

11 Mpixel Si-Ge Micro-mirror Array on CMOS

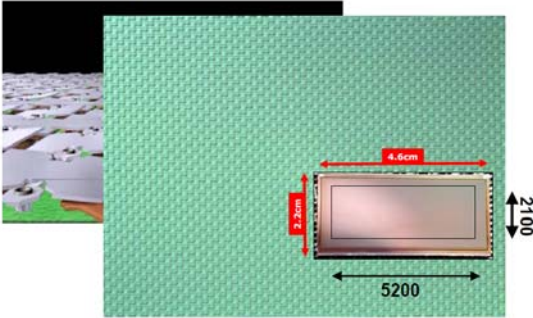
Ann Witvrouw

Exhibit #3: 11 megapixel micro-mirror array with 8 μm pitch made in poly-SiGe above standard 0.18 μm analog-CMOS wafers fabricated by NXP, featuring 6 interconnect levels.



11MPixel micro-mirror array

- To be used as SLM (Spatial Light modulator)

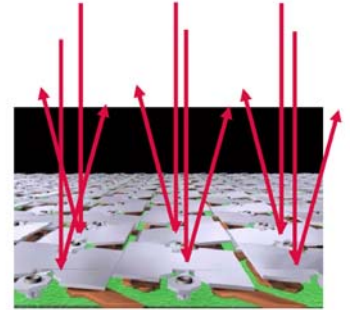


Project together with ASML, Bruco, NXP, Philips Appl. Tech.

11MPixel micro-mirror array: application

Spatial Light Modulator:

- Light is deflected by each mirror to create image
- Applications: video projection, mask writing, maskless imaging



Micro-mirror array: Challenges

11M mirrors
MEMS + CMOS integration
Yield impact
Stitching

8x8 μm^2 pitch mirrors
Well controlled layer thickness
Hinge width requires good litho

10 nm peak-valley mirror flatness:
Stress control of mirror
Measure 11M mirrors with <10 nm accuracy

6 kHz update rate
600 Gbit/s data requires > 2500 (analog) wires

10 μrad global flatness
CMP optimized in CMOS & MEMS
Cleaning challenge (# part./ $\text{cm}^2 \leq 1$ of 0.8 μm)

Additional challenges:
Reliability: 10 years ($1\text{E}+12$ tilt cycles)
Assembly of delicate chip

2100 x 5200 Mirror array

49 mm

22 mm

Reflected light

Incident light

Mirror

Hinge

Flatback

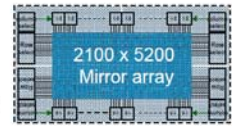
Micro-mirrors: State-of-the-art

TI DLP Discovery 4000:
1920x1080 (2M)
Digital
Mirror Pitch 10.8 μm
Mirror Area 21 x 12 mm^2 (2.5 cm^2)
<www.dlp.com

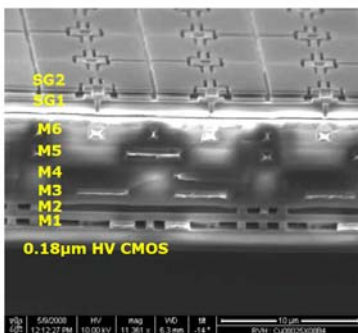
Fraunhofer SLM:
2048x512 (1M)
Analog
Mirror Pitch 16 μm
Mirror Area 33 x 8 mm^2 (2.6 cm^2)
<www.ipms.fraunhofer.de

This work:

5200x2100 (11M)
Analog
Mirror Pitch 8 μm
Mirror area 42 x 17 mm^2 (7 cm^2)



Micro-mirrors: processing



SiGe is chosen to achieve required mirror specs including reliability at CMOS-compatible T

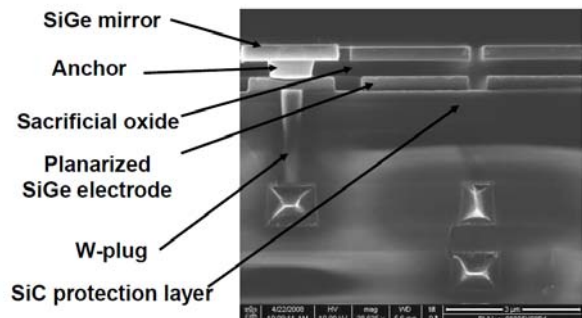
SiGe-based micro-mirror module

Planarised interface

0.18 μm analog CMOS with 6 metal levels (from NXP)

< L. Haspelagh et al., Proc IEDM 2008

Micro-mirrors: processing



Micro-mirrors: functional & reliability analysis

Cupping map of a 100x100 array

White Light Interferometry

7 nm peak-valley

Flat mirrors!

No Creep!

Functional

No fatigue!

2.8 $\cdot 10^{12}$ cycles!

Cu6K180 X82 A4
Mean: 2.3 MHz
Std dev: 9.29Hz

Micro-mirrors: packaging and testing

Mirror performance after packaging
123648 mirrors tested

Item	Specification	Results
Good Mirrors %	/	99.5 %
Mean Cupping	< 10 nm	5.4 nm
Residual Piston	< 1nm	< 1 nm

Direct imaging:
3 mirror contact holes

Packaging and assembly
A. Witvrouw et al. Proc. MEMS09

Imaging results: J. Lauria et al. Microel. Eng. 86, 569-572 (2009)