MEMS TECHNOLOGIES DRESDEN

TECHNOLOGY DEVELOPMENT, PILOT-FABRICATION AND FOUNDRY SERVICES

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19.04.2010

Fraunhofer IPMS: Dresden, since 2003,MEMS/ MOEMS,230 empl.,25 M budget

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AGENDA

- MEMS Services
- Technology Toolset
- Selected Processes
- Solutions
- Detailed Equipment List

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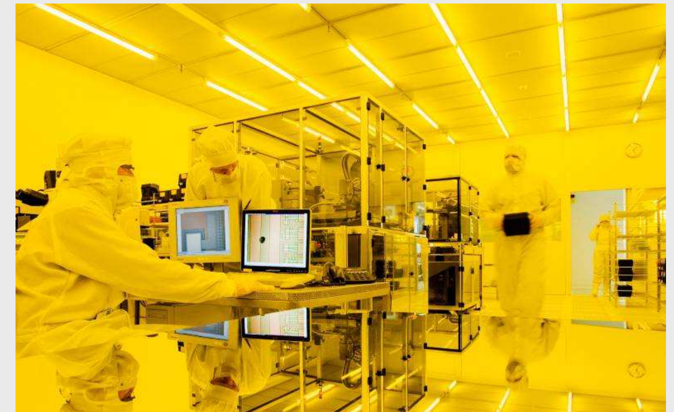
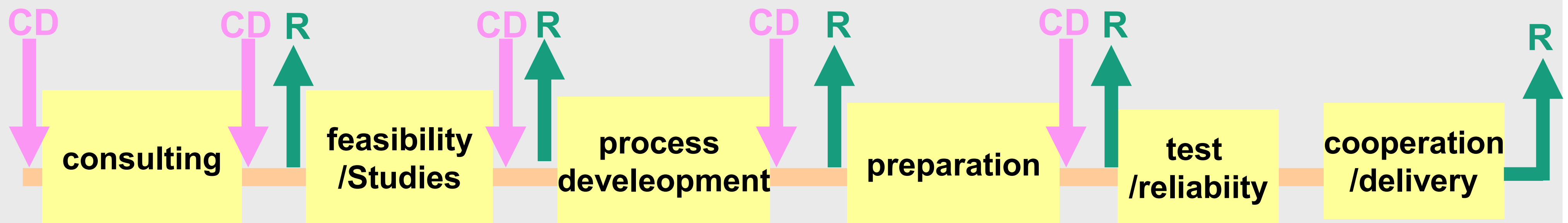
OUR BUSINESS MODELL: *From R&D TO Pilot-Fabrication*

- Consulting service
- Complete process development
- Demonstrators and Prototypes
- Pilot-Fabrication
- Foundry Services
- Interworking: tool sharing/ manpower sharing/ ext cooperations



MEMS Technologies Dresden

Flexible value chain [CD=customers demand; R= result]



