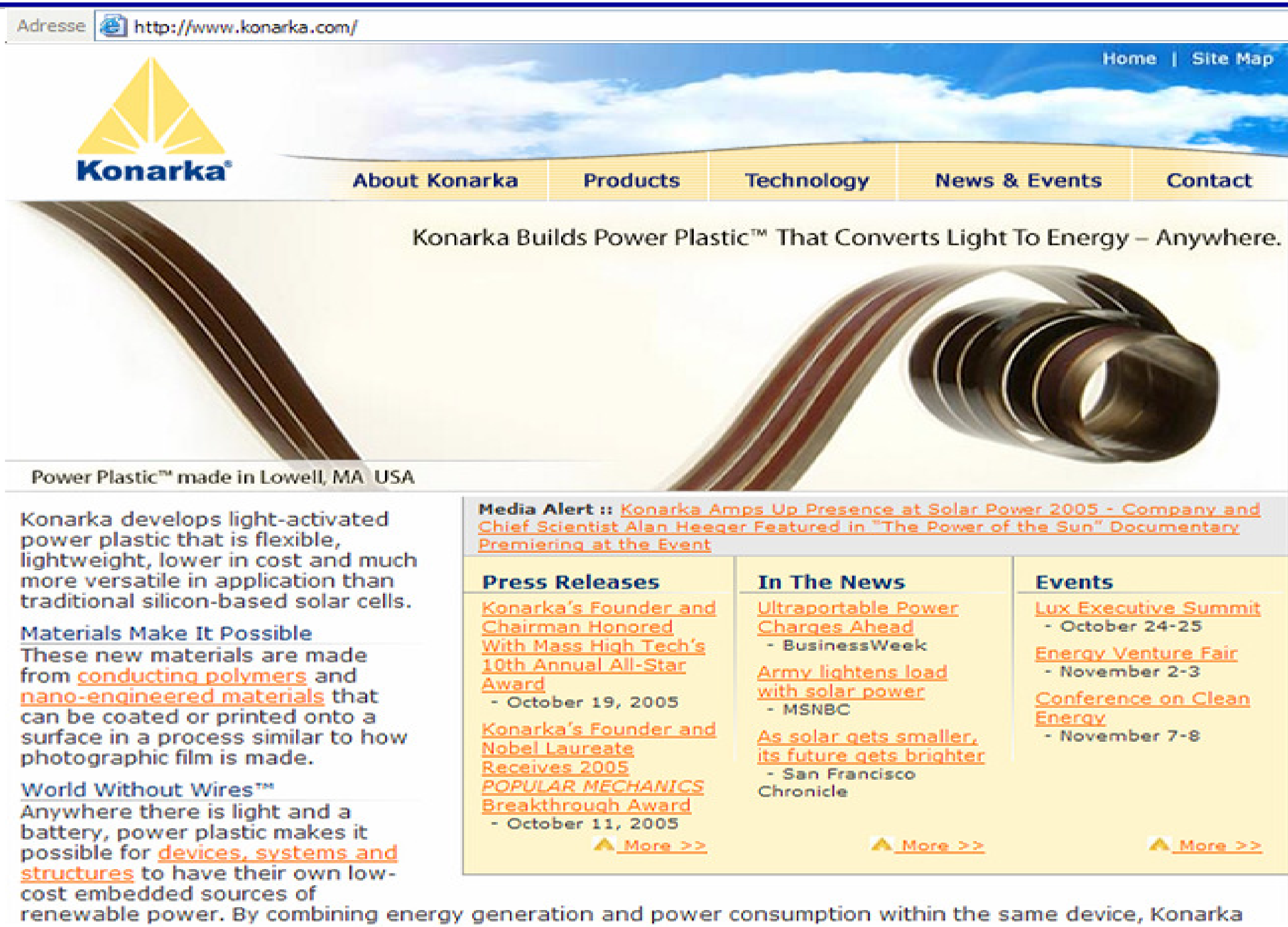
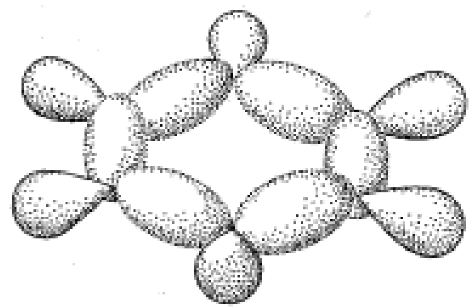
www.konarka.com





