Novaled AG

Technology Entrepeneurship am KIT 2.2.2011

Jan Blochwitz-Nimoth, Founder, CSO Novaled AG

Outline

- Novaled development 2001-2010
- Novaled management tools
- Novaled technology: doping, OLED, other organic electronics

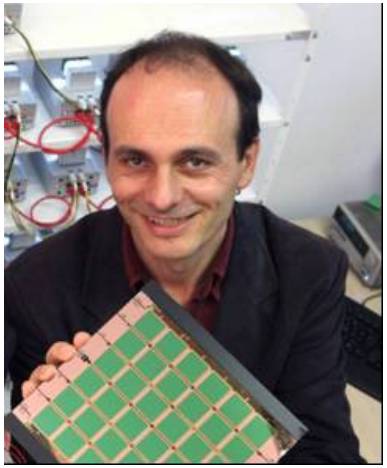
  Novaleds markets: OLED display, OLED lighting, OPV, Electronic

Novaled at a Glance

Foundation and Legal form	› 2001 by Karl Leo, Jan Blochwitz-Nimoth, Martin Pfeiffer, Jörg Amelung as a spin-off of TU Dresden and FhG to commercialize OLED technology › Stock corporation by March 2006
Today	› World leader in energy-saving in the field of small-molecule OLEDs and OLED applications with the Novaled PIN® technology and materials
Turnover and Financing	› 2010: €11.2 Mio. (2009: €8.1 Mio.); CAGR: >30% in the last 3 years › Venture capital funded, 3rd round of financing in 2009
IP	› > 400 patents, the largest number in the molecular (organic) doping field
Personnel	› A business driven organization with skills in Physics, Optics & Chemistry; Assembly & Manufacturing; Marketing & Sales › Headcount: 100
Offices	› HQ: Dresden with presence in Japan (office), Taiwan and Korea (agents)

Novaled founders team 2001-2003

Prof. Karl Leo
- Prof. TUD-IAPP
& Institutsleiter Fraunhofer;
- Involved in Spin-Offs: CreaPhys, Novaled, Sim4Tec, Heliatek, LedOnOLED



Dr. Martin Pfeiffer
- PhD at IAPP on doped organic semiconductors
- co-founder of Heliatek

Dr. Jan Blochwitz-Nimoth
- PhD at IAPP on PIN-OLEDs

Jörg Amelung
- physics Uni Darmstadt, Elektronik
- co-founder of LedOnOLED

Involvement of TU Dresden and Fraunhofer

TU Dresden

- Framework Agreement closed before 1st financing round (conditional)
- TUDAG becomes shareholder of Novaled
  - TUD profits from value development of Novaled without limiting freedom to operate for Novaled
- Novaled has first right to purchase IAPP IP on Organic electronic
- Intensive scientific cooperation agreed

FhG-IPMS

- Framework Agreement on cooperation closed before 1st financing round
- Fraunhofer role: help bridging transition from idea to product

Novaled's co-operation with TU Dresden

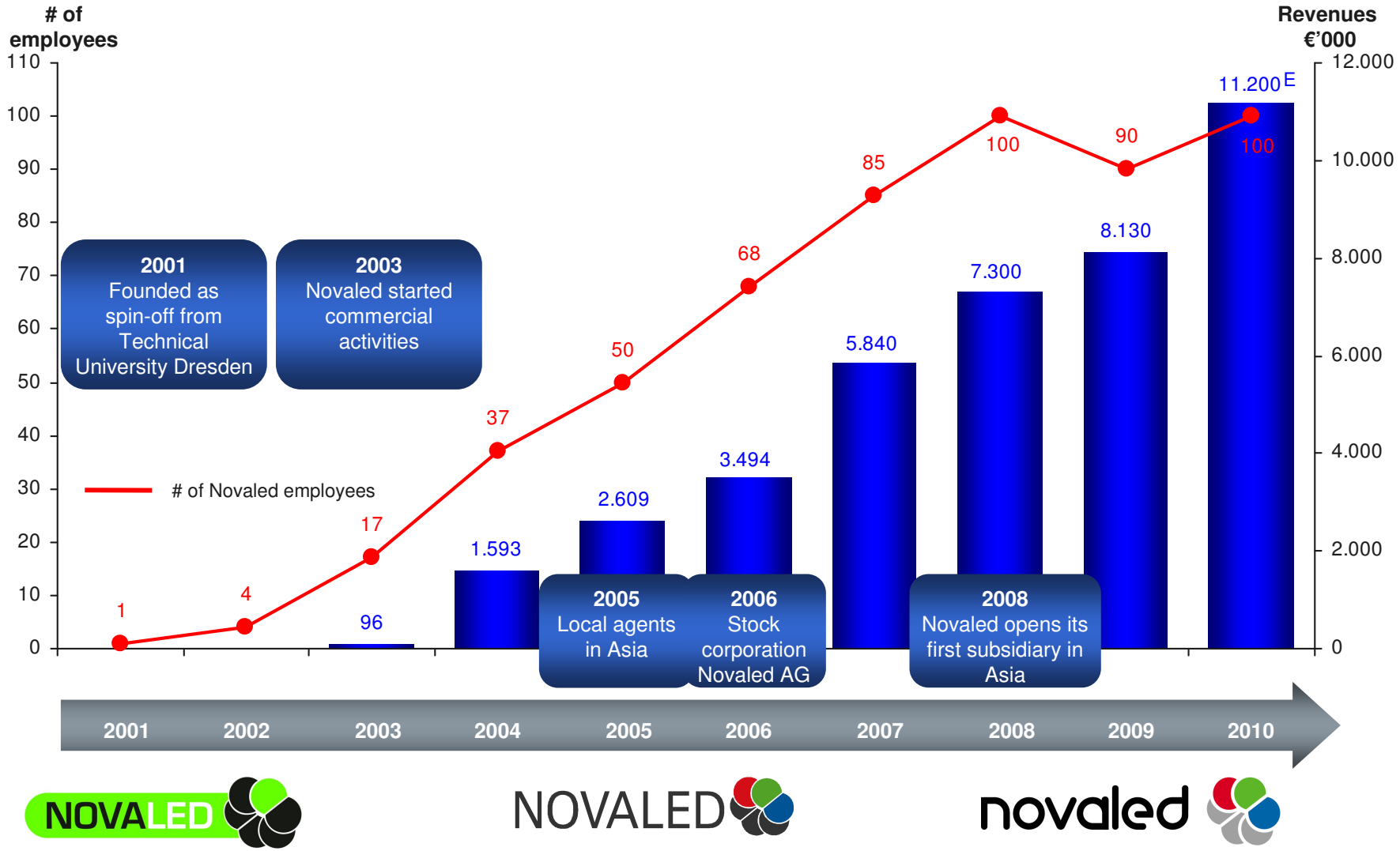
At the beginning:

- Co-use of laboratories
- First offices
- Sample production for University
- Hiring people
- Partially parallel development

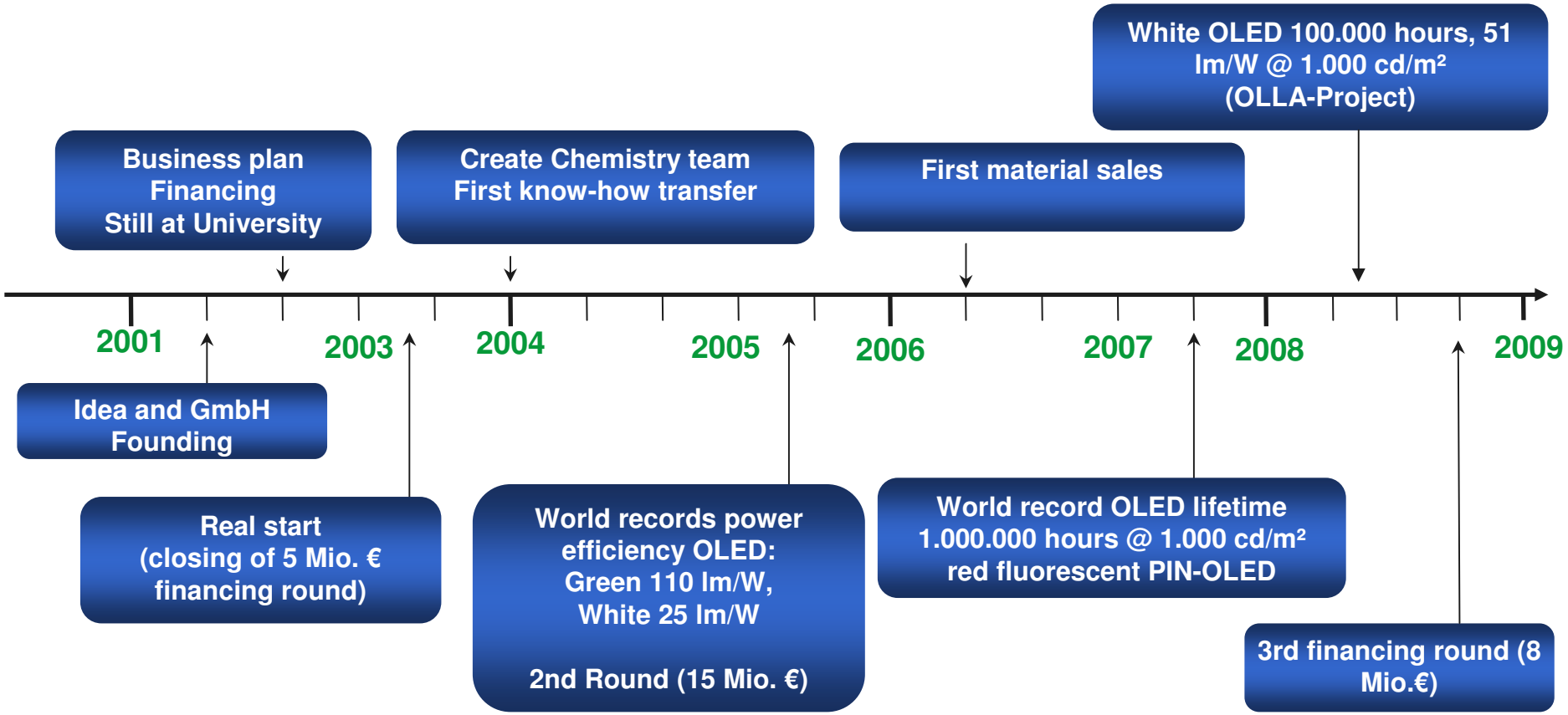
Today:

