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FlexiDis Newsletter

INTRODUCTION

Welcome to the first issue of the FlexiDis newsletter. Our purpose is to inform you of the goals and progress of the project, as well as upcoming activities. This newsletter will also be available in .pdf format on the project homepage and upon subscription at www.flexidis-project.org.

The FlexiDis, or "flexible displays", project has the realization of flexible active-matrix displays as its primary goal. This is currently the largest research project in displays that the European Commission co-funds (for more information please see the inset).

The aim of this project is to research the materials and processing technology, fabrication tools, and application requirements to make and introduce reliable, flexible active-matrix displays to the market.

The Polymer Vision's READIUS™ can unroll its display to a scale larger than the device itself. (Courtesy of Polymer Vision and Philips)

Scientific and Technological Objectives

The best way to move forward with flexible displays is to make a set of demonstrators with a variety of different display effects and active-matrix backplane technologies.
For this purpose, we have chosen four demonstrators (all produced using viable manufacturing methods) as the goals for eventual testing in applications. The display demonstrators are organic light-emitting displays (OLED) on flexible metal and polymer substrates with inorganic thin-film driving transistors, and electrophoretic (EP) display on flexible plastic substrates with organic and inorganic thin-film driving transistors. The cross comparison of these demonstrators will show the compatibility, stability and "industrialisability" of the different backplane/frontplane combinations.

Progress:

Recent results (shown in brief abstracts on the next pages) in the FlexiDis project have shown novel flexible display manufacturing methods, advanced materials preparation, and new rollable display applications as well as improved device understanding and engineering.

Courtesy of Plastic Logic Limited

The FlexiDis Newsletter is part of the dissemination activities of the EU funded Integrated Research Project FlexiDis – Flexible Displays.

For more information please visit our website:
www.flexidis-project.org

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FlexiDis Partners	**Country**
Philips Research Eindhoven	NL
Philips Research Redhill	UK
Thomson	F
University of Cambridge	UK
Merck Chemicals	D
Ecole Polytechnique Fédérale de Lausanne	CH
ST MicroElectronics	F
Universität Stuttgart, Chair of Display Technology	D
CEA-LETI	F
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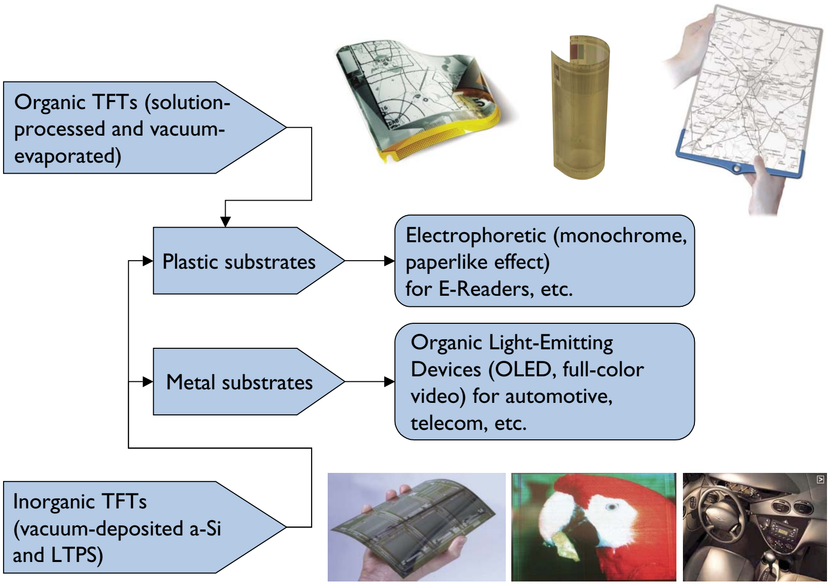
Centre National de la Recherche Scientifique, Palaiseau	F
IMEC	B
Plastic Logic Ltd.	UK
Philips Applied Technologies	NL
LEGO	DK
BMW	D
Nokia Research Center	FIN
Institute of Polymer Mechanics (IPM), Univ. Latvia	LV
NovaLED GmbH	D
ASML	NL
Deutsche Thomson Brandt GmbH	D
Thales Avionics LCD	F

FlexiDis is funded under the 6th EU-Framework programme (IST-2004-004354)