(b)

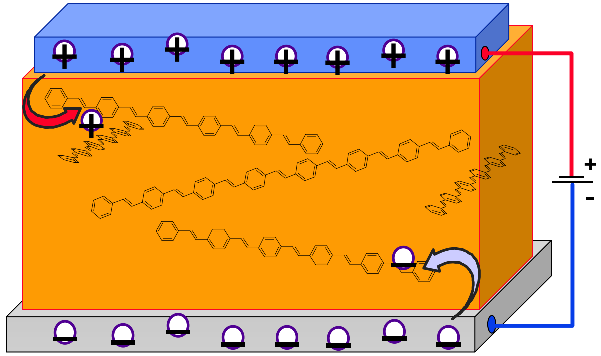
What is a π-electron ??

Are their differences to inorganic semiconductors ??

www.merck-oled.de

What determines the color of the emission of an OLED ?

A typical device consists of 3 layers

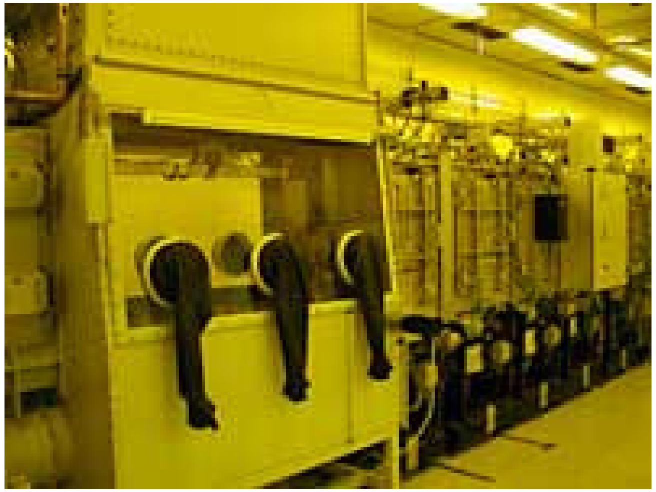


How to drive electrons through a thin piece of plastic ?

1. Introduction
2. Optoelectronic properties of organic semiconductors
3. Organic light emitting diodes (OLEDs)
4. Device and display production
5. Organic FETs
6. Organic photodetectors and solar cells

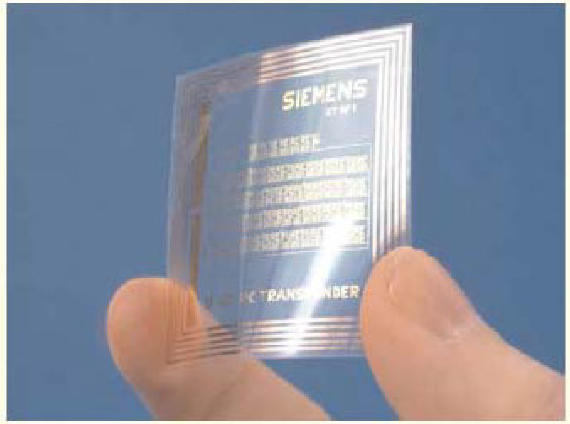
How do you get light out of a piece of plastic ?

1. Introduction
2. Optoelectronic properties of organic semiconductors
3. Organic light emitting diodes (OLEDs)
4. Device and display production
5. Organic FETs
6. Organic photodetectors and solar cells



How do you produce OLEDs on a large scale ?

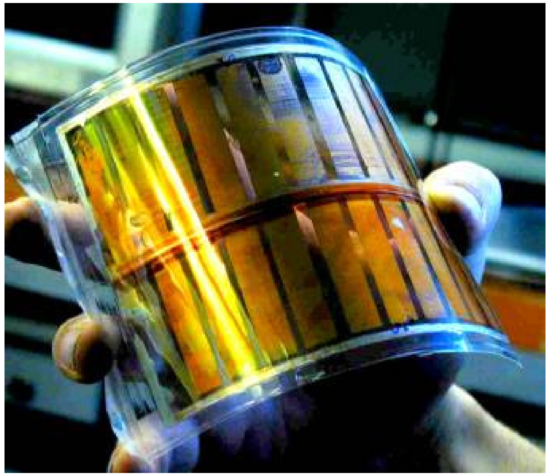
1. Introduction
2. Optoelectronic properties of organic semiconductors
3. Organic light emitting diodes (OLEDs)
4. Device and display production
5. Organic FETs
6. Organic photodetectors and solar cells



ID-Transponder auf flexiblem Substrat
(Quelle: Siemens)

How do you use plastic for information processing ?