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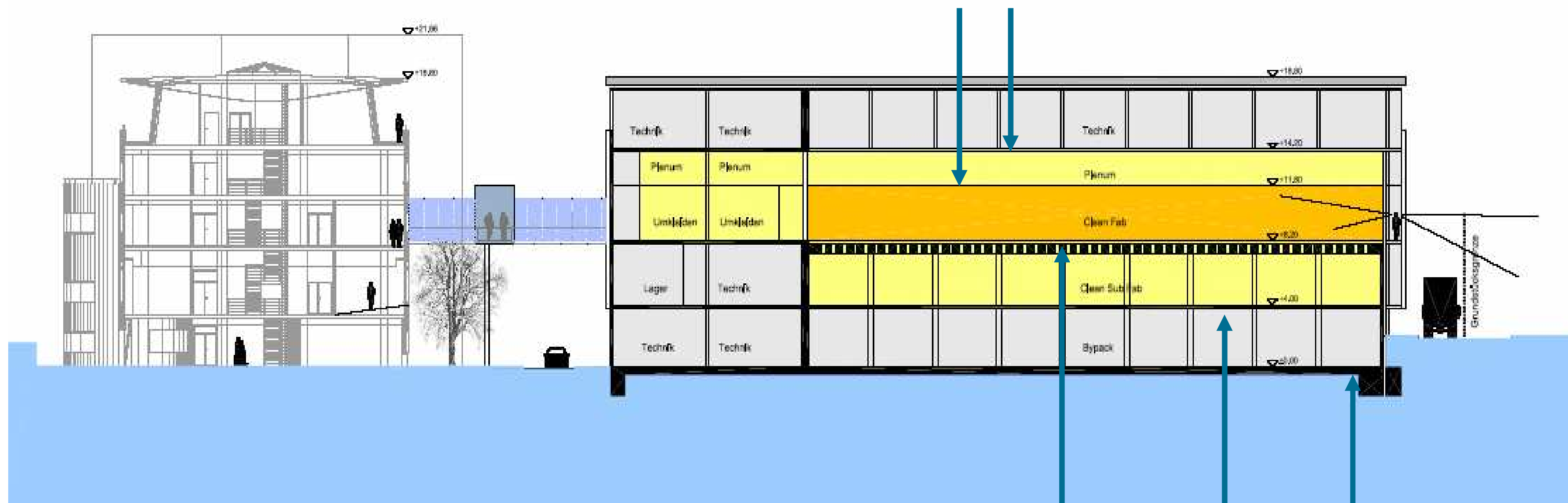
MEMS CLEAN ROOM

- 1500 m^2, class 10
- complete 6” Wafer line
- 3 shift operations for R&D and pilot fabrication
- PPS based planning and documentation
- ISO 9001:2008 certification since 2003

MEMS/MOEMS-CLEAN ROOM: INFRASTRUCTURE

Air condition system/ cooling systems



Clean room, Class 10

Supply level, media

Supply level, media + logistics

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- MEMS Services
- **Technology Toolset**
- Selected (Core-) Processes
- Best Practice Solutions (success stories)
- Detailed Equipment List

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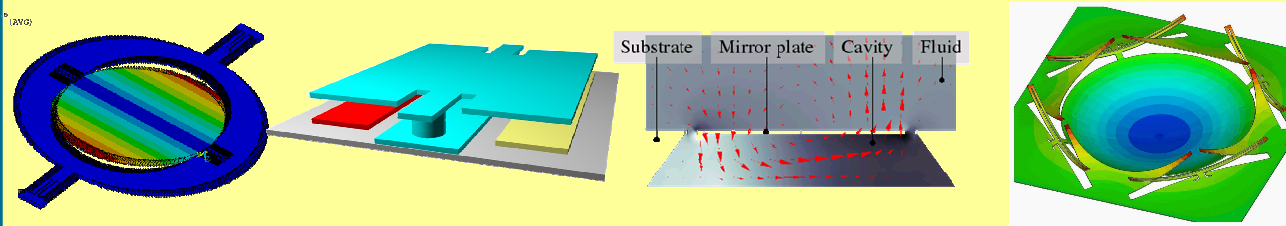
TOOLSET meets costumer needs

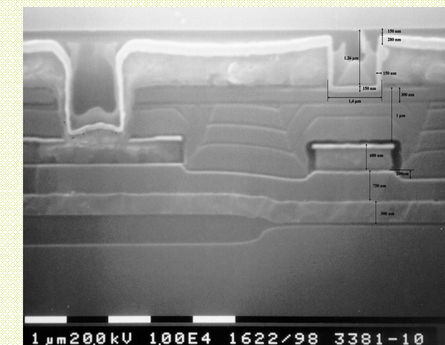
1: MEMS/MOEMS Design and Simulation



4: CMOS

- HV- CMOS- Process
- Application: Backplane for Spatial Light Modulator

Active silicon (IR Sensors)

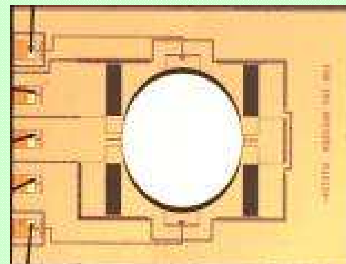


2: Surface MEMS Technology

- MEMS on CMOS-Backplanes
- Application: Spatial Light Modulator

3: Bulk MEMS Technology

- 3- dim. Structures in Silicon
- Applications: MEMS Scanner Pressure Sensor



OLED-on-CMOS

- OLED Integration on CMOS
- Application: Microdisplays and Sensor applications

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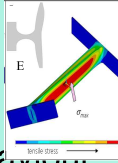
1: MEMS/MOEMS Design and Simulation