The Project duration is 1 October 2004 to 30 September 2007

Information Society Technologies

SIXTH FRAMEWORK PROGRAMME



Demonstrators and applications addressed in the project

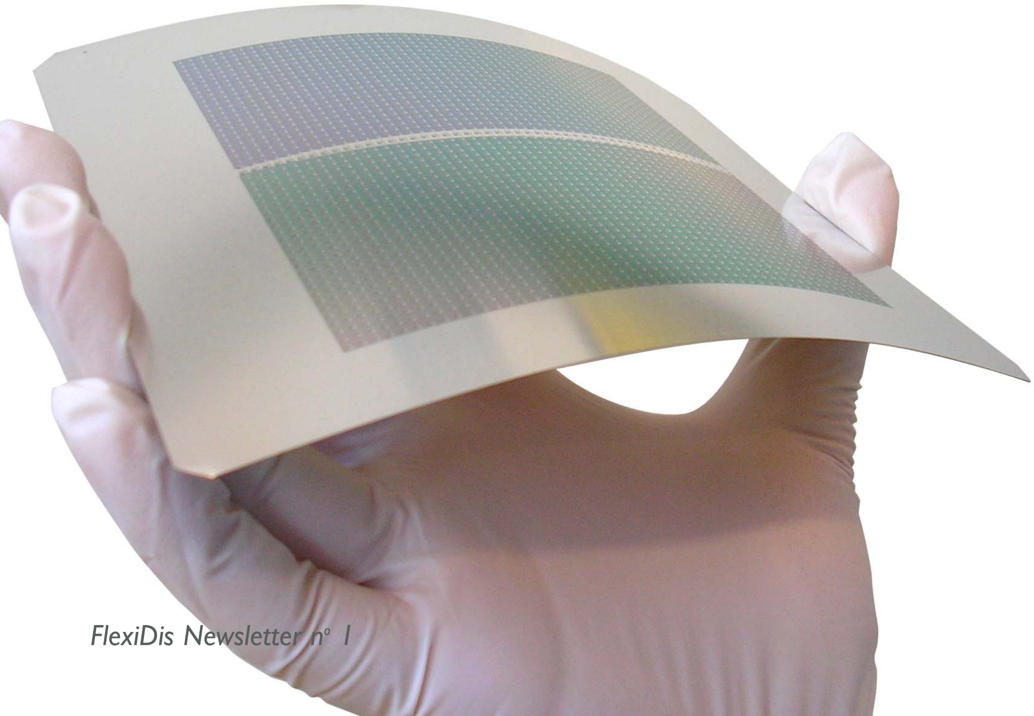
First TFTs on thin metal foil made with LTPS process at CEA-LETI

by François Templier, CEA-LETI

An LTPS process on metal foil has been developed for the fabrication of flexible AM-OLED displays. TFTs have been recently made at CEA-LETI, using a self-aligned PMOS LTPS process on thin metal foil (see picture). Transistors exhibit interesting characteristics, with field-effect mobility of 84 cm²/V.s and subthreshold slope of 0.37 V/decade. These devices have been shown to keep their good characteristics even with bending to a radius of curvature of 5 cm. This self-aligned LTPS process on metal seems to be very promising for the manufacturing of high quality and high resolution flexible AM-OLED displays.

These results are presented at the Eurodisplay 2005 Conference, held in Edinburgh, Scotland, 19-22nd Sept. 2005.

Optical photograph of processed LTPS TFTs on stainless steel foil.
Plate size is 154 x 132 mm; and thickness is 152 µm. (courtesy of CEA-LETI)



Workshop Mechanical analysis of multilayer thin film structures

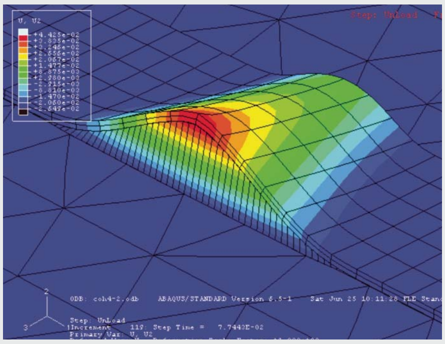
by Yves Leterrier, EPFL

A FLEXIDIS workshop on "Mechanical analysis of multilayer thin film structures for flexible displays" was held at EPFL Lausanne, on July 4-5, 2005. The event gathered scientists and engineers from EPFL, IPM-Riga, Philips Applied Technologies, Philips Research and CEA-LETI. The objective was to discuss ongoing experimental, theoretical and simulation work on thin film structures on flexible substrates and to eventually provide guidelines for optimal material and process development.