1. Introduction
2. Optoelectronic properties of organic semiconductors
3. Organic light emitting diodes (OLEDs)
4. Device and display production
5. Organic FETs
6. Organic photodetectors and solar cells



Large area and low cost …

that could also be useful for

photovoltaics and sensors !

Some remarks on organic electronics history

Scientific Interest in Organic Materials

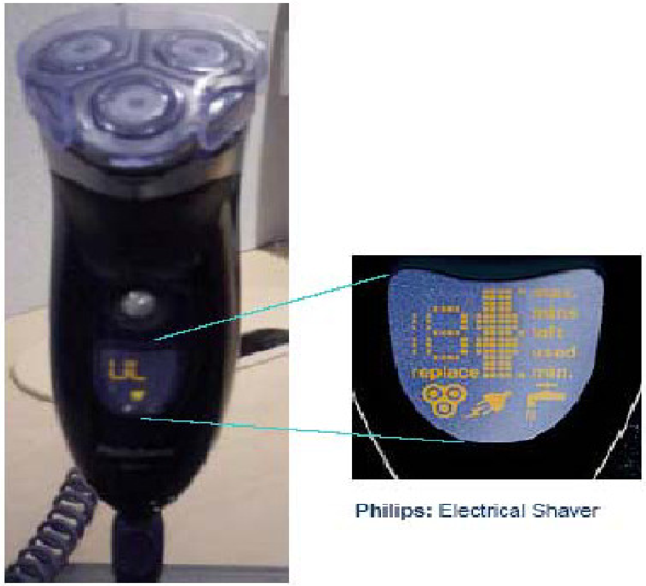
- 1828 - Wöhler first synthesized urea without the assistance of a living organism
- 1950's - steady work on crystalline organics starts
- 1970's - organic photoconductors (xerography)
- 1980's - organic non-linear optical materials
- 1987 - Kodak group published the first efficient organic light emitting device (OLED)
- Since then, the field has dramatically expanded both commercially and scientifically (OLEDs, transistors, solar cells, lasers, modulators, ...)

Source:
Bulovic, MIT

Some remarks on organic electronics history

-a piece of plastic electronics
in our daily life !