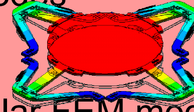
Structural mechanics



- ✓ hinges
- ✓ cantilevers
- ✓ dynamical behaviour
- ✓ inertial effects
- ✓ optimization algorithms
- ✓ stress/load analysis
- ✓ linear and non-linear effects

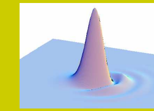
Modal analysis eigenmode

analysis for wanted und interfering modes



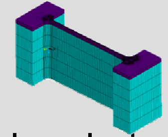
- ✓ flexible modular FEM model generation for 1D- or 2D-scanning mirrors, translation mirror
- ✓ pre-stress modal analysis include additional nonlinear constraints

Optics



- ✓ Bragg mirrors
- ✓ AR/HR coatings
- ✓ influence of mirror deformation on optical properties
- ✓ point spread function (PSF)
- ✓ modulation transfer function (MTF)

Coupled field



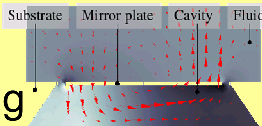
magneto-structural analysis

electro-thermal analysis

structural-thermal or structural-thermal-electric analysis

piezoelectric or piezoresistive analysis

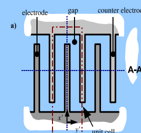
Fluid mechanics



- ✓ friction
- ✓ damping
- ✓ fluidic flow analysis
- ✓ flow profiles
- ✓ fluid / structure interaction
- ✓ non-linear effects
- ✓ optimization

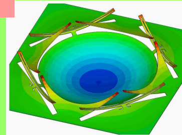
Electrical field

- ✓ Steady-state current conduction analysis
- ✓ time-transient electric field analyses
- ✓ electrical field distribution



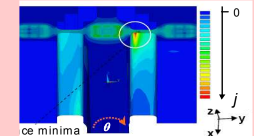
- ✓ 2D- or 3D-FEM-field models
- ✓ capacitance simulation for complex structures
- ✓ electrostatic forces

Piezo electricity



- ✓ electric / structure mechanics interaction
- ✓ multilayered material stack deformation profiles
- ✓ voltage dependent deformation of bi- and multimorph layers
- ✓ thermal stress optimization
- ✓ layered stack optimization

Piezoresistivity



- ✓ structure mechanics / electric interaction
- ✓ load dependent resistance & voltage
- ✓ stress-, electric- and current-field distribution
- ✓ normal and sheer stress transducer concepts
- ✓ structural and doping level optimization

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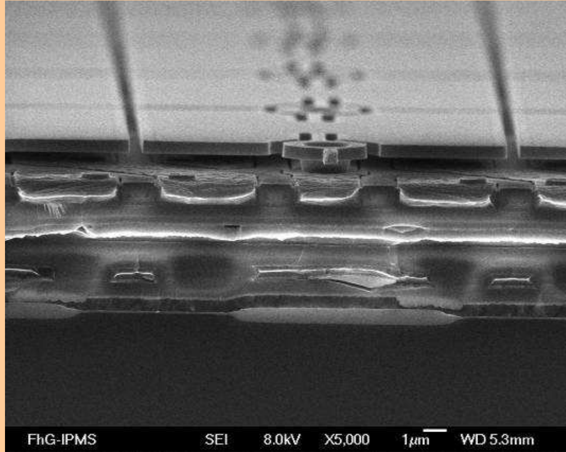
2: SURFACE MEMS TECHNOLOGY