The following topics were covered:

- Thermoelastic properties, nanoindentation and internal stress analysis in thin films
- Viscoelastic analysis and simulation of dimensional stability under hygrothermal loading
- Buckling analysis of thin films on compliant substrates
- Damage analysis of thin layers on steel
- Cracking and cohesive properties of brittle layers on polymers

Methods and models for accurate determination of elastic properties, coefficient of thermal expansion, residual stresses and damage processes in ultrathin layers were presented. The workshop confirmed that these properties are required for correct simulation of initiation and propagation of damage such as layer cracking, buckling, and delamination, especially in case of time-dependent viscoelastic and moisture sensitive polymer substrates.



Simulation of transverse buckling in a narrow strip on a compliant substrate (courtesy of IPM-Riga)

Dielectrics for OTFTs with vacuum sublimed molecular semiconductors

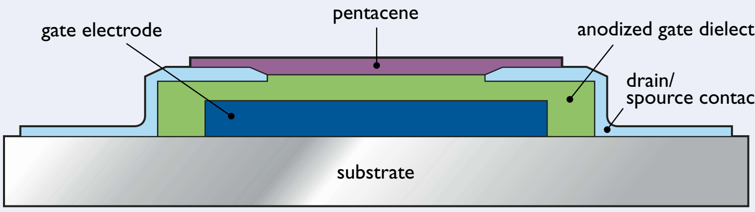
by Silke Göttling, Jochen Brill, Chair of Display Technology, University of Stuttgart

Thin film transistors (TFT) with organic semiconducting material instead of silicon as the active layer have a big potential for flexible display technologies. These organic thin film transistors (OTFT) can be used in a wide range of applications where flexible materials and low cost are required.

Finding a low temperature dielectric with good electrical properties is one of the most important steps in developing OTFTs. Different dielectric materials are investigated for their compatibility in organic thin film transistors. Two different organic and four inorganic materials are investigated. The organic dielectrics, a polyacryl and a polyimide, are deposited by spin coating. The inorganic materials are plasma enhanced chemical vapour deposited (PECVD) Si_3N_4 and SiO_2 layers, which have been developed for polysilicon TFTs and anodically oxidized Ta_2O_5 and Al_2O_3.
In this work the transfer of OTFT processes to plastic substrates is important. Therefore a low temperature dielectric with good insulating properties is needed. Spin coating and anodic oxidation are low temperature processes. The deposition temperature for the PECVD SiO_2 and Si_3N_4 layers is 280°C and is not suitable for the application on plastic substrates. But they are useful to compare the proved dielectric properties with those of the low temperature ones.

Anodically oxidized Al_2O_3 has been further investigated due to the electrical performance, the low deposition temperature, the high dielectric constant and the possibility to form thin layers, which reduces the required OTFT operating voltages. Additionally the processes for structuring aluminium are compatible to plastic substrates.

OTFTs are built on glass and plastic substrates. Bottom gate, bottom contact OTFTs are processed using aluminium as gate metallization. The surface of the structured aluminium is anodically oxidized forming the oxide layer. As drain- and source contact material gold is sputtered and patterned. Finally, pentacene is evaporated as semiconducting layer. The cross section of the fabricated OTFTs is presented in the figure. More details will be published in SPIE Proc. Vol. 5940: Organic Field-Effect Transistors I



Schematical of OTFT set-up (courtesy of Chair of Display Technology of University of Stuttgart)