Some example products



Philips: Electrical Shaver

Samsung Electronics

conjugated polymers

Evaporated small molecules

A snapshot of the OLED-market

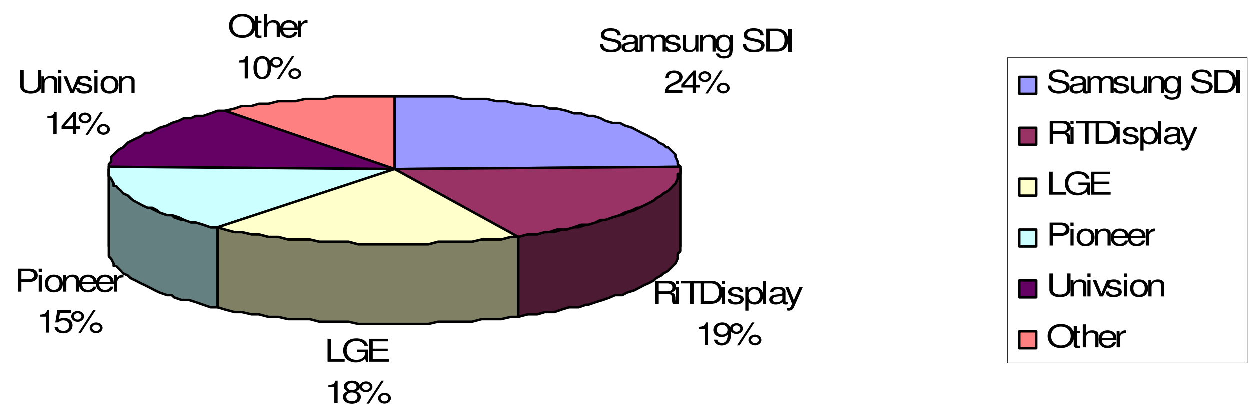
Top 5 Applications in Q2 2005

Rank	Application	Shipments (000)
1	Subdisplay	7,073.0
2	MP3	6,143.0
3	Car Audio	435.0
4	Main Display	331.3
5	Auto Console	157.0
	Others	69.0
	Total	14,208.3

Top 5 revenue Q2 2005

Rank	Manufacturer	Revenue (US$M)
1	Samsung SDI	37.2
2	RiTdisplay	28.1
3	Pioneer	19.6
4	Univision	14.1
5	LGE	6.5
	Others	19.2
	Total	124.8

OLED-market: 3rd quarter 2006



Total: 21 Mio. OLED-Displays

Market shares in the 3rd quarter 2006, Source: DigiTimes

2nd quarter 2007:

Tabelle 1
Die Top 5 der OLED-Hersteller bilden im zweiten Quartal 2007 zusammen ein Umsatzvolumen von 109,8 Millionen US-Dollar, das entspricht einem Marktanteil von 88,9 Prozent. Speziell in den PMOLED-Display Markt (passive matrix organic light emitting diode) sind zwei Anbieter aus China neu eingestiegen: Visionox und Truly.

Rank	Company	Q2'07 Revenue (US$M)	Market Share	Q/Q Growth	Y/Y Growth
1	Samsung SDI	33.8	27.4%	30%	50%
2	Pioneer	24.7	20.0%	-2%	62%
3	RiTdisplay	23.0	18.6%	-2%	67%
4	LGE	22.7	18.4%	-7%	-17%
5	TDK	5.6	4.5%	-5%	-29%
	Others	13.6	11.0%	-29%	-40%
	Total	123.4	100.0%	-1%	13%

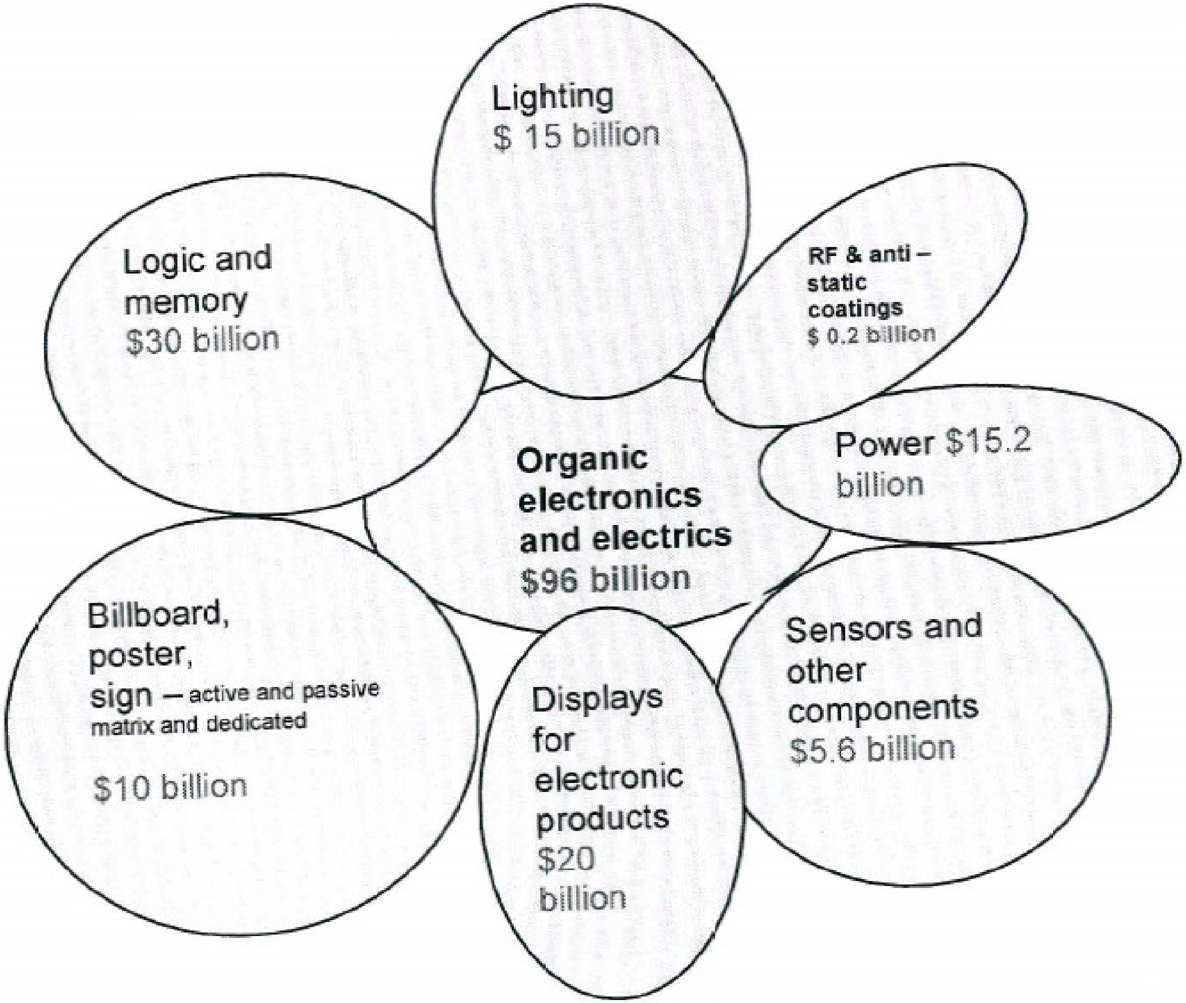
Tabelle 2
Die fünf größten Anwendungsgebiete von OLED-Displays im zweiten Quartal 2007