- Novaled finances basic research project
- Cooperation in local networks
- Discussion on lower levels
- Make know-how available (e.g. equipment) in both directions

Novaled - A Unique Growth Story



Our Way


White OLED 100.000 hours, 51 lm/W @ 1.000 cd/m² (OLLA-Project)
Business plan Financing Still at University
Create Chemistry team First know-how transfer
First material sales
2001
2003
2004
2005
2006
2007
2008
2009
Idea and GmbH Founding
Real start (closing of 5 Mio. € financing round)
World records power efficiency OLED: Green 110 lm/W, White 25 lm/W
2nd Round (15 Mio. €)
World record OLED lifetime 1.000.000 hours @ 1.000 cd/m² red fluorescent PIN-OLED
3rd financing round (8 Mio.€)

Financial Backing by Leading Capital Firms

Public Funding

- Novaled fast growth not possible without public funding
- Even before 1st round of financing: verbal commitment by Saxony to support a Novaled project

- Financial support by public funding from
  - Saxony: early phase, more early stage projects
  - BMBF: OLED and OPV Initiatives
  - BMWA: smaller SME related projects
  - EU (FP6, FP7, mainly ICT program): OLED lighting

Gefördert aus Mitteln der Europäischen Union

Europa fördert Sachsen. EFRE Europäischer Fonds für regionale Entwicklung

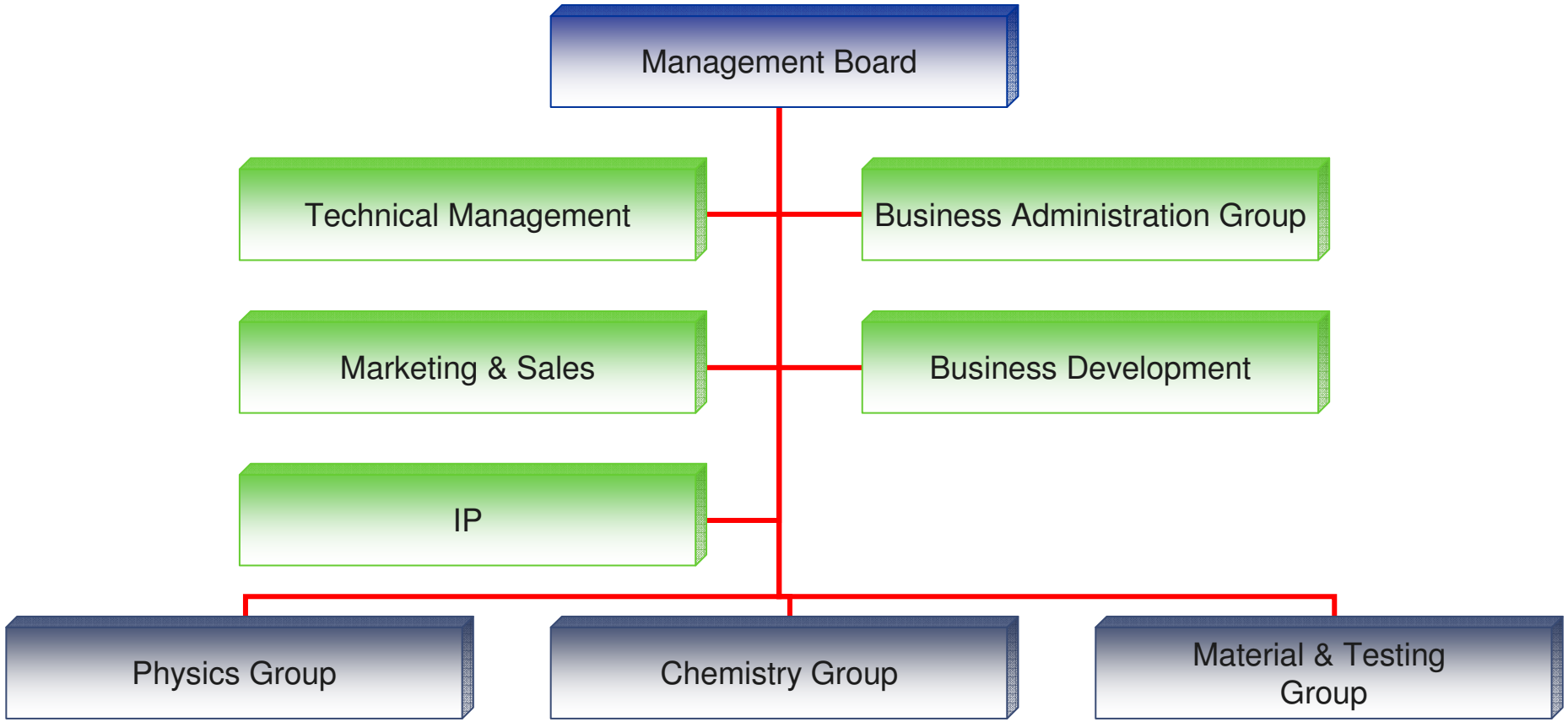
SPONSORED BY THE Federal Ministry of Education and Research

SEVENTH FRAMEWORK PROGRAMME

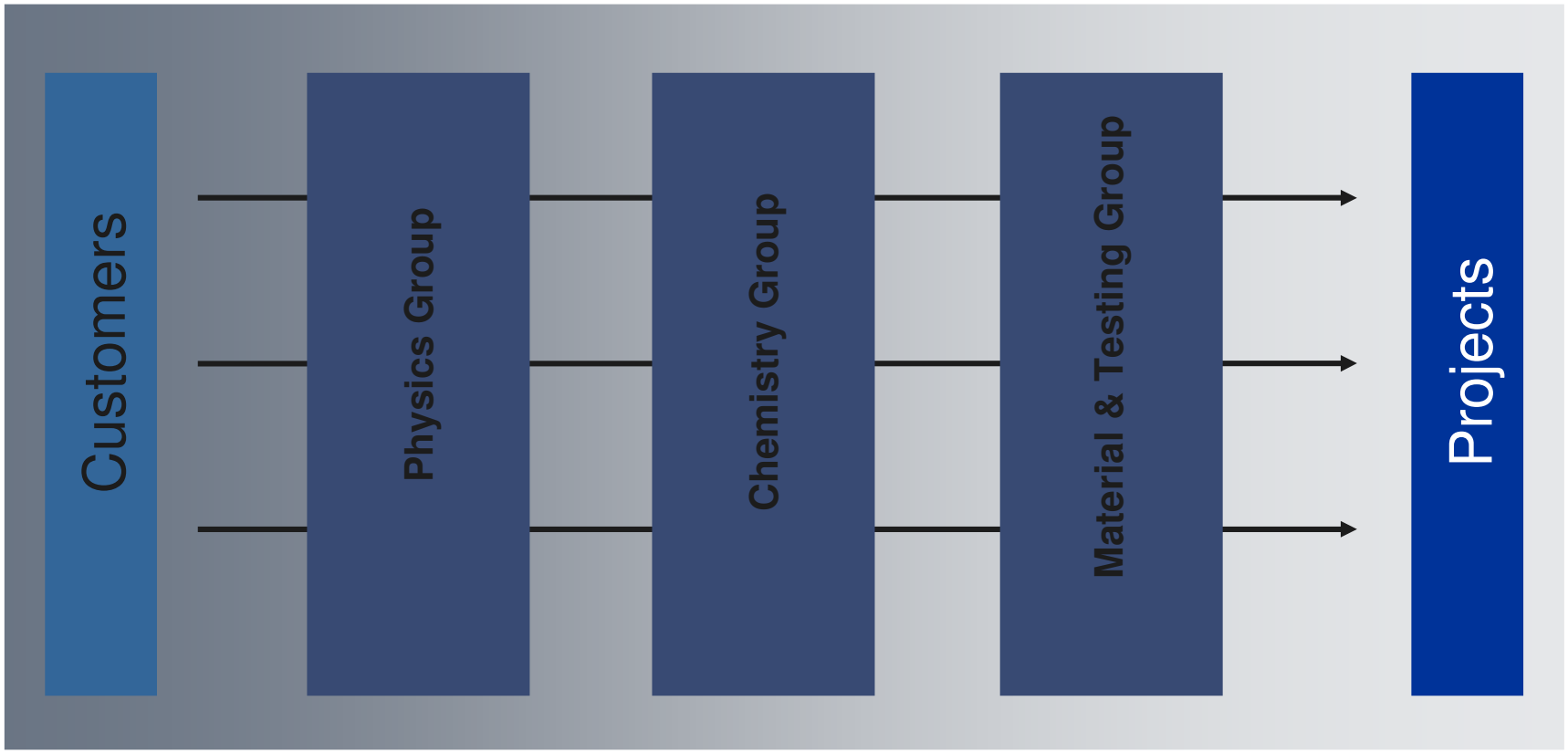
Novaled Organization development

- ‘Letterbox company’: 2001-2003
  - Founders are still at University or Fraunhofer
- GmbH (German limited liability company): 2003-2005
  - 2 Managing Director (Geschäftsführer)
  - Supervised by Advisory Board (4 members)
  - 3 Groups (Physics, Chemistry, Manufacturing&Testing)
  - Project driven matrix structure
- AG (stock corporation, non-traded): 2005-today
  - 3 Management Board Members (Vorstände, first CEO, CTO, CFO; today CEO, CFO, CMO)
  - Supervised by Supervisory Board (6 members: 4 risk investors, 1 founder, 1 industry)
  - 3-4 Groups, project structure changes every 1-2 years
  - In 2009: created business line structure (stopped matrix organization)