Connecting the packaged drivers to the displays

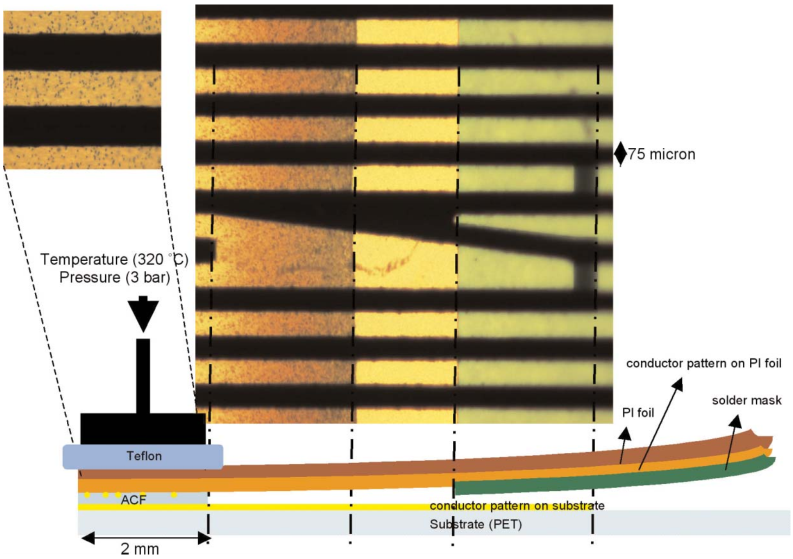
by Jonathan Govaerts, IMEC

Within FlexiDis, IMEC has a task of connecting the packaged drivers to the OTFT display backplane. To this end, an "Anisotropic Conductive Film" is applied and prebonded to the interconnection area on the OTFT backplane fabricated on a PET substrate, then the packaged driver (TCP/TAB or COF) is aligned and placed on the ACF, and finally driver and OTFT backplane are bonded together by means of a thermo compression step.

Two important features in the thus realised interconnection are evidently (electrical) contact resistance and (mechanical) adhesion. To measure these, some preliminary tests are necessary: a pattern on the substrate is combined with a correspondingly patterned flexible substrate, replacing the driver. These patterns are designed for 4-point measurements of the contact resistance, as well as daisy chain measurements. Those patterns are designed for 5 different dimensions, with pitches of 200, 150 and 100 micron, and even below 100 micron: 80 and 60 micron. The number of contacts being bonded at the same time in this way varies from 200 up to 400.

The main challenges in making these interconnections is to perform bonding at a temperature compatible with the PET substrate material, and the large bonding area which is about 40 mm long and 2 mm wide in our setup.
Some first results, from a 150-micron-pitch interconnection, show that it is possible to interconnect 264 contacts at the same time, with an alignment accuracy of over 10 micron over a total bonding width of 40 mm. As an illustration, a view in close-up is given in the figure, together with some schematic clarification:

Interconnects as described in the text (courtesy of IMEC)

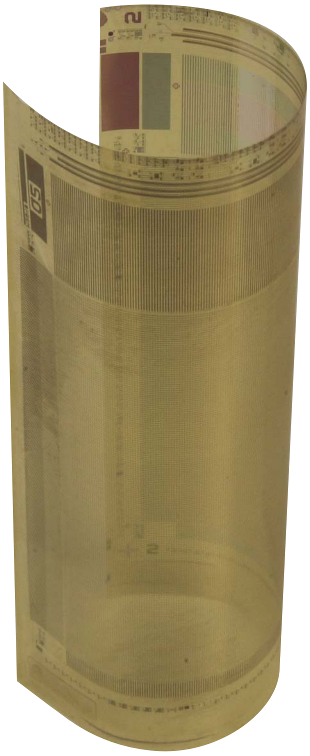


Thin Plastic Electrophoretic Displays Fabricated by the EPLaR™ Process

by Ian French, Philips Research Redhill

Philips Research has developed a new way of making flexible, plastic active matrix displays using standard amorphous silicon TFT fabrication facilities. Using this technique electrophoretic displays with three micron thick plastic a-Si TFT backplanes have been fabricated. We believe that these are the thinnest plastic displays ever made.

One viable route to industrialize flexible displays is to develop a process for manufacturing plastic displays that could be used in conventional TFT factories with standard processing and produce TFTs with standard electrical properties. The advantage of this is that it offers the fastest and most economical route to manufacturing and benefits from the many years of experience in developing machines and processes for high yield manufacturing. At Philips Research we have therefore developed a process in which polyimide layers are applied to glass substrates by spin coating. This polyimide layer will ultimately become the main mechanical layer of the plastic display, but during the TFT processing and display making it is just another thin layer on the glass substrate. After testing of the completed display the polyimide is removed from the glass substrate by a laser release process. The laser used to release the plastic displays is not a conventional tool in a-Si TFT factories, but laser release can be carried out in a separate display module making factory. We call the entire process for making plastic displays EPLaR™, which stands for **E**lectronics on **P**lastic by **La**ser **R**elease. So far Philips has demonstrated EPLaR™ Electrophoretic displays with a-Si TFT pixel switches, and we are working to extend it to low temperature polysilicon TFTs and OLED and LCD displays.