Surface MEMS Technology= Fabrication of sensors & actors on the wafer surface

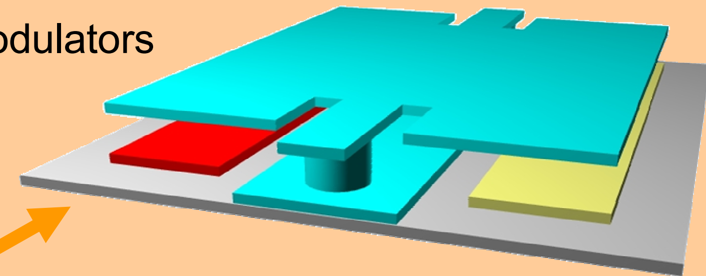
MEMS on CMOS Integration for free standing structures on Si- Substrates

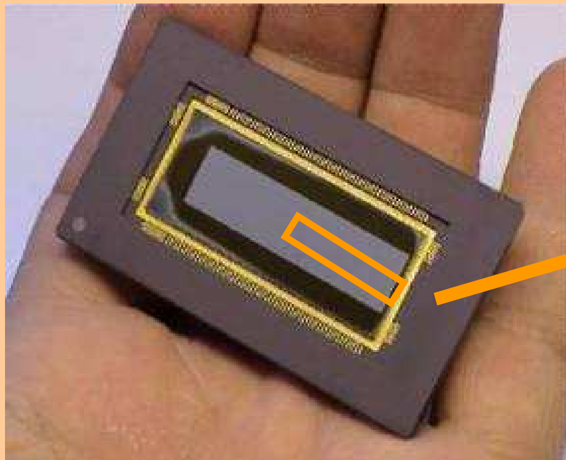
Application: Spatial Light Modulators

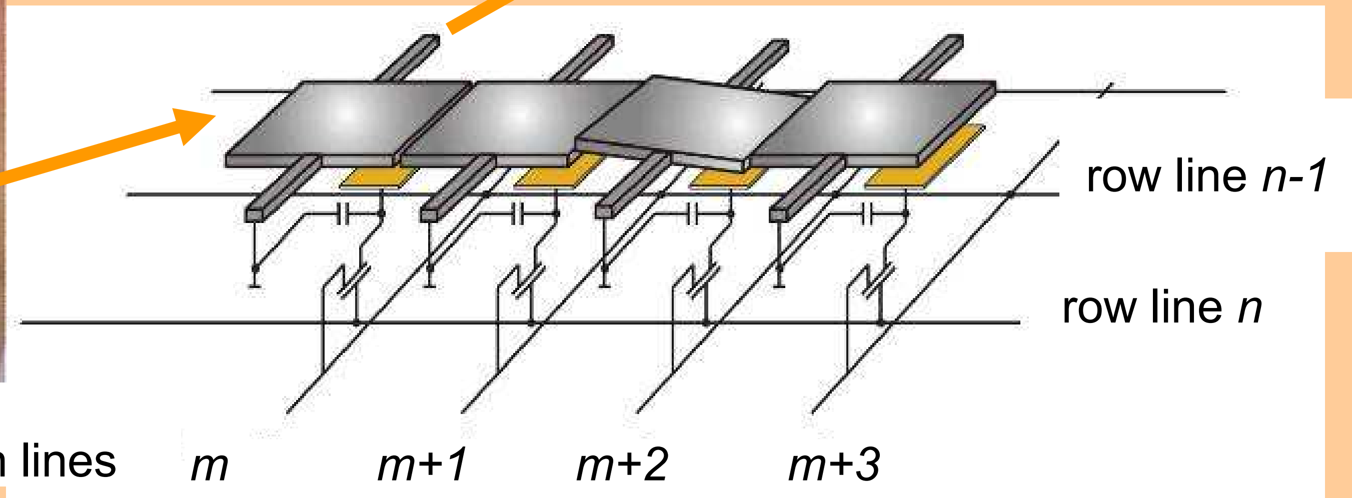
16 µm pitch

2048 x 512 pixel

2 kHz frame rate







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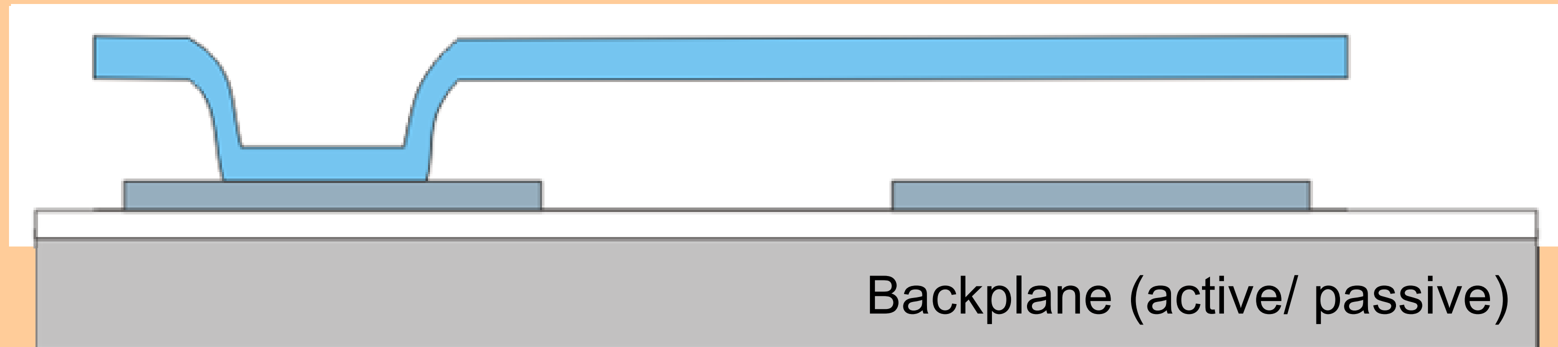
2: SURFACE MEMS TECHNOLOGY/ PRINCIPLE