Novaled Organisation around 2007: matrix structure I



Novaled Organisation around 2007: matrix structure II



Cross-functional-organisation

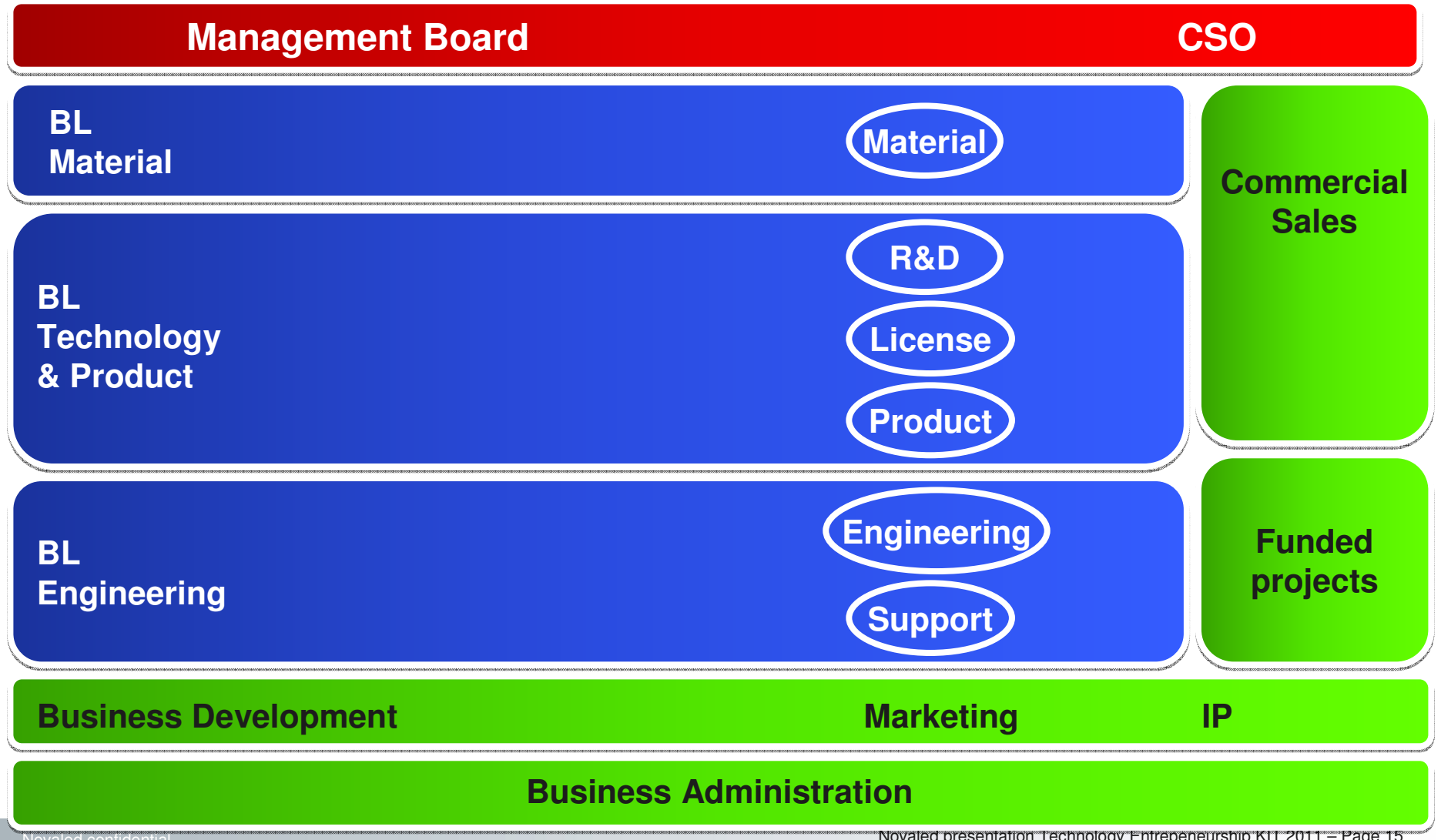
Novaled managing directors and later Management Board 2003-2009

Gildas Sorin (2003)
Managing director, later CEO;
Background in Electronics, Manager in Thomson and Philips

Dr. Jan Blochwitz-Nimoth (2001)
Managing Director, later CTO,
Background in Physics, Optics

Harry Böhme (2006)
CFO
Backround in Legal, Finance, Manager in Intershop

Novaled organization 2010



Novaled Management Board 2011

Gildas Sorin

Chief Executive Officer
Director

- 30 years international exposure
- Long high tech business management experience

Harry Boehme

Chief Financial Officer
Director

- 18 years experience in corporate law and corporate finance in high tech industries

Gerd Guenther

Chief Marketing Officer
Director

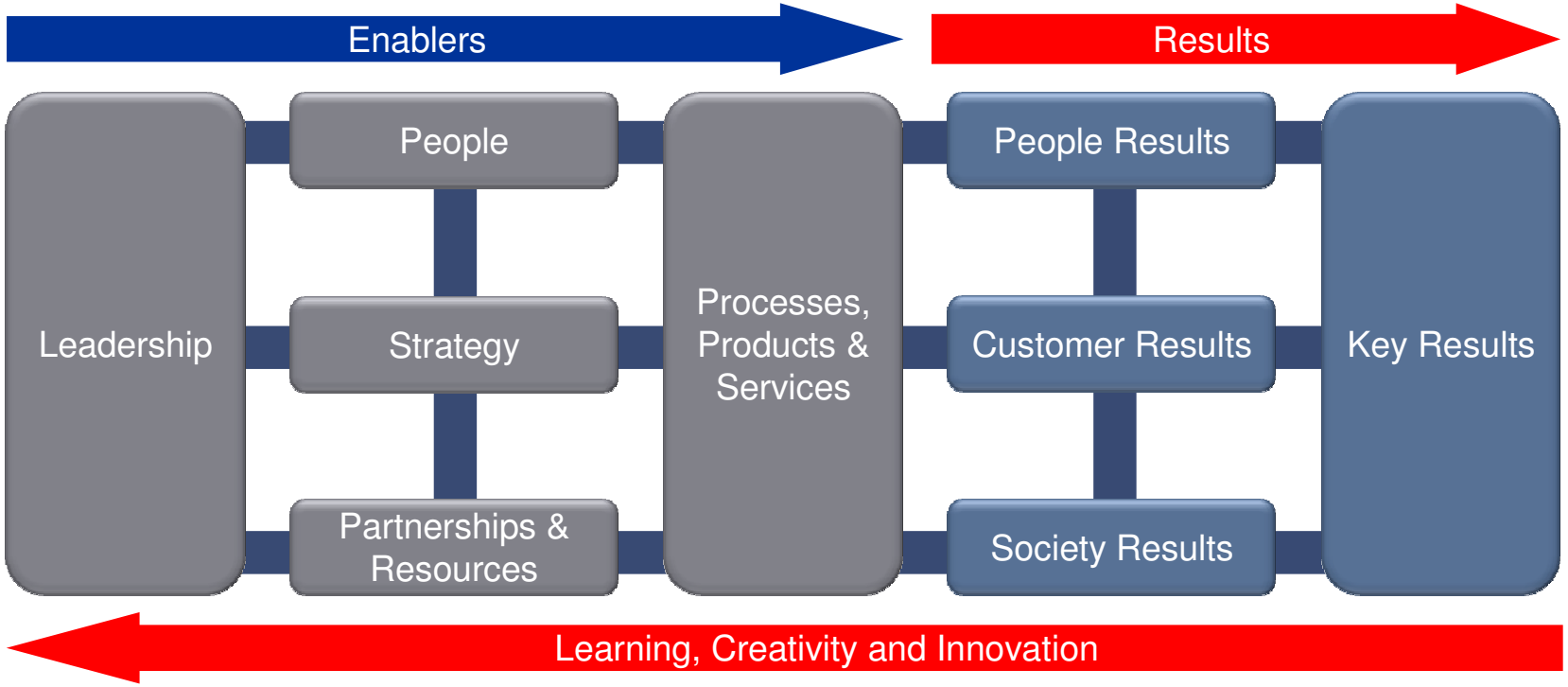
- 20 years international and management experience in the consumer electronics field

Novaled and Quality management

- 2001-2003
  - nothing
- 2003 till 2006
  - Implementation of first management tools (BBS, PPS)
  - To be considered: research staff usually skeptical
- 2006 - today
  - Decision for EFQM: total quality approach
  - Circumvent ISO as long as possible (due to fabless approach this is feasible)
  - EFQM Committed to Excellence Award 2008
  - Quality Audits passed
  - EFQM Excellence 5 Star Award 2010
    - Seems rare at such early stage
- 2011:
  - ISO to be done (customer request with growing business)

Novaled - an Active Member of the European Foundation for Quality Management (EFQM)

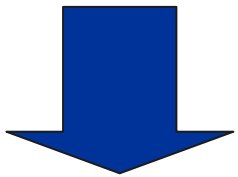
- Novaled's Total Quality Approach
- EFQM-Model of Excellence as management framework



EFQM
Shares what works.