50 x 50 mm a-Si TFT array on 3 µm thick freestanding polyimide layer made by the EPLaR™ process. (Courtesy Philips Research)

An a-Si TFT pixel on freestanding polyimide made by the EPLaR™ process is shown in the figure. The deposition temperature of this TFT array was 240°C, which is the standard deposition temperature that we use for making a-Si TFTs. This shows that by using the EPLaR™ process we can make a-Si TFTs deposited at normal temperatures with standard design rules on extremely thin (3-µm) plastic substrates. We believe that these are the thinnest plastic a-Si TFT arrays that have ever been made.

An EPLaR™ electrophoretic (courtesy of E-Ink Corporation) display with 200 rows and 200 columns is shown as well. It has a pixel pitch of 240 µm, giving a resolution of 100 dpi. We can see that the display can show high quality grey-scale and black-and-white images, but that there were several line-outs. This was mainly due to problems with clamping the very thin plastic.

So far Philips Research has demonstrated displays made with polyimide as the plastic supporting layer, which would limit the technology to emissive (OLED) or transmissive displays. We are working to extend the EPLaR™ technology to clear plastics, which will allow us to make transmissive displays, such as LCDs. We also plan to develop the process for Low Temperature Polysilicon TFTs so that we can increase the circuit performance on plastic substrates and use the technology for non-display flexible electronics. Ultimately, the goal of FlexiDis is to show that this can be transferred to a factory, for which Thales Avionics LCD will play an instrumental role.

Plastic electrophoretic display made by the EPLaR™ process. (Courtesy Philips Research)

High performance and innovative OLED structures and display presented by Thomson Research and Novaled at the SID'05

by Christophe Prat and Gunther Haas, Thomson Research, and Jan Blochwitz-Nimoth, NovaLED

In a standard bottom-emitting OLED, the bottom electrode is transparent (typically made of ITO) and the top electrode is a thick reflective metal film. The nature of these materials should fulfill precise electrochemical requirements to be compatible with the neighboring organic layers. They must also exhibit good optical properties in terms of transparency or reflectivity.

Due to the opaqueness of the active matrix backplane on metal, the OLED structure must be of so-called 'top-emitting' type; i.e., the top electrode should be transparent and the bottom one must be reflective. The fabrication of this device is not straightforward due to the required compatibility of the bottom electrode with the organic layers and to the difficulty with depositing a top electrode having high conductivity, high optical transmission, and all without damaging the underlying structure. The compromise that results from these constraints usually leads to performances lower for the top-emitting device than for the bottom-emitting one.

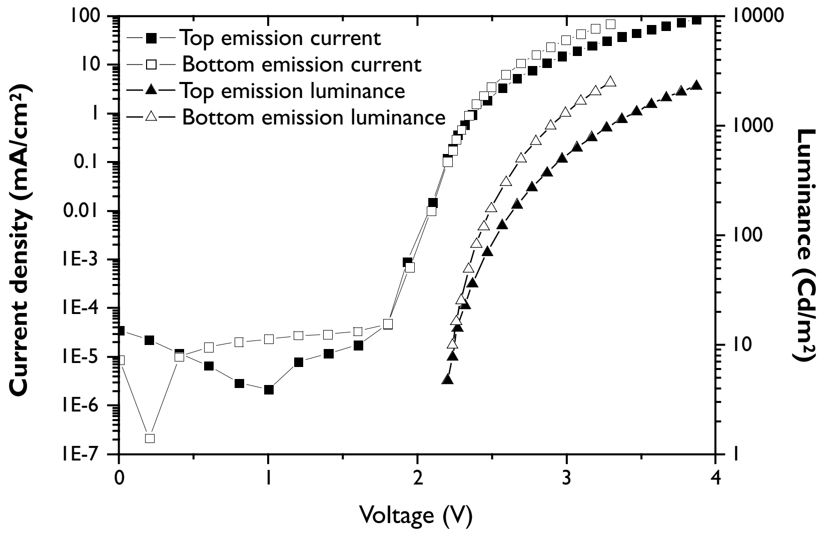
We have therefore employed a pin-OLED structure, comprised of five organic layers: a p-type-doped hole transport layer next to the anode, a first interlayer, the emitting layer, a second interlayer, and a n-doped electron transport layer next to the cathode. With this structure, due to the doping of the charge injection layers, the constraint concerning the nature of the electrodes is relieved.