Rank	Application	Q2'07 Shipments (000)	Market Share	Y/Y Growth	Q/Q Growth
1	Sub-display	14,063	70.9%	77%	12%
2	MP3	3,465	17.5%	-47%	-14%
3	Main Displays	873	4.4%	16%	-11%
4	Car Audio	531	2.7%	35%	-11%
5	Industrial	762	3.8%	295%	-4%
	Other	140	0.7%	12%	0%
	Total	19,834	100.0%	24%	4%

Quelle: DisplaySearch

A more optimistic view

Fig. 7.2 The potential annual global sales of each type by 2020



Source: IDTechEx

Some more introductory impressions

Let‘s watch what the Philips vision was and partly is on that ...

PHILIPS

State of the art

5 inch by Kodak in 2000

40 inch by Epson in 2004
and
Samsung in 2005

Sony 11 inch OLED TV
on the market in Dec. 2007

A visionary device …not yet realized

THE ULTIMATE HANDHELD COMMUNICATION DEVICE

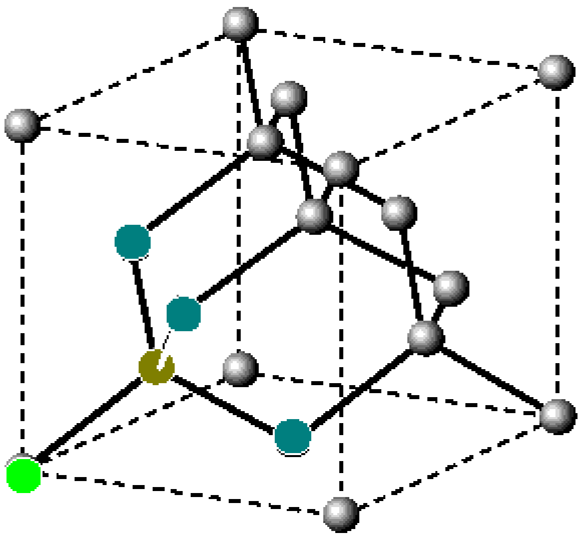
UDC, Inc.