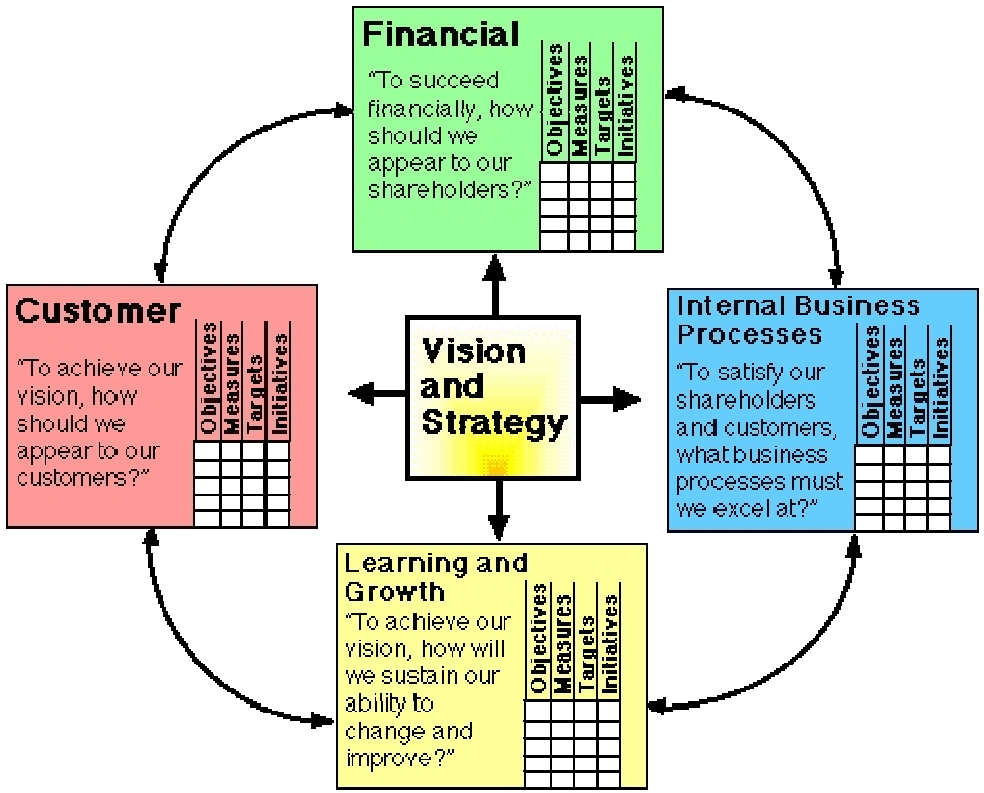
Business Balanced Scorecard (BBS)

- Target:
  - Performance Measurement
  - Managing Performance
  - To hold everyone responsible for the Company business objectives
- Focus on the crucial factors - Critical Success Factors (CSF) - for business success/ achieving the strategic goals and creating value



- Present the factors in a chain of four perspectives

BBS - Four Perspectives



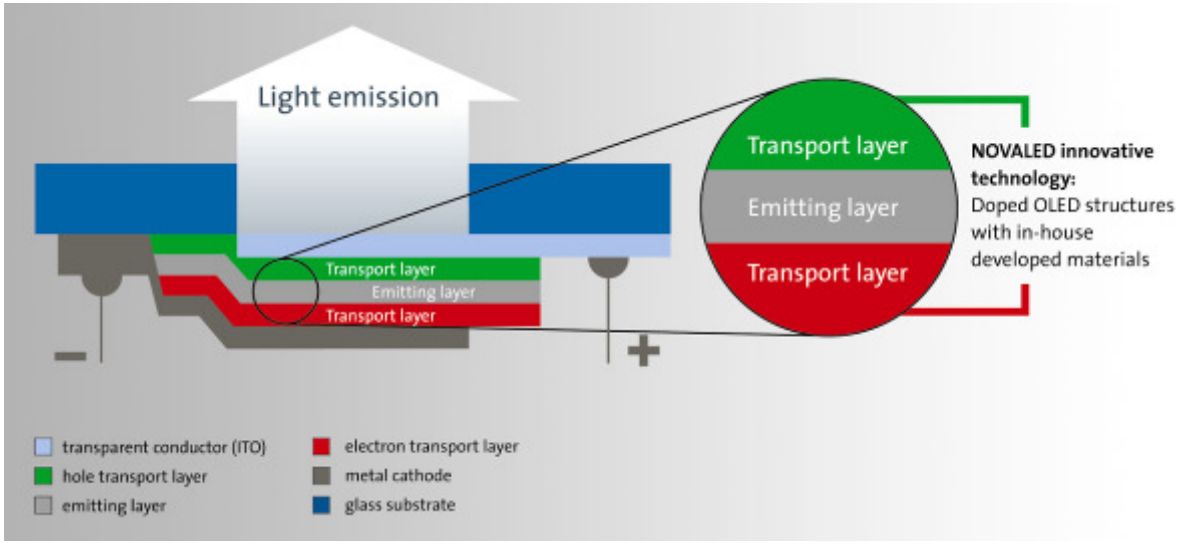
Key performance indicators (KPI's) to measure the critical success factors have to be

SMART:

- *Specific,*
- *Measurable,*
- *Ambitious,*
- *Realistic,*
- *Time phased*

Novaled Technology & Markets

Novaled OLED Technology



Basic OLED scheme bottom emission

Novaled develops an innovative highly efficient OLED structure based on proprietary doping materials

World Leader in Power Efficiency

OLED Benefits

- Ultra Thin (<150 Nanometer)
- Excellent color and contrast
- 180° viewing angle
- Large area diffuse light source
- Transparent

Advantages for Novaled Customers

- Extremely low operating voltage
- Highest efficiency
- Inverted, top-emitting structures
- Transparent, metal-free OLEDs
- Easy integration on all substrates

Organic Semiconductors

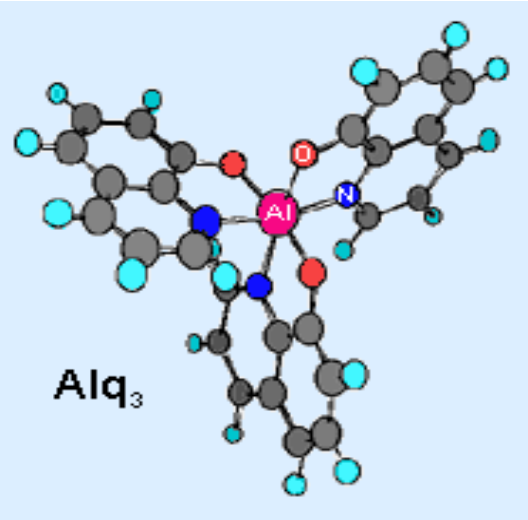
Delocalized pi-electron systems, Example: Benzene

Source: T. Däubler, Botest systems

- **Electrons are delocalized over the molecule**
- **Positive and negative charges can be stabilized**
- **π-systems enable hopping between molecular sites**

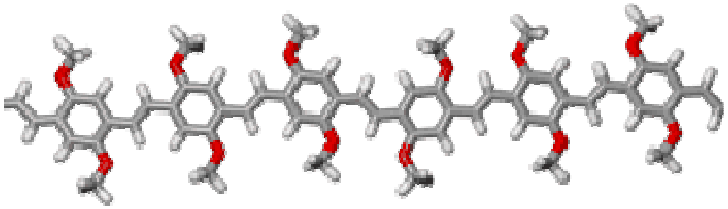
OLED Materials

Small Molecules



Technology: Evaporation

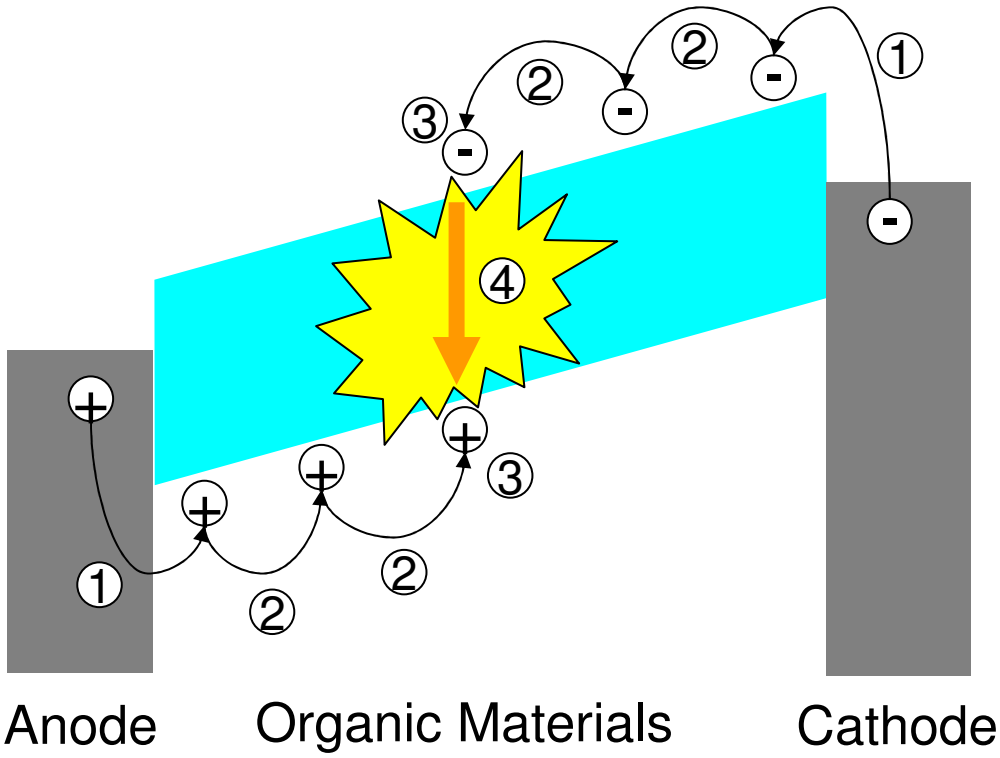
Polymer



Technology: Spin-On/Ink-Jet

Source: Covion

What happens inside the OLED?