In the FlexiDis work, the OLED structure presented is deposited onto a Cr bottom reflective electrode, and the top electrode consists of a thin semitransparent metal/dielectric bilayer. The performances of this device is presented in the figure and compared with a bottom-emitting one made with the same organic stack. Results show that the turn-on voltage is independent of the nature of the bottom electrode, ITO or Cr. Moreover, the reverse currents of 10^{-4} mA/cm^2 remains comparable for both structures. However, it appears at high voltage that the current density of the top-emitting OLED is limited compared with the bottom-emitting device; This is thought to be due to the lower conductivity of the transparent top electrode adding a resistance in series in the equivalent circuit. Consequently, the luminance is lower at high voltage. Maximum efficiency is achieved for the red bottom emission structure (5.6 Cd/A and 8 Lm/W). However, the performances achieved for the top-emitting device (maximum of 4 Cd/A and 5.5 Lm/W) are quite encouraging. Indeed, considering an operation voltage of 3 V at which a luminance of 500 to 600 cd/m^2 is achieved (order of magnitude of the value required for a display before the polarizer) the gap between top and bottom emitting device is closing significantly. Moreover, a metal with a better reflectivity than Cr can be considered as bottom electrode.

In a first attempt to make a display, non-inverted OLEDs have been deposited onto an active QVGA backplane of 3.25" diagonal (provided by ITRI/ERSO in Taiwan). As the bottom electrode is made of ITO, the resulting display is emitting from both sides. Measurement from the top side exhibits a luminance of 120 cd/m^2 at an overall voltage of less than 7 V and a current consumption of less than 50 mA.

a photo of the active-matrix display. (Courtesy Thomson Research and NovaLED)

Current-voltage, and Luminance-voltage characteristics of bottom and top emission from a non-inverted red OLED, (Courtesy Thomson Research and NovaLED)



PARTNERS AND TASKS

Philips

- EPLaR (Electronics on Plastic by LAser Release) process description
- Electrophoretic display on active-matrix inorganic TFTs on plastic
- Integrated circuits for EPLaR
- Development of the novel EPLaR process on ultrathin flexible plastic substrates
- Driver design for electrophoretic displays in the EPLaR process
- Distortion-compensated patterning of inorganic TFTs on flexible substrates
- Mechanics of layers on metal and plastic foils under bending stress (cohesive properties and failure statistics)
- Market evaluations of flexible displays in mock-ups
- Characterization of OTFT materials and devices (Polymer Vision)
- Miniaturization of driving electronics for electrophoretic / OTFT displays
- Reliability measurements (mechanical, electrical and optical) for discrete devices and displays
- Thin film encapsulation for OLEDs
- Industrial process development and integration
- Substrate handling
- Dissemination activities (conference and meeting organization)
- Exploitation of results (introduction of new products based on flexible displays)
- Project coordination and administration

Thomson Research

- Full-color OLED display on inorganic TFT active-matrix backlanes (LTPS and µc-Si) on metal foil
- OLED RGB deposition (mask patterning) on flexible substrates
- Transparent top electrode process
- Realization of development vehicles and demonstrators
- Product mock-ups incorporating development vehicles and demonstrators
- Circuit design for inorganic TFT active-matrices on metal foil including integrated driver design
- Development of driving schemes and realization of driving electronics

NovaLED

- RGB OLEDs on flexible substrates (inverted structure for OLEDs)
- Life time tests of OLEDs
- Transparent top electrode process

University of Stuttgart, Chair of Display Technology

- Development of large area processes for OTFT based on evaporated materials
- Device modelling of OTFT
- Development of OLED-compatible µc-Si TFT on metal foil processes
- Specification of display module, TFT testing and standardization
- Integration of OTFT active matrix with electrophoretic ink
- Demonstration of µc-Si on metal foil OLED pixel test circuits

CEA-LETI

- TFT modelling of inorganic (LTPS) devices on flexible metal substrate
- OLED display back plane design
- LTPS on flexible metal : TFT and backplane process development and fabrication
- Development of thick insulator by a new SolGel process
- Reliability of LTPS TFTs on flexible metal