Outline of the course

1. Introduction
2. Optoelectronic properties of organic semiconductors
   - 2.1 Basic electronic properties
     - 2.1.1 Molecular materials
     - 2.1.2 Electronic states in molecules
     - 2.1.3 π-electrons
   - 2.2 Optical properties
   - 2.3. Electronic transport
3. Organic light emitting diodes (OLEDs)
4. Device and display production
5. Organic FETs
6. Organic photodetectors and solar cells

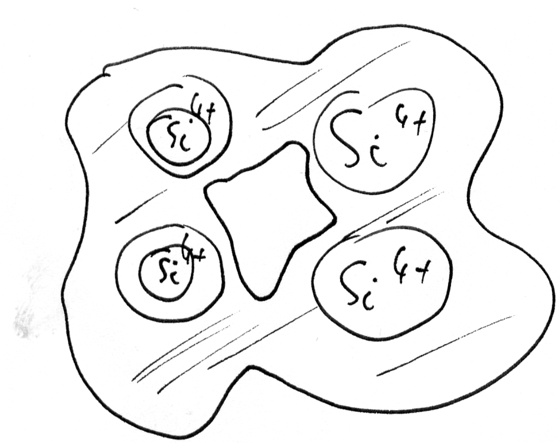
2.1.1: Molecular materials

Important differences to inorganic semiconductors:



diamond structure

Lattice structure of Si

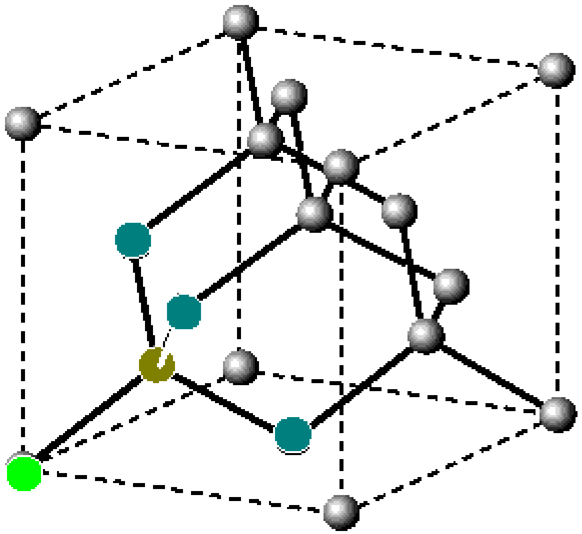


- covalent bond (electrons are shared by atoms)
-strong interaction from one unit cell to the other

↓

- high melting point ($T_{melt,Si}$= 1420 °C)
- delocalized electrons

2.1.1: Molecular materials



diamond structure

-Simplified description of the electronic properties of such crystals due to the periodic potential

$$U(\vec{r}) = U(\vec{r} + \vec{R}) \quad (\vec{R}\text{: lattice vector})$$

-electronic wavefunction can be classified according to the wavevector *k* and the band index n

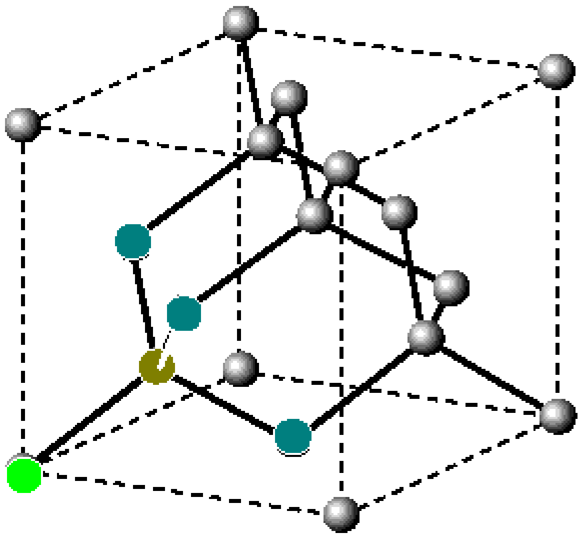
$$\Psi_{nk}(\vec{r}) = e^{j\vec{k}\vec{r}} u_{n\vec{k}}(\vec{r})$$

$$u_{nk}(\vec{r}) = u_{nk}(\vec{r} + \vec{R})$$

(periodic function)