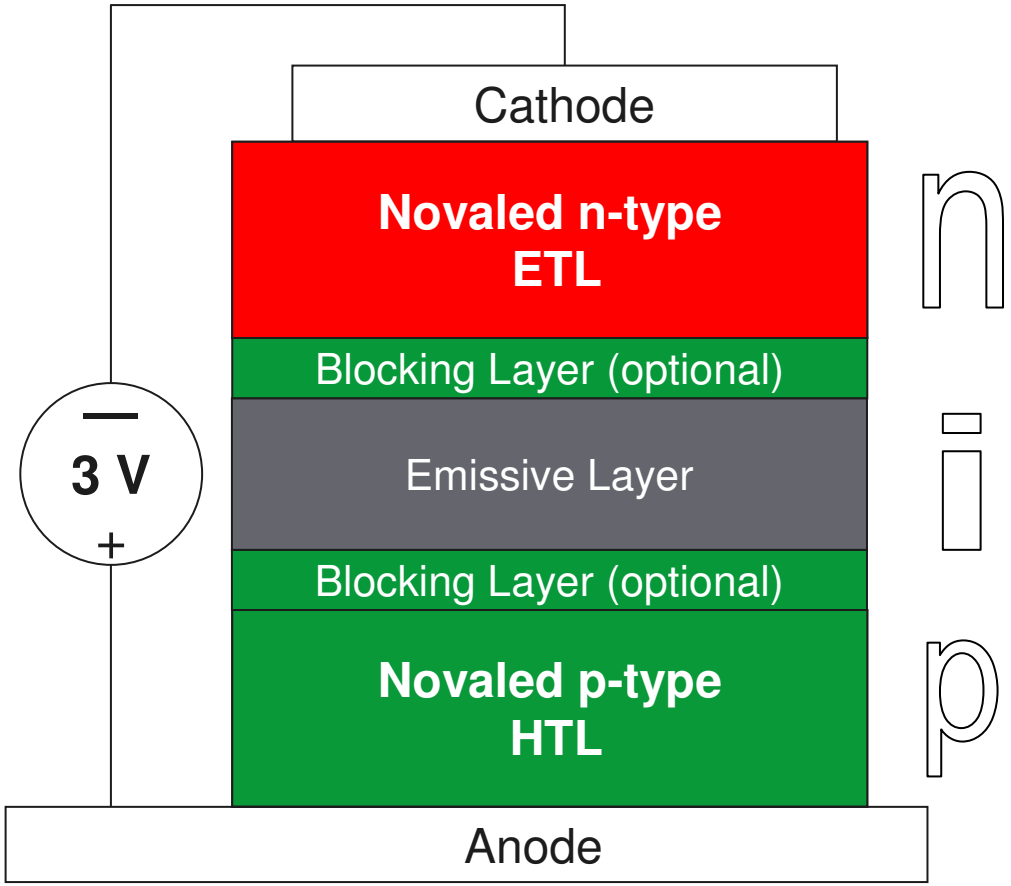
(1) Charge carrier injection

(2) Charge carrier transport

(3) Exciton formation

(4) Recombination

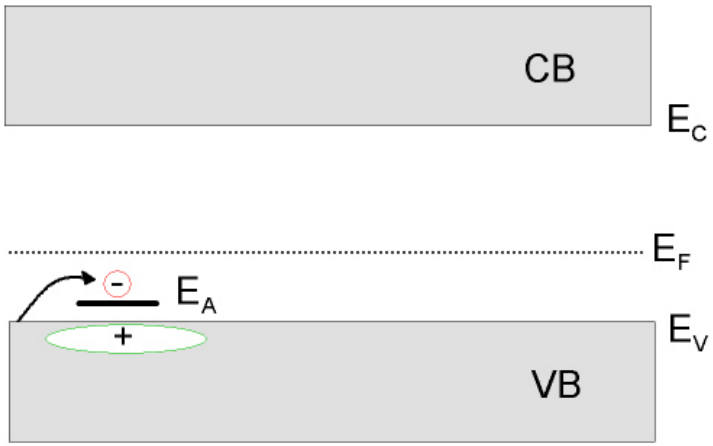
Novaled PIN OLED® Technology



- No injection layer between ETL or HTL and electrodes required!
- No ITO treatment necessary due to doping technology
- Results in maximum power efficiency, longest lifetime and freedom in OLED design

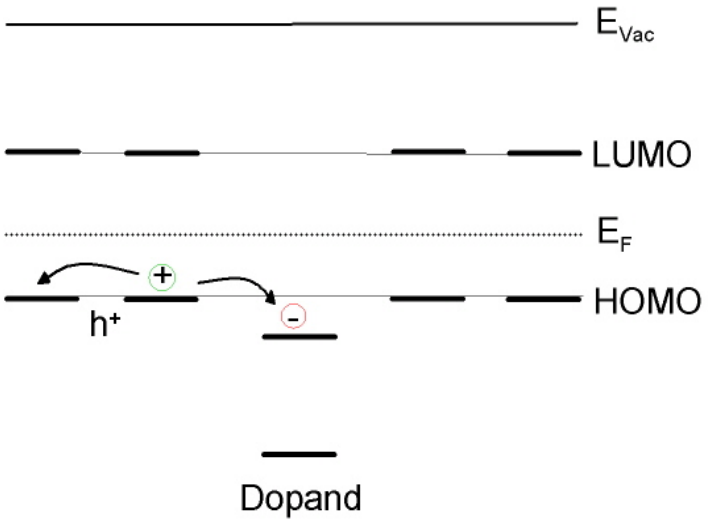
(redox) Doping

P-doping of Inorganic SCs



- add acceptor atom to create hole

P-doping of Organic SCs

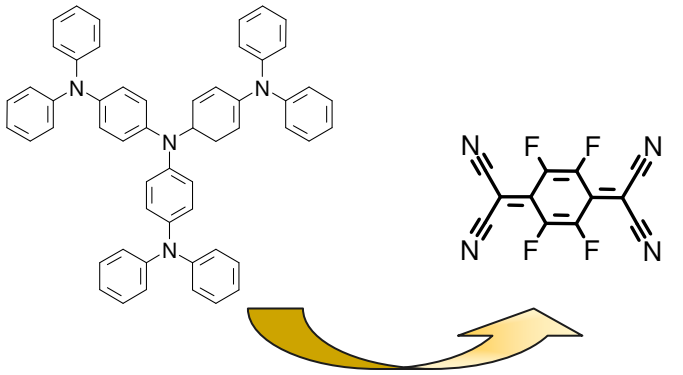


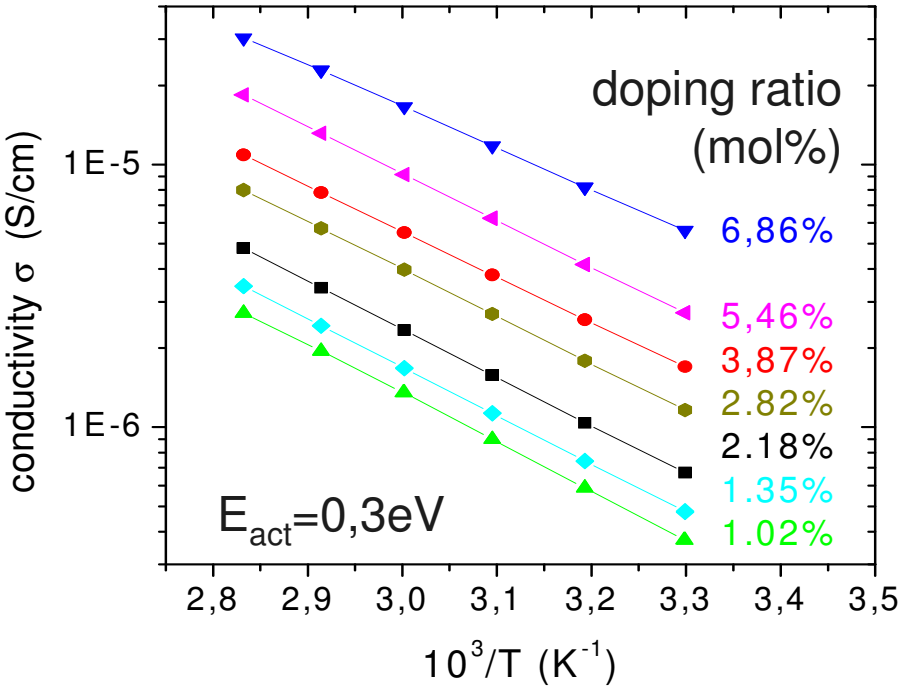
- add dopant molecule with low-lying LUMO
- hole mobile? (coulombic attraction, molecular disorder)

P-doping of amorphous HTLs

Matrix: TDATA

Dopant: F_4-TCNQ





Electron transfer ⇒ mobile holes ⇒ increased conductivity

OLED Efficacy

$$\eta_{external} = b_I \times \frac{h\nu}{eU} \times \eta_{recomb} \times \eta_{optical}$$

Factor	Current status
1/U: inverse operating voltage	For high brightness higher than thermodynamic limit
$\eta_{optical}$: optical out-coupling	w/o enhancement methods around 20%
η_{recomb}: recombination efficiency (singlet-triplet, PL efficiency)	Phosphorescent emitters, blue not stable yet
b_I: electron-hole balance	1 can be reached, more complicated for phosphorescent devices, injection dependent

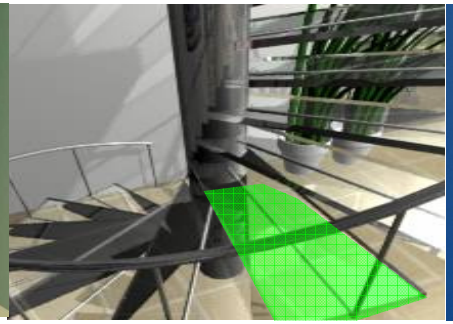
Doping Technology for Organic Electronics

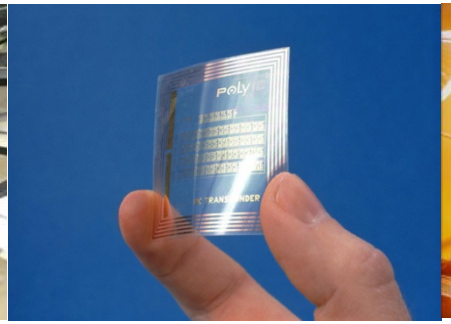
- Doping shall improve every organic electronic application where charge carrier transport and injection are key properties