CNR Roma

- Transport properties of LTPS TFTs on flexible substrates
- Low-temperature oxide and microcrystalline silicon (µc-Si) deposited by ECR-PECVD
- Advanced laser crystallization techniques

CNRS - Ecole Polytechnique Palaiseau

- Microcrystalline silicon (µc-Si) development
- Process for substrate preparation and insulator layer
- Spice Model of microcrystalline silicon TFT

Thales Avionics LCD

- Development of TFT technology using EPLaR in a TFT manufacturing line using the EPLaR process.
- Active matrix for Electrophoretic material / EPLaR
- Active matrix a-Si for OLED / EPLaR
- a-Si TFT integrated driver design for electrophoretic displays in the EPLaR process to drive Electrophoretic films ands OLED

IMEC - University of Gent

- Flip-chip interconnect + additive technologies
- Standard packaged drivers interconnection
- External driver electronics design

IPM, Institute of Polymer Mechanics, University of Latvia

- Characterization of polymer substrate viscoelasticity,
- Modelling of multilayer fracture

Ecole Polytechnique Fédérale de Lausanne

- Mechanics and physics of thin films on polymers
- Guidelines for material and process optimization
- Adhesion test methods for functional layers on steel
- Gas-barrier coatings on polymers

ASML

- Equipment design for maskless lithography
- Pattern recognition studies
- Proven ingredients for linear or non-linear compensated maskless imaging of display layers

Plastic Logic

- Technology development for organic TFT display backplanes based on solution-processed, printed devices
- Novel pixel architectures and registration processes suitable for fabrication on low temperature flexible substrates
- OTFT / Electrophoretic Display design
- Display evaluation and market studies
- Electronic paper displays on flexible substrates driven with OTFT back planes

University of Cambridge

- OTFT device physics
- Development of direct-write, printing-based processes for OTFT device manufacturing
- Training and mobility of Researchers

STMicroelectronics

- Design methodology adapted to high pin count devices with medium-voltage technologies (20-90V)
- New family of drivers in BCD technology applied to displays (including evolution to SOI).
- New packaging TCP/TAB (Thin Chip Package/Tape Automatic Bonding)

Merck Chemicals

- Materials and physical processes in semiconducting dielectric and conducting materials
- Semiconducting dielectric and conducting materials for plastic transistors

Nokia Research

- Display module reliability specs and testing
- Metrics
- Demonstrator evaluation
- Telecom mock-ups with the demonstrator displays

LEGO

- Mechanics + reliability of layers on flexible substrates
- Market + reliability specification
- Flexible display integrated in toys

BMW

- Market requirements + reliability specifications
- Demonstrator evaluation and mock-up building in automotive environments and instrument clusters

Partial List of Recent Publications

Ultra-thin Encapsulation for Large-Area OLED displays,
J.J.W.M. Rosink, H. Lifka, G.H. Rietjens, A. Pierik,
SID 2005 Digest

Thin Plastic Electrophoretic Displays Fabricated by a Novel Process,
Ian French, David McCulloch, Ivar Boerefijn, Nico Kooyman,
SID 2005 Digest

Pentacene Organic Thin Film Transistors with Anodized Gate Dielectric,
Silke Goettling, Jochen Brill, Norbert Fruehauf, Jens Pflaum, Eduardo Margallo-Balbás,
SPIE 2005 Digest

Effects of fabrication parameters on the electrical stability of Gate Overlapped LDD polysilicon TFTs,
A. Bonfiglietti, A. Valletta, M. Rapisarda, L. Mariucci and G. Fortunato,
AMLCD 2005 Digest

Growth of microcrystalline silicon on flexible substrates,
Y. Djeridane, V.D. Bui, H. Jae Kim, Y. Bonnassieux and P. Roca i Cabarrocas,
SID 2005 Digest

Modelling Velocity Saturation Effects in Polysilicon Thin-Film Transistors,
A. Valletta, P. Gaucci, L. Mariucci and G. Fortunato,
AMLCD 2005 Digest

LTPS Process on Metal Foil for Flexible Active Matrix OLED Displays,
François Templier, Bernard Aventurier, Muriel Moreau, Aurélien Mortillaro, Roselyne Templier, Antoine Passero,
Alice Gallissian, Delphine Passard, Laurent Dubost,
Eurodisplay 2005