2.1.1: Bloch electrons in inorganic semiconductors

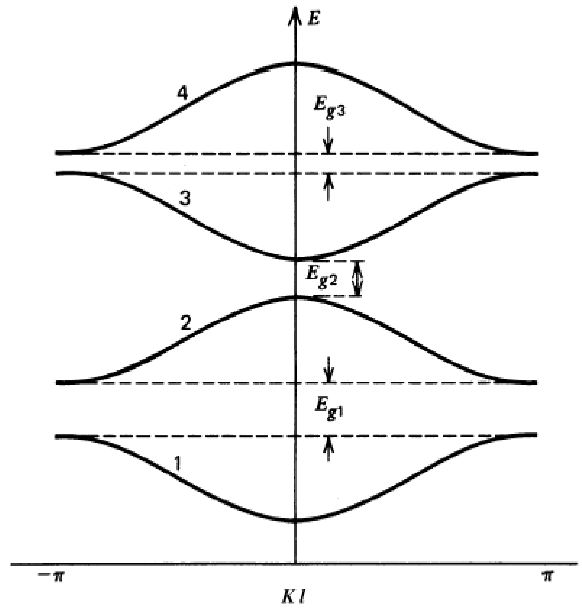
-description of electrons in terms of a *band structure*



diamond structure

„conduction band“

„valence band“

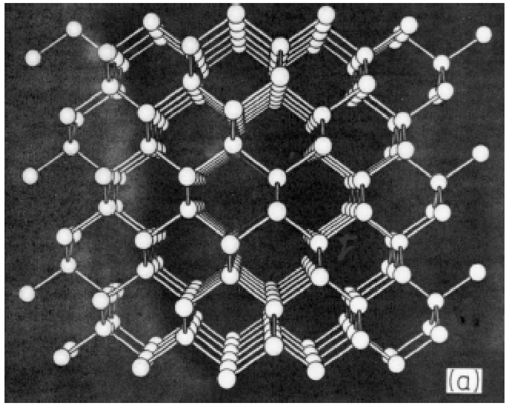


ka

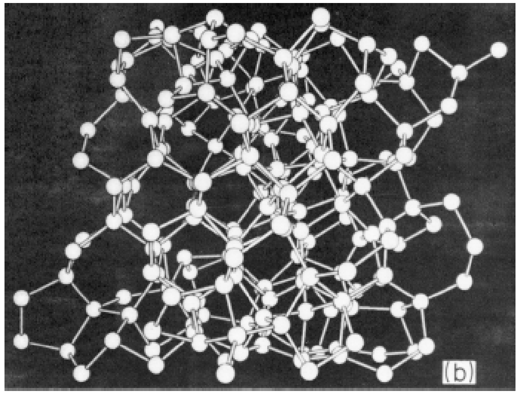
→ Electronic properties and optical transitions are detemined by the crystallinity of the semiconductor material

