



**IST-028154**

**FORK**

**Development of a 4K compatible LCOS microdisplay device for D-cinema, medical imaging and simulation applications**

**Instrument: Specific Targeted Research Project  
Thematic Priority: Information Society Technologies (IST)**

**Deliverable D7.1.2**

**Final R&D results available on the internet**

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**Duration: 30 months**

**Responsible Contractor : IMEC  
Contributing Contractors : All**

**Revision : 1.0**

<b>Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)</b>		
<b>Dissemination Level</b>		
<b>PU</b>	Public	<b>X</b>
<b>PP</b>	Restricted to other programme participants (including the Commission Services)	
<b>RE</b>	Restricted to a group specified by the consortium (including the Commission Services)	
<b>CO</b>	Confidential, only for members of the consortium (including the Commission Services)	

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## **1. Executive summary**

The purpose of this deliverable is to provide a public summary of the main results of the FORK project on 'Development of a 4K compatible LCOS microdisplay device for D-cinema, medical imaging and simulation applications'. This summary will be uploaded on the FORK website.

## 2. Introduction

### 2.1 Project data

- **Title:** Development of a 4K compatible LCOS microdisplay device for D-cinema, medical imaging and simulation applications
- **Acronym:** FORK
- **Thematic Priority:** Information Society Technologies (IST)
- **Instrument:** Specific Targeted Research Project (STReP)
- **Starting date:** 1 February 2006
- **Duration:** 30 months
- **Consortium:** 7 partners : See Section 2.4

### 2.2 Abstract

Liquid Crystal on Silicon (LCOS) combines two very well-known technologies, namely the IC/CMOS and the Liquid Crystal (LC) technologies. As both of these are very mature, it is obvious that LCOS has a huge potential for very high-end applications, more than any other (projection) technologies.

The aim of the FORK project was the development of an LCOS microdisplay device for very diverse applications in simulation, medical imaging, control rooms and digital cinema. These applications require or benefit from very high pixel counts, high contrast ratio's, very high light fluxes and very good colour and brightness uniformity, analogue pixel addressing and high response times.

In order to meet all of these criteria, challenging research was needed in the field of LCOS backplane and driver design, LCOS backplane processing, IC (Integrated Circuit) stitching, new or improved Liquid Crystal (LC) mixtures, LC assembly and thermal design and packaging.

The FORK project consortium gathered European competence centres, each having expertise in one or more of the technology fields mentioned above. This consortium has drawn an ambitious though realistic work plan which would allow reaching the targeted project objectives successfully.

### 2.3 Objectives

#### A. Applications

The first major class of applications is (flight) simulation, characterized by high contrast ratio and fast response time requirements, as well as the need for a compact form factor.

A second class of applications is aimed at Presentation and Virtual & Augmented Reality systems, including Digital Cinema. These applications require high light outputs but are allowed to have a larger form factor.

A third class of applications is medical imaging. A high effective contrast ratio is required in typical office ambient light conditions, which implies a high light output. Since medical images are typically grayscale images a neutral gray colour is required from dark to bright grayscales.

#### B. Silicon processing

The main challenge from silicon processing point of view is the expected die size of the LCOS display. 4kx2k pixels have to be placed on the display area surrounded by logic circuitry. We can expect chip diagonals exceeding the maximum diagonal allowed by the lithographic equipment. To build such a

big die, it has to be constructed by several lithographic shots. This technique is known as "Stitching". One objective was the development of a fast stitching technology suitable for small volume production. Another objective is to develop design rules or transformation algorithms for chip layout generating software tools that are tolerant for the stitching seam areas and take into account overlay area effects such as line width variations.

To comply with the extremely high quality demands of the envisaged applications, a reduction of micro and macro range in-homogeneous-ness of the chip topology has been targeted.

Finally, an integrated spacer technology had to be developed, taking into account the interaction with the alignment layer process.

### **C. Liquid crystal assembly and liquid crystal mixtures**

An LCOS technology had to be developed that:

- is adapted to large active matrix diagonals
- is certified for high light fluxes and related issues and
- exhibits high switching speeds.

Both existing LC mixtures and newly developed mixtures had to be used to target these objectives.

### **D. Backplane and electronics design**

The first challenge is to develop a very small pixel circuit, so that the resulting LCOS imager is compatible with manufacturable optical engines. Several pixel architectures had to be investigated.

The second challenge is the use of stitching and its implications for the design.