Low-temperature ECR-PECVD silicon dioxide as gate insulator for polycrystalline silicon thin film transistors,
L.Maiolo, A.Pecora, G.Fortunato and N.D.Young,
Journal of Applied Physics, submitted 2005

LTPS on Passivated Stainless Steel Substrates for AMOLEDs and Other Applications,
Nigel Young, David McCulloch, Michael Trainor, David Fish and Sandra Godfrey,
AMLCD 2005 Digest

Investigation on permeation qualitative characterization of PECVD Ultra-barrier layers for AMOLED,
Sofia Martins, Alice Gallissian, Laurent Dubost, Delphine Passard,
CIP 2005, 15th International Colloquium on Plasma Processes, June, 2005

Growth of Microcrystalline-Silicon Thin Films on Plastic Substrates,
Y. Djeridane, V. D. Bui, Y. Bonnassieux, and P. Roca I. Cabarrocas,
Eurodisplay 2005 Digest

Other European projects

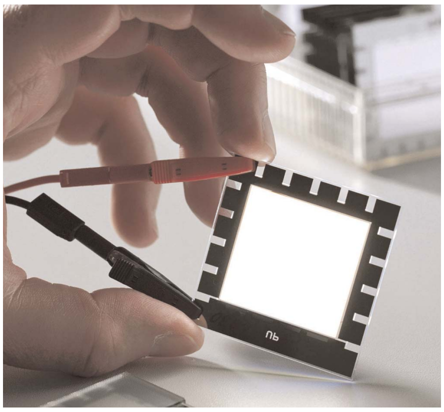
Olla

by Peter Visser, Philips Lighting

In parallel with FLEXIDIS another large European project was started: the OLLA project. The mission of this integrated project is to demonstrate the full potential of Organic Light Emitting Diodes (OLEDs) for illumination purposes.

There are two major solid-state lighting technologies: inorganic and organic LEDs. The Inorganic LEDs are point sources, which are now entering the market in applications like flashlights and signal lights. Organic LEDs are large area light sources made from several layers of small molecule or polymer emitting materials. As OLEDs are ultra flat and highly efficient they have the potential to become the next generation light source for many applications.

“Lighting applications require much higher brightness and longer lifetime compared to display applications” says Peter Visser, coordinator for OLLA.“ as you normally do look not directly into a light source, as you do with a display, but towards the reflection on objects. ” The OLLA project aims to develop white OLEDs with a brightness level of 1000 candela per m^2, lifetime of 10.000 hours and an efficiency of 50 lumens per watt.



As both projects work on the development of light-emitting materials, regular alignment is foreseen.“ OLLA now focuses on achieving its high targets on normal glass substrates. But in the near future we will also look for flexible substrates as being researched in FlexiDis. But we will not only look for technical alignment, but also in practical organizational sense. We now have planned together a booth on the on the Communicating European Research Event in Brussels in November 2005.“ Peter Visser said.

For more information on OLLA: www.olla-project.org

www.olla-project.org

Events Calendar

19-22	Sep2005	Eurodisplay 2005 Conference Edinburgh, Scotland http://www.sid.org/conf/eurodisplay2005/eurodisplay2005.html
4-5	Oct 2005	Plastic Electronics 2005, Conference & Showcase Messe Frankfurt, Germany October 4 + 5, 2005 www.plastictronics.org
23-26	Oct2005	Polytronic 2005, the 5th International IEEE Conference on Polymers and Adhesives in Microelectronics and Photonics, Wroclaw, Poland http://www.polytronic2005.org
14–15	Nov2005	CER Communicating European Research, Brussels http://europa.eu.int/comm/research/conferences/2005/cer2005/index_en.html
22-23	Nov2005	Forum 2005 'be-flexible' 6th International Workshop onThin Semiconductor Devices & 4th International Workshop on Flexible Electronic Systems, Munich, Germany www.be-flexible.de
6-9	Dec2005	IDW/Asia Display ' 05 Takamatsu, Japan http://idw.ee.uec.ac.jp/
6-9	Feb2006	USDC's 5th Annual Flexible Displays & Microelectronics Conference Phoenix , USA http://www.usdc.org/resources/flex06_info.htm
4-9	Jun2006	Society for Information Display, SID 2006 San Francisco, USA www.sid.org