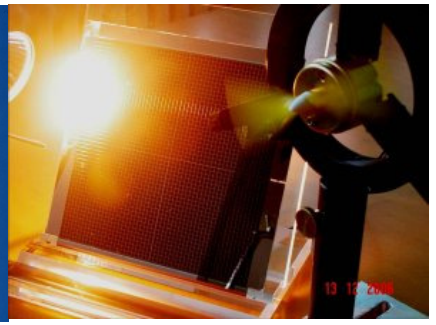
- Application of doping depends on business status of certain technology areas
  - → Started with **OLED displays**
  - → continued with **OLED lighting**
  - → continues with **Organic solar cells (OPV)**
  - → will be Electronic devices (e.g. display drivers, ORFID)

- **Doping is at the heart of Organic Electronic**


Sony


internal


PolyIC


Heliatek

OLED can be Applied in Numerous Applications…

Display

- Small Size for Portable Handheld Devices, MP3-Players, Digital Cameras
- Medium to Large Size Screens for Monitors & TVs
- Example: SONY TV XEL-1 (11”) LG TV (15”)

Lighting

- Design Lighting (decorative, functional)
- Automotive / Aerospace (cabin, dash)
- Signage and Advertisement
- Domestic Appliances
- General Illumination
- Healthcare (Medical & Cosmetics)
- Backlighting Units (e.g. for LCD)

…Bringing Added Value to Displays and Lighting

Display

LCD Manufacturer Advantage

- Keep LCD Momentum
- Potential to be cheaper in the future

End Customer Advantage

- Better Performance
- Advanced Design
- Energy Saving Potential

Lighting

Luminaire Maker Advantage

- New Business Opportunities
- Re-arrangement of Value Chain
- Integrated reflector:
  fixture and luminary become obsolete

End Customer Advantage

- Flat (and flexible) area light source for revolutionary designs
- Offering NEW Features
- Green Approach: Low Power Consumption and Mercury free

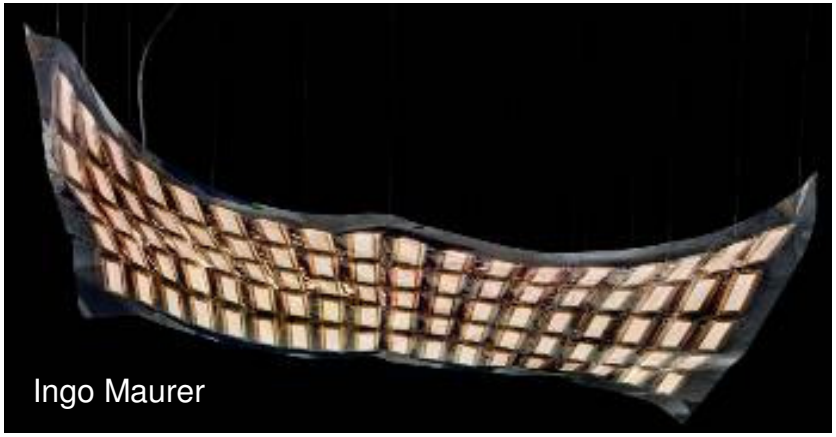
Where are we now? OLED Displays on the Market

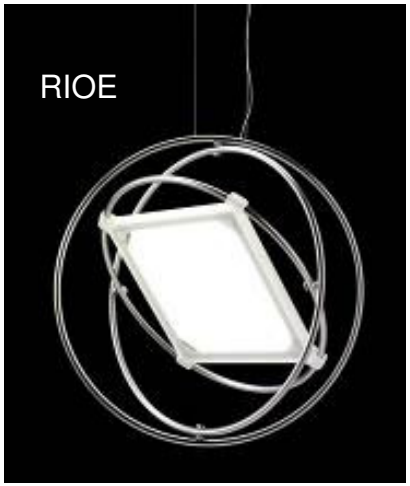
OLED has a Bright Future for Lighting

A triple (r)evolution

- **Flat (and flexible) area light source for revolutionary designs**
- **“Green Product”**
  - Low power consumption
  - Mercury free
- **Value chain modification**

Where are we now? First lighting products and studies introduced

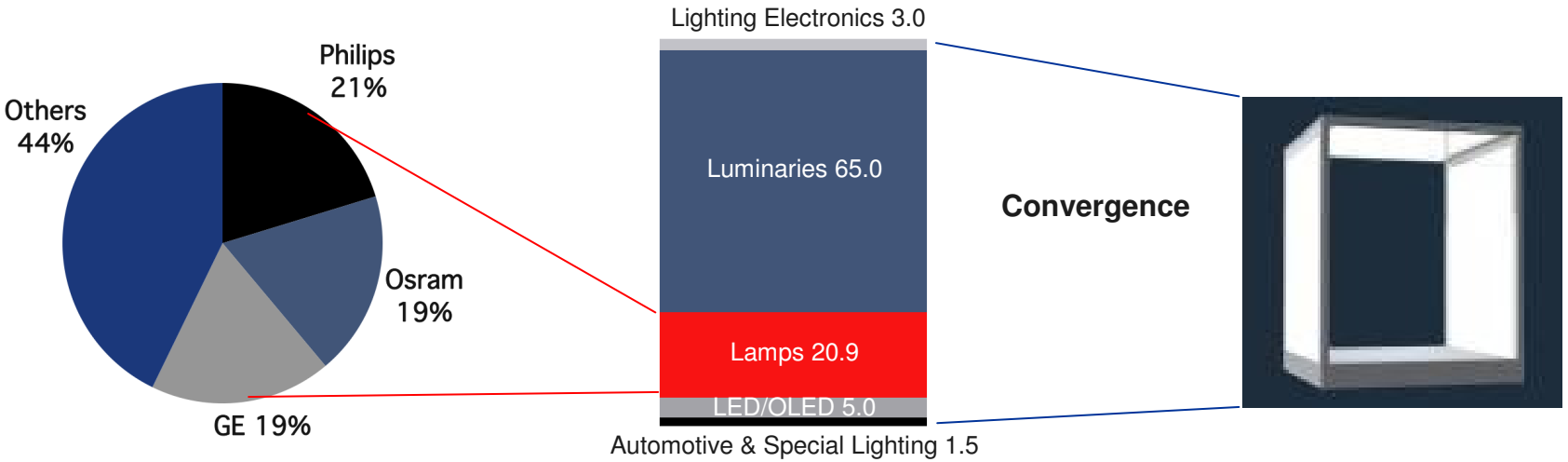




OLED will Modify the Lighting Value Chain

Current Lighting Landscape → **Future**

Key Vendors	Segments ($bn)	New Paradigm



- Cards reshuffled
- New players
- New business opportunities

Doping has a Bright Future for Printed Electronics

- Low cost (with cheap substrate) computing
- Flexible electronics
- Printed solar cells

Low-cost sensor tags, for instance on food packaging, will enable to monitor various parameters and to keep an eye on product quality

Model of a polymer flexible RFID-tag.
Source: Polylc

Novaled's markets

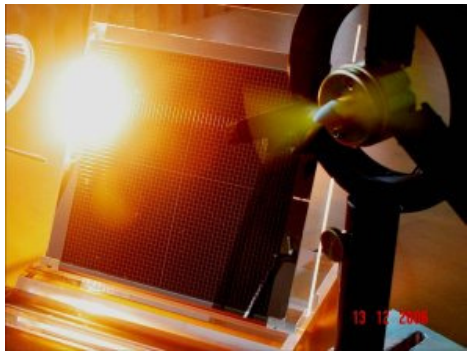
1st: Displays
- now (mobile) and future (TV)
- trend to AM-OLED displays

Sony X-EL1

2nd: lighting/signage
- starts now
- highest power efficiency a must

Osram /Ingo Maurer

3rd: OPV
- technology development
- Pilot production in 2011



Heliatek

4th: Organic electronic
- Organic circuitries featuring organic CMOS OTFTs, memory, RFID, battery...

Novaled – business model

R&D Skills

Sales Process
IP Licensing/Material Sales/Product

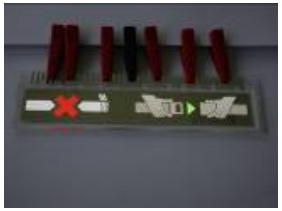
Comments

Physics
Optics
Chemistry
Prototyping
Production Eng.

- Platform/Product
- Novaled PIN OLED® Structure
- Proprietary OLED Materials

- **As a fabless technology provider, Novaled**
  - Licenses its IP
  - Sells proprietary materials
    - Dopants and Transport Materials
- **Start product with fabless approach**

Contracted Production of Proprietary Materials
Fabless Approach



Novaled's Materials: Overview

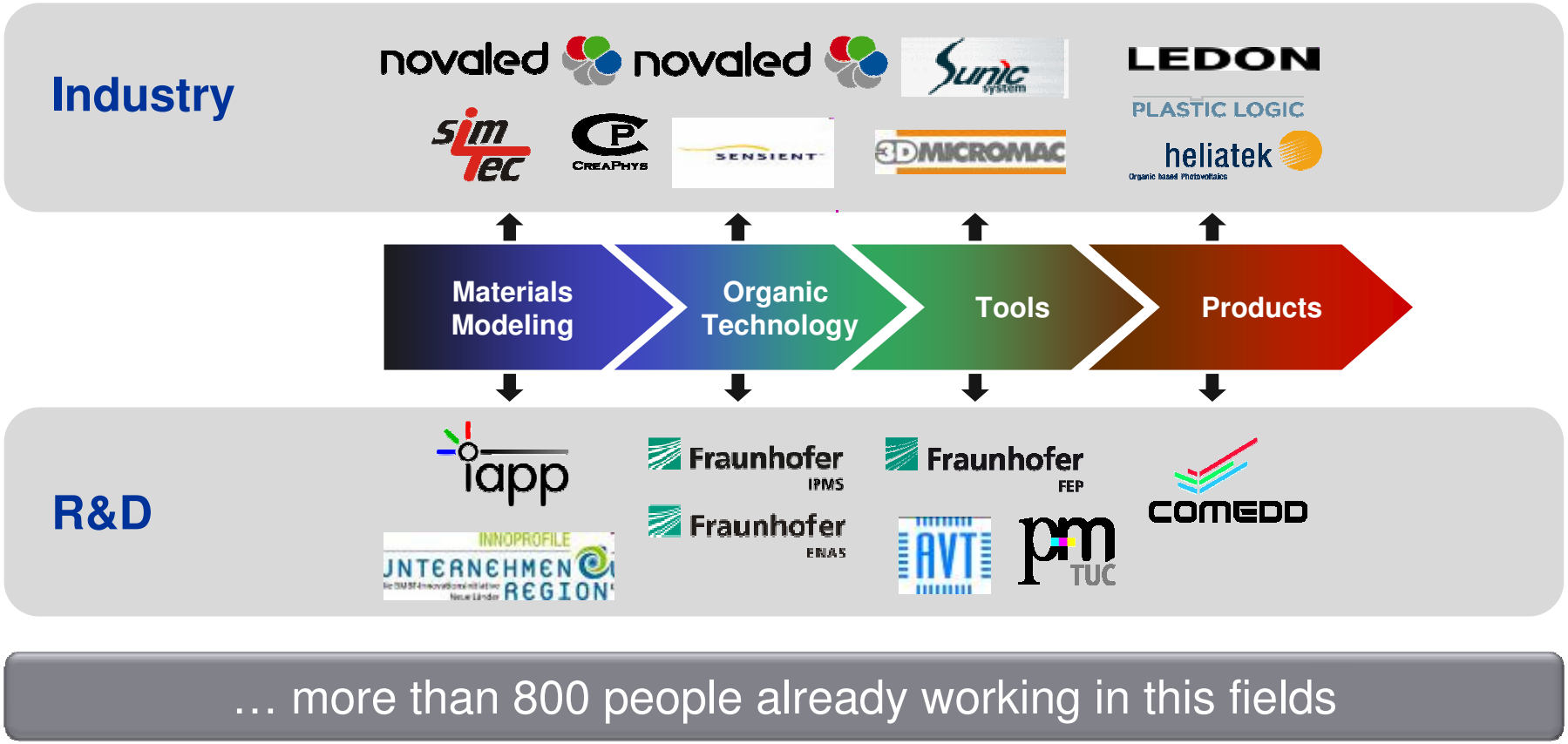
Material Requirements:

- evaporation temperature in reasonable range ⇒ simple process control
- low vapor pressure ⇒ no cross-contamination
- no diffusion of dopants in matrix at elevated temperatures ⇒ device reliability

Hole Side	Electron Side
Dopable hole transport matrix material with high T_g: NHT-5 - T_g > 145° C - new improved material (higher lifetime and efficiency): **NHT-18**	**Dopable electron transport matrix material with high T_g: NET-5** - T_g>105°C ⇒ superior to Bphen (T_g=63°C) at the same electron mobility ⇒ superior to Alq_3 - further materials for extended lifetime and higher temperatures are also available: **NET-8, NET-18**
Temperature & diffusion stable molecular p-dopant (strong acceptor): NDP-2 - $T_{evaporation}$ > 140° C - enhanced lifetime - new improved material: **NDP-9**	**Temperature & diffusion stable molecular n-dopant (strong donor): NDN-1** - $T_{evaporation}$ > 200° C - enhanced lifetime - molecular dopant ⇒ no alkali-metals!!! - new air stable material: **NDN-26**, $T_{evaporation}$ > 135° C

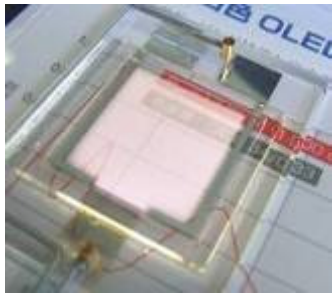
Novaled Local Network

The value chain in the Organic Electronics Saxony



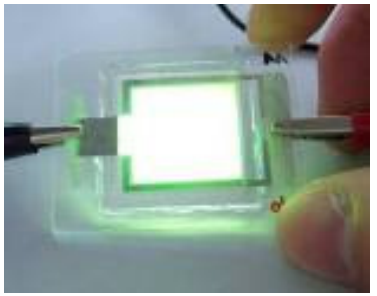
… more than 800 people already working in this fields

Freedom of Device Architecture



Transparent PIN OLED

PIN OLED in headlight



PIN OLED
on Printed ITO

PIN OLED
for Lighting

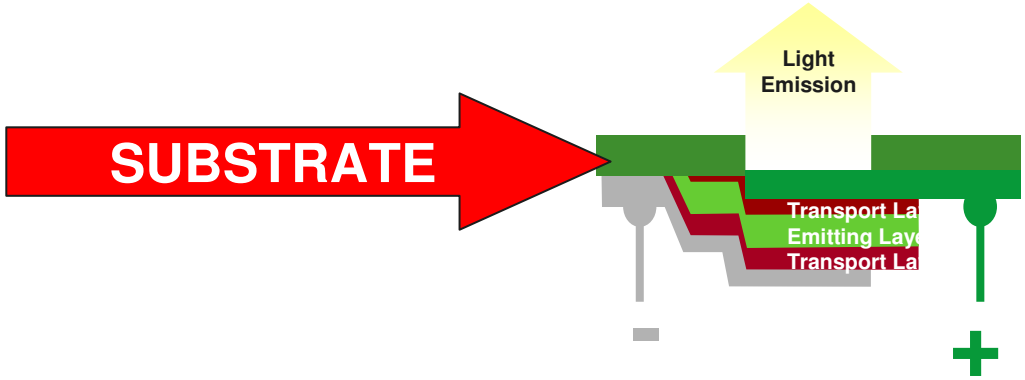
stacked
top & bottom emission
inverted & non-inverted

PIN AM OLED

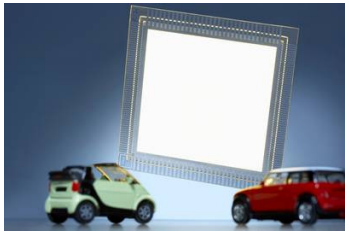
PIN PM OLED

PIN OLED on
Steel Substrate

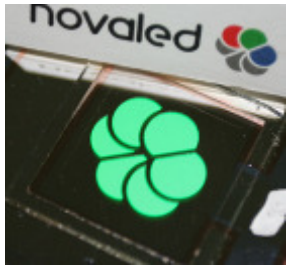
Substrate options for OLED‘s



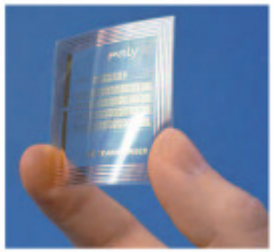
Glass substrate



Metallic substrate



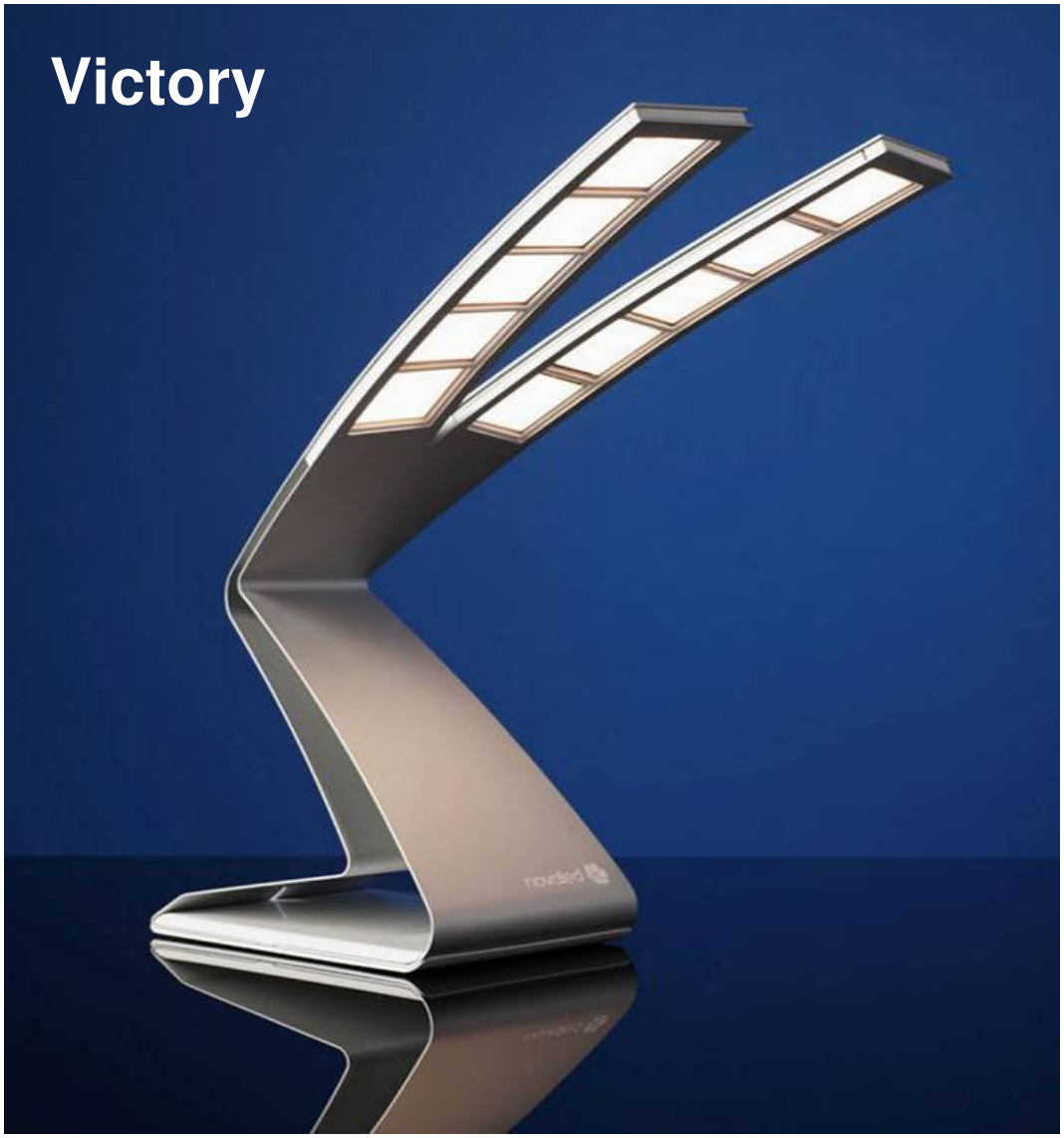
Plastic films



Prototype Devices - Achievements

Project with Arcelor Mittal (shown at Light+Building 2010):
serial connection of 4 sub-OLEDs, high overall emission area (64%)