... of actuator

- ... actuator
- Materials: ... SiO_2, Si, …
- Sacrificial layer ...
  - Chemical Mechanical Polishing (CMP), Reflow, …

> Polymeric materials: CF_4/ O_2- Plasma

> Si: XeF_2- Vapour Etch

> SiO_2: HF- Vapour Etch

- Principle is expandable for multi level MEMS

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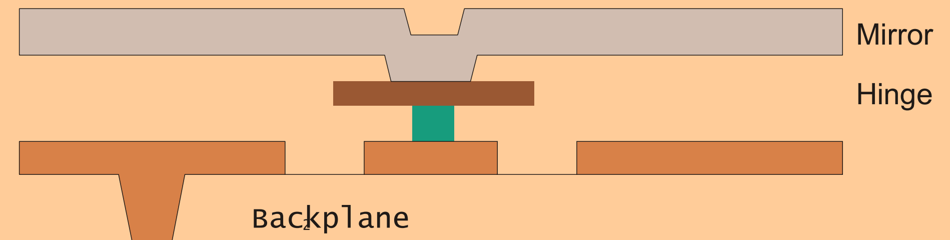
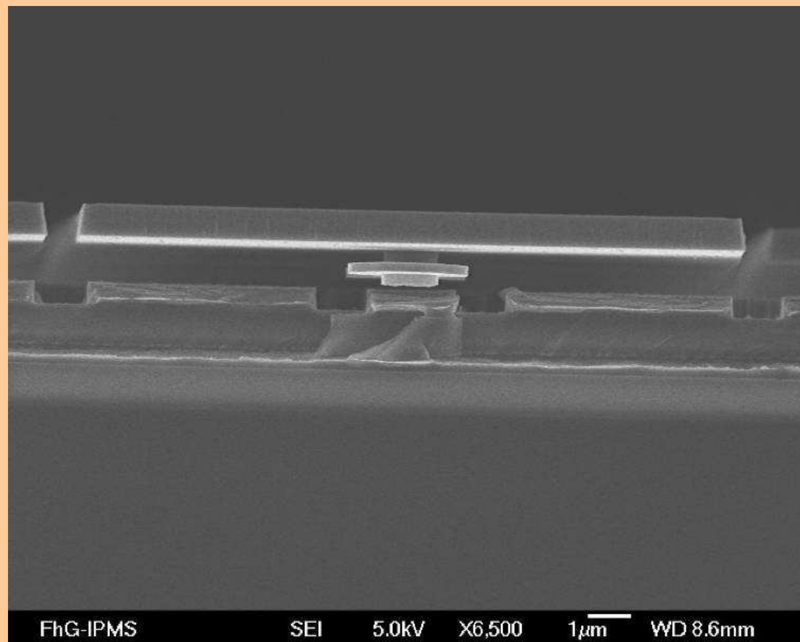
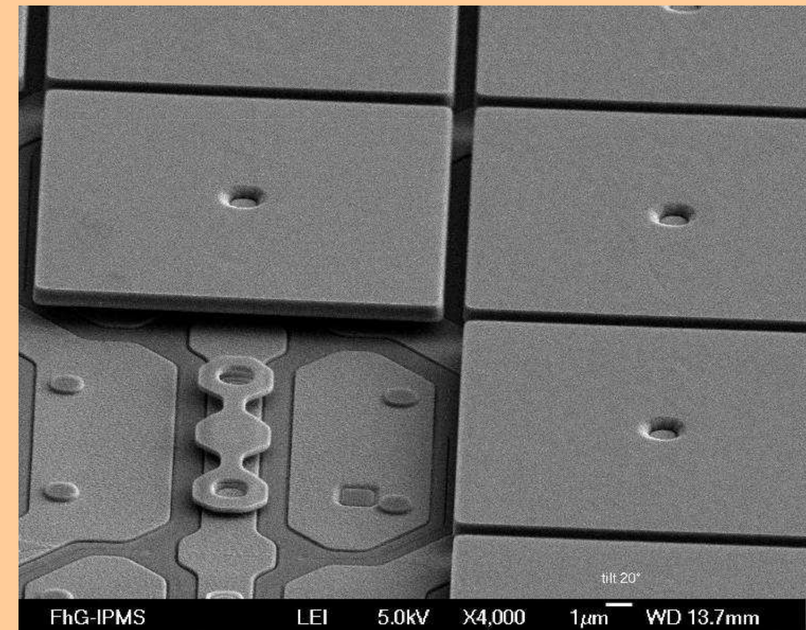
2.:SURFACE MEMS TECHNOLOGY

Spatial Light Modulator Architecture

- Hidden hinge actuators
- Inorganic sacrificial layers
- Actuator: amorphous materials
- Mirror: Al- Alloys, Stacks







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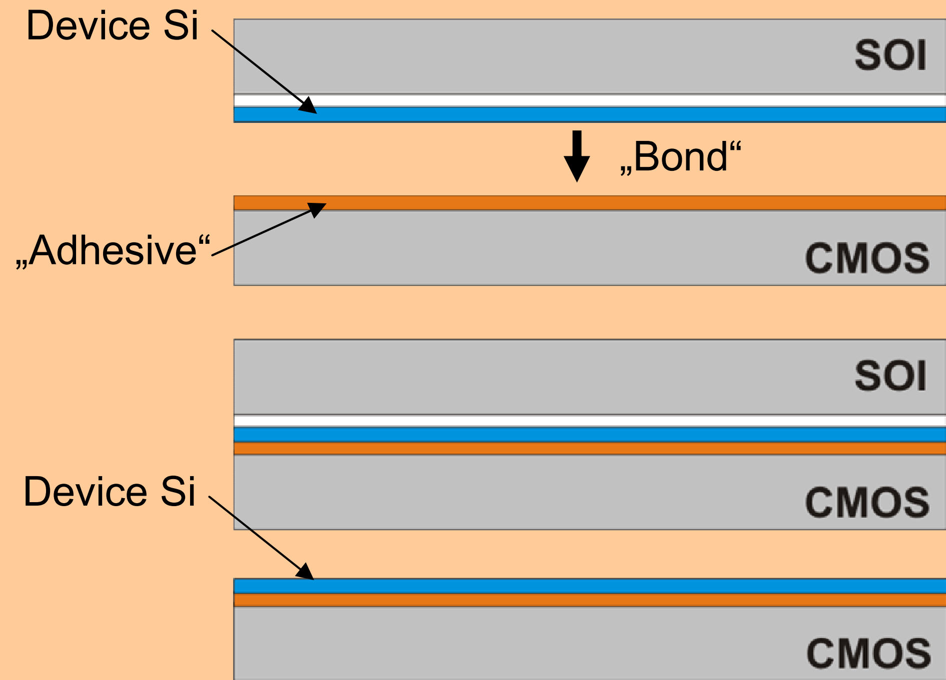
2.: SURFACE MEMS TECHNOLOGY

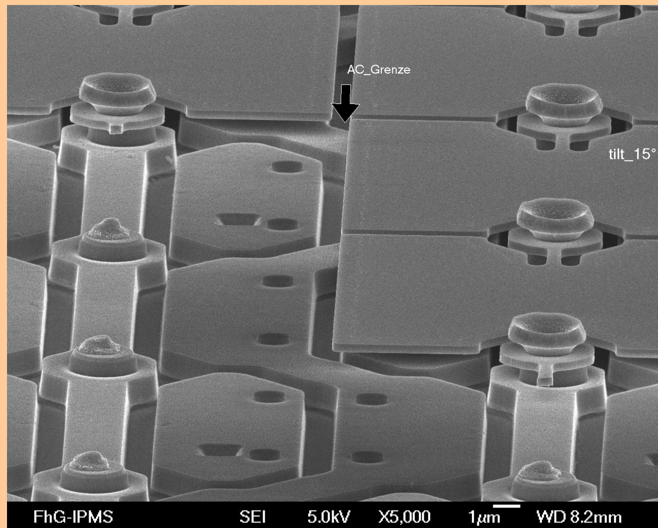
Development of c-Si actuators

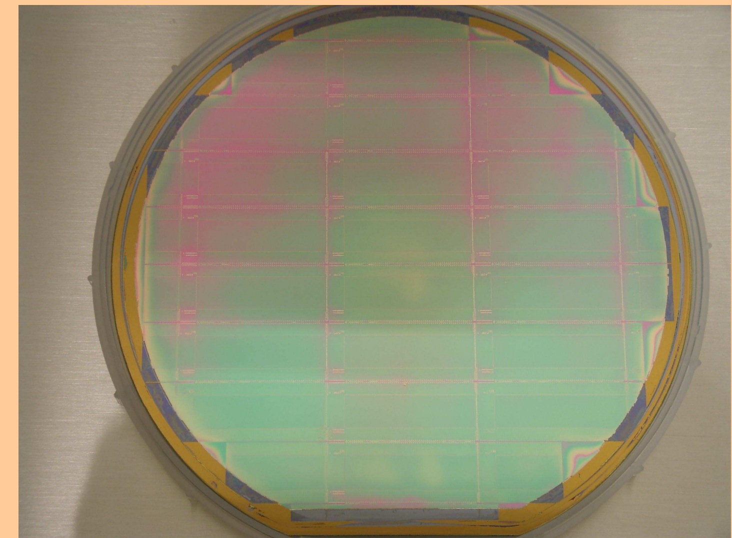
- Drift free c-Si actuators on CMOS wafers
- Layer transfer bond (adhesive and direct bond)



Status

- Test with adhesive bond structures are fabricated
- Process development in progress
- Direct bond under development





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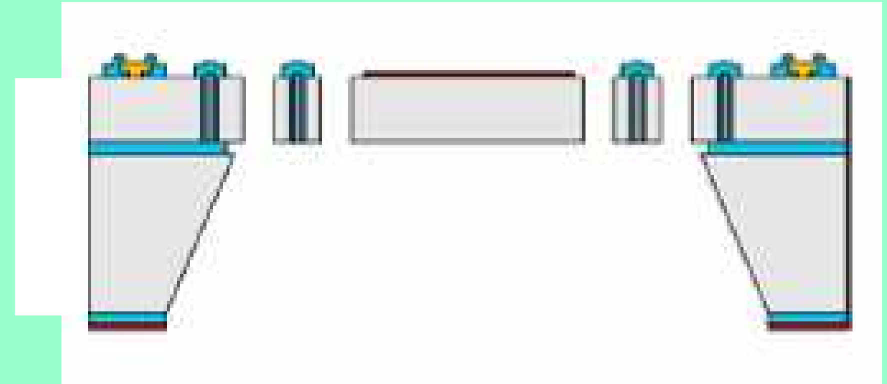