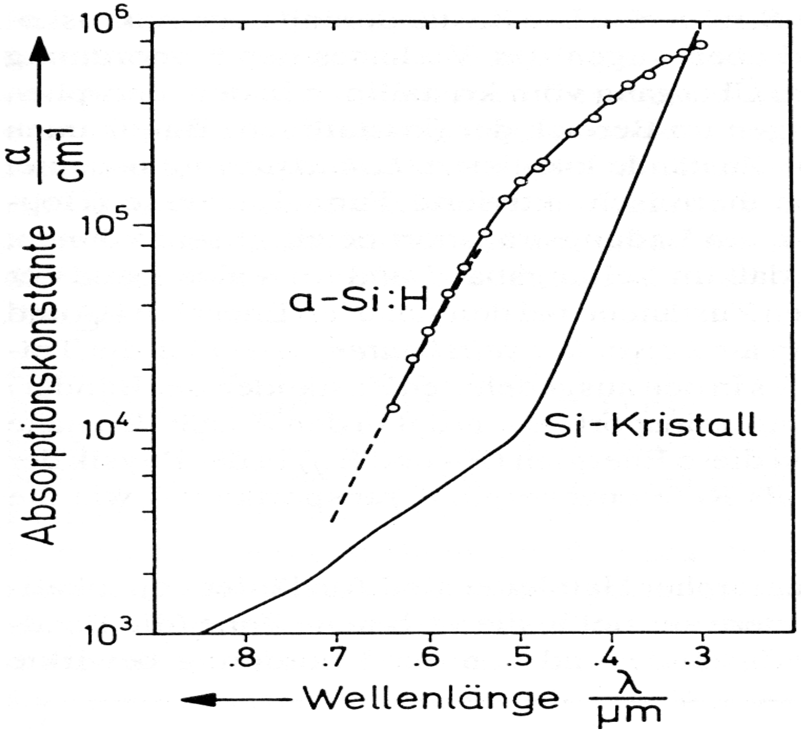
2.1.1: Crystalline vs. amorphous

c-Si



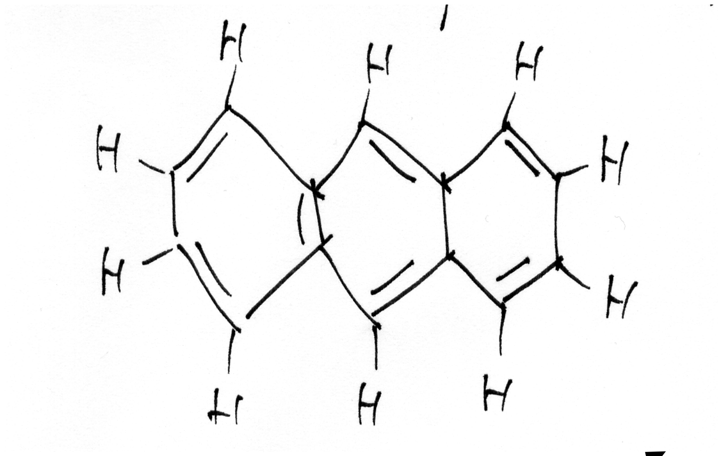
a-Si

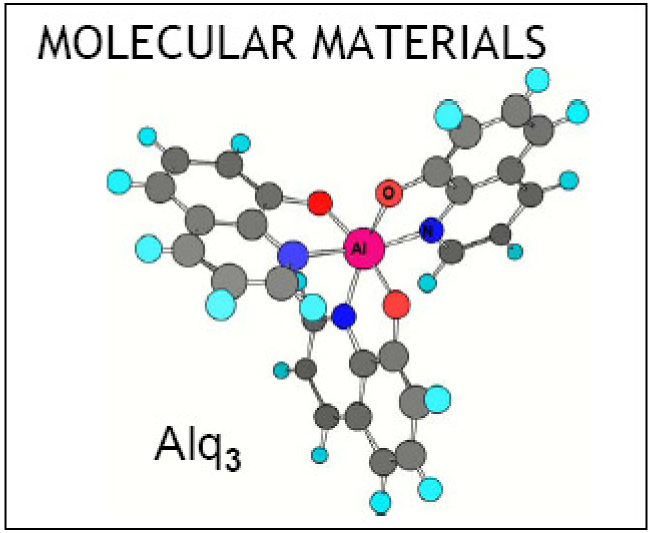




-strong changes when the solid is amorphous instead of crystalline
… and most organic semiconductors are amorphous

2.1.1: Organic solids





Anthracene

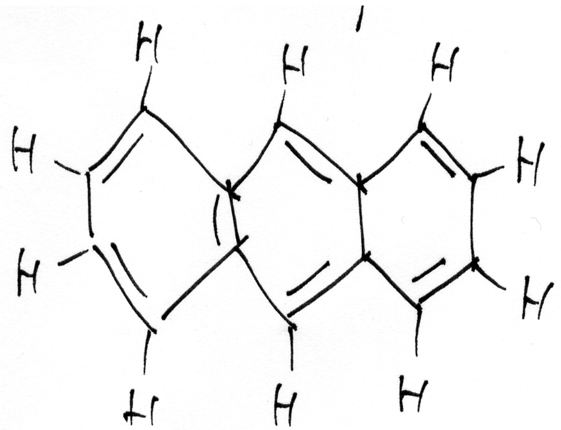
Organic semiconductors can be crystalline or amorphous

-solid is formed by van-der-Waals (dipole-dipole) interaction
i.e. electrons still belong to one unit cell

2.1.1: Organic solids

- weak interaction from molecule to molecule

low melting point
($T_{melt,Anthr.}$=217°C)



weak delocalization of electrons
(... transport might be hard)

-electronic properties do not stronly depend on the environment

-very similar optical properties in the solution and in the solid state