frosted-white off-state vs. white light emission in on-state



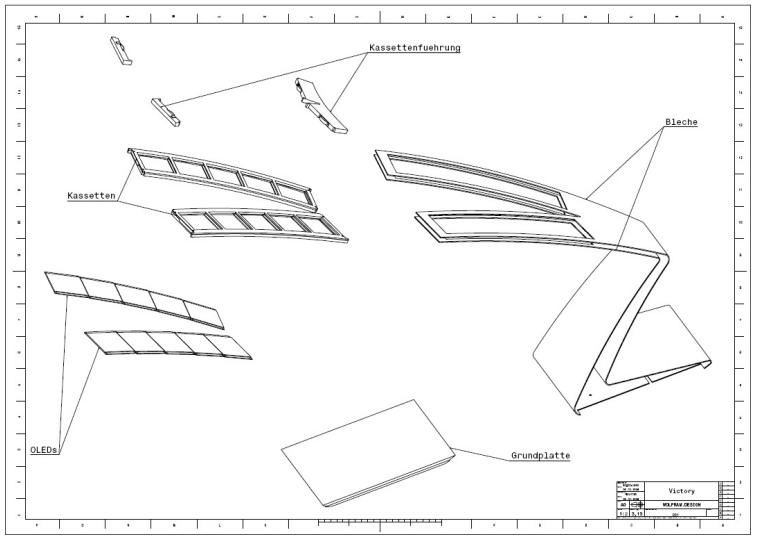
Design idea:

- functional, decorative, capable of being used in an office setting
- ‚V' shape of luminaire body

Construction:

- 10 OLEDs on glass, 5x5cm active area
- 5 each in series
- contacted in cassettes (no OLED module)

Drawing:



OLED Enspiro (TRILUX)

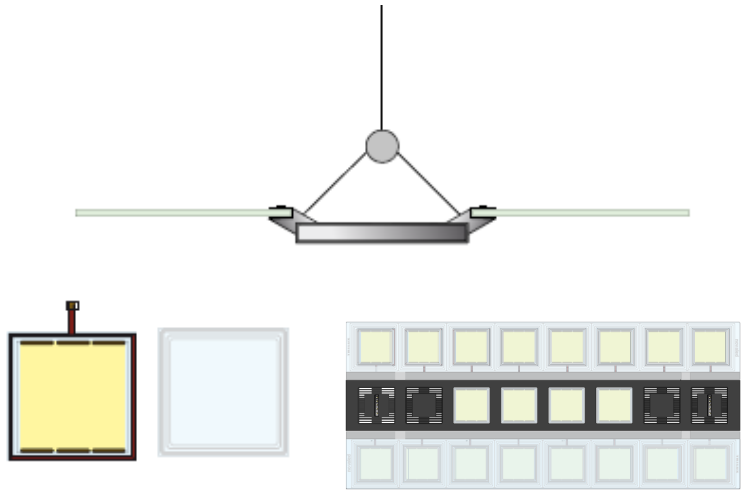
Design idea:

- Hybrid luminaire (LED & OLED)
- functional, decorative, capable of being used as an office suspension

Construction:

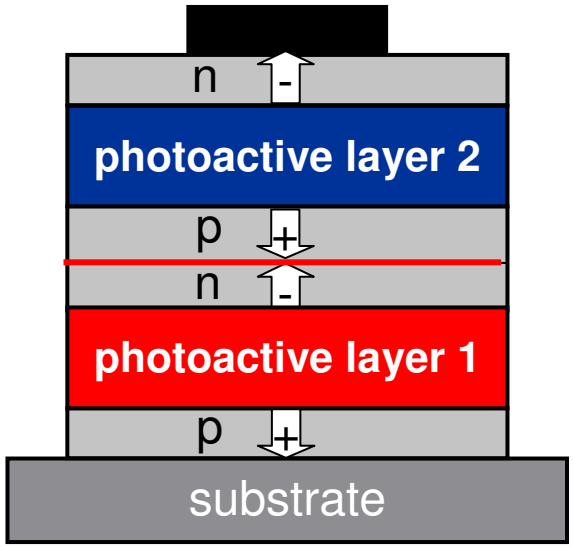
- 10 OLEDs on glass, 5x5cm active area
- 5 each in series
- contacted in cassettes (no OLED module)

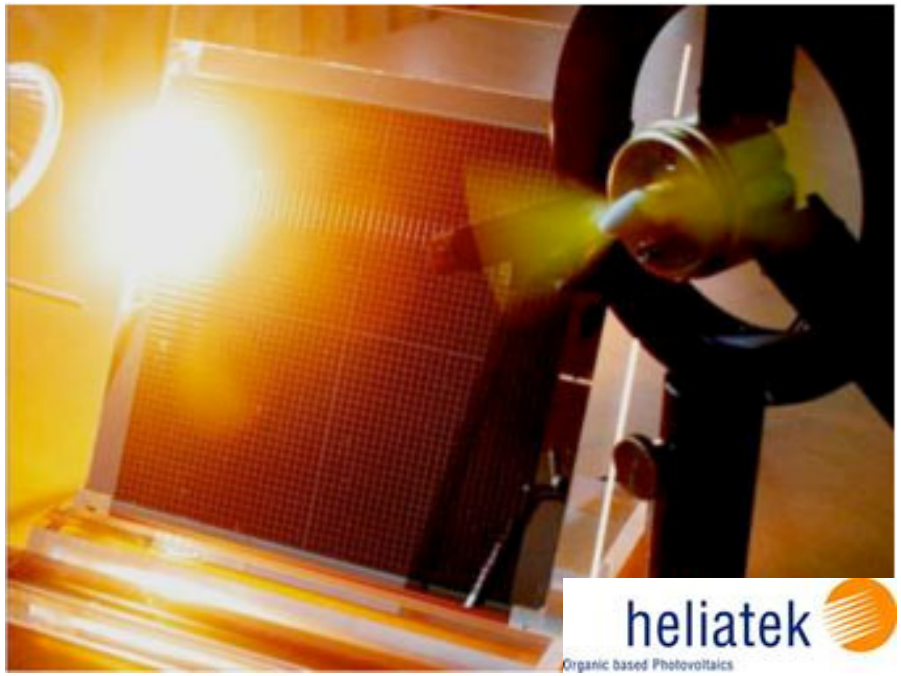
Drawing:



Application of Redox Dopants for OPV

PIN tandem solar cell



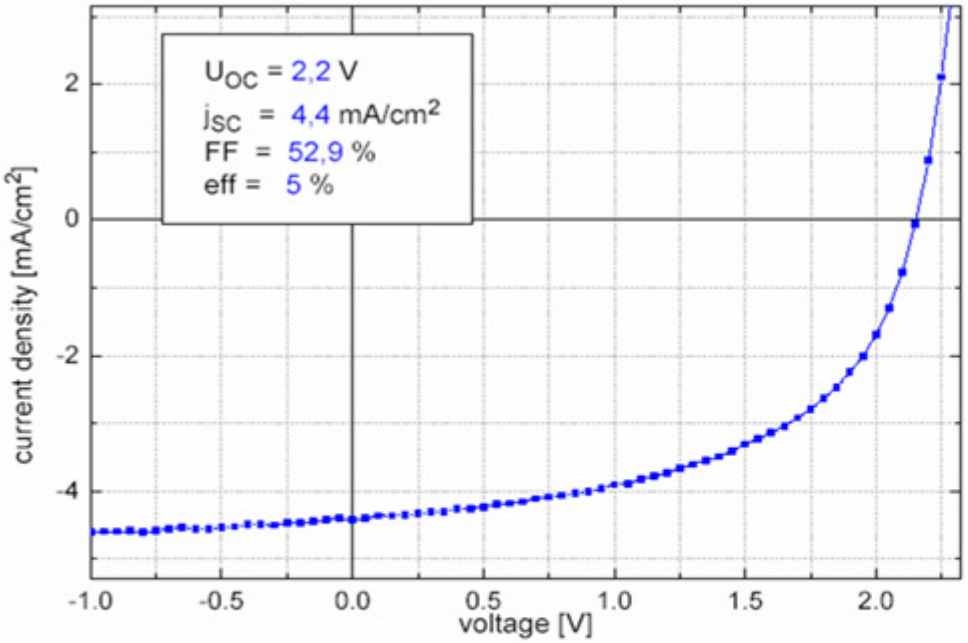


Efficiency and stability:

PIN Tandem solar cells for

- optimized efficiency by optimum harvesting of complete sun spectrum,
- high stability

PIN approach used in OPV



- measured with sun simulator
- efficiency reproduced when measured in natural sunlight

Latest result:
8,1% with 1,1 cm² active area

heliatek
Organic based Photovoltaics

- based on Heliatek multiple p-i-n architecture
- combining novel absorber materials from Heliatek and BASF
- using p- and n-dopants provided by Novaled

Heliatek has taken a license to use Novaled's PIN-OLED™ technology and Novaled's molecular dopants to develop organic solar cells.

Summary

- **Early Days**
  - Technology developed at University
  - Spin-Off
    - IP deal with University
    - Venture capital financing secures fincancials needed to ***fast*** develop products (and hence the company)
    - Experienced manager at early stage

- **Novaled today:**
  - Novaled Products (materials, technology) used in final products
  - 2011: will be the break-even year
  - Around 100 employees (Chemistry, Physics, Optics, Engineering, …)
  - Further growth in exisiting (OLED) and new areas (OPV, Electronic)

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