The third objective is the design of an integrated driver circuit capable of refreshing the 8.8 million pixel device at 120 Hz.

### **E. Packaging**

The main challenge for the package is to deal with the heat generated by the enormous required light output. Standard packages are not suited for the targeted high light fluxes where a lot of heat has to be removed from the imager. Therefore a novel custom-made LTCC (low temperature co-fired ceramic) package had to be developed within this project. .

## **2.4 Original Consortium**

- Gemidis NV. (Co-ordinator)
- IMEC vzw.
- Philips Semiconductors GmbH, later replaced by NXP Semiconductors Germany GmbH
- Universidad Politécnica de Madrid (UPM)
- Wojskowa Akademia Techniczna (WAT)
- BARCO NV.
- SEOS Ltd.

## **2.5 Work packages**

- Work package 1 : Specifications
- Work package 2 : Microdisplay design
- Work package 3 : Microdisplay chip processing
- Work package 4 : LC assembly and technology
- Work package 5 : Microdisplay chip packaging
- Work package 6 : Validation and assessment
- Work package 7 : Dissemination and exploitation
- Work package 8 : Demonstration activities
- Work package 9 : Management and coordination

### **3. Premature termination of the project**

During the FORK project the consortium has suffered several setbacks:

1. Withdrawal of Philips Semiconductor, who were quickly replaced by NXP Semiconductors Germany
2. Withdrawal of NXP Semiconductors Germany
3. Failure to find a company to replace NXP Semiconductors Germany as a partner
4. Being forced to accept a sub-contractor as a replacement of NXP Semiconductors Germany
5. Liquidation of co-ordinator Gemidis

This finally led to the premature termination of the project in July 2008.

## 4. Results

Although the FORK project was prematurely aborted, the consortium was able to produce several results that are potentially valuable.

The project was put in a state of reduced activity after the withdrawal of NXP Semiconductors Germany, pending the advent of a company to replace NXP as a partner. The activity within the project was essentially confined to **Work package 4 on LC Assembly and Technology**, and in particular focussed on the development of low viscosity, medium birefringence, liquid crystal mixtures for the Vertically Aligned Nematic (VAN) technology that had been selected by the consortium. This liquid crystal development work has proved to be successful and has led to the formulation of a new mixture, based on some novel compounds synthesised by WAT, that meet all of the parameters specified by the consortium. Equally important, the new mixture performs better than the commercially available VAN mixtures.

The work at WAT was supported by UPM who characterised the mixtures formulated by WAT. In addition, UPM studied the stability of the near-homeotropic alignment obtained from rubbed polyimide and evaporated silicon dioxide. It was found that under high light intensities the alignment on polyimide degraded due to a decrease in surface anchoring strength. In view of this result the consortium then focussed on the use of evaporated silicon dioxide alignment layers based on the technology developed by IMEC. Work at IMEC confirmed that the VAN mixtures formulated by WAT gave uniform near homeotropic alignment on evaporated silicon dioxide. In addition, IMEC modelled and overcame fringing field effects.

The development of an improved mixture for VAN LCDs is the main achievement of the FORK project. It is the wish of the consortium to exploit this important result as far as possible.

Before activities in **Work package 5 on Microdisplay packaging** were halted due to the withdrawal of NXP, IMEC had started the development of a low temperature co-fired ceramic (LTCC) chip-carrier. Key objectives of this work were the design and fabrication of a chip-carrier having water-cooling channels in order to control the temperature of the LCOS display while exposed to the high intensity projection lamp. Careful control of the firing profile and use of a pure oxygen atmosphere for the firing led to the fabrication of a chip carrier with improved planarity relative to commercial alumina chip-carriers.

Besides the above results achieved in the work packages 4 and 5, some intermediate results could also be achieved in other work packages of the project such as :

- **Work package 3 : Microdisplay chip processing :**
  - A novel stitching layout design rule was developed for microdisplay chip processing
  - Alignment and overlay marks have been evaluated and designed
  - Stitching accuracy results have been elaborated. The results are very promising
  
- **Work package 6 : Validation and assessment :**
  - First positive lifetime validations of a compact lamp module solution with which a sufficiently high light output can be obtained in LCOS based engines for simulation applications.
  - Choice of an adequate cube and LCOS panel configuration concept that can be applied for larger (i.e. 1.55") LCOS panels and that sufficiently preserves a high contrast ratio, and construction of some quality verification tools for this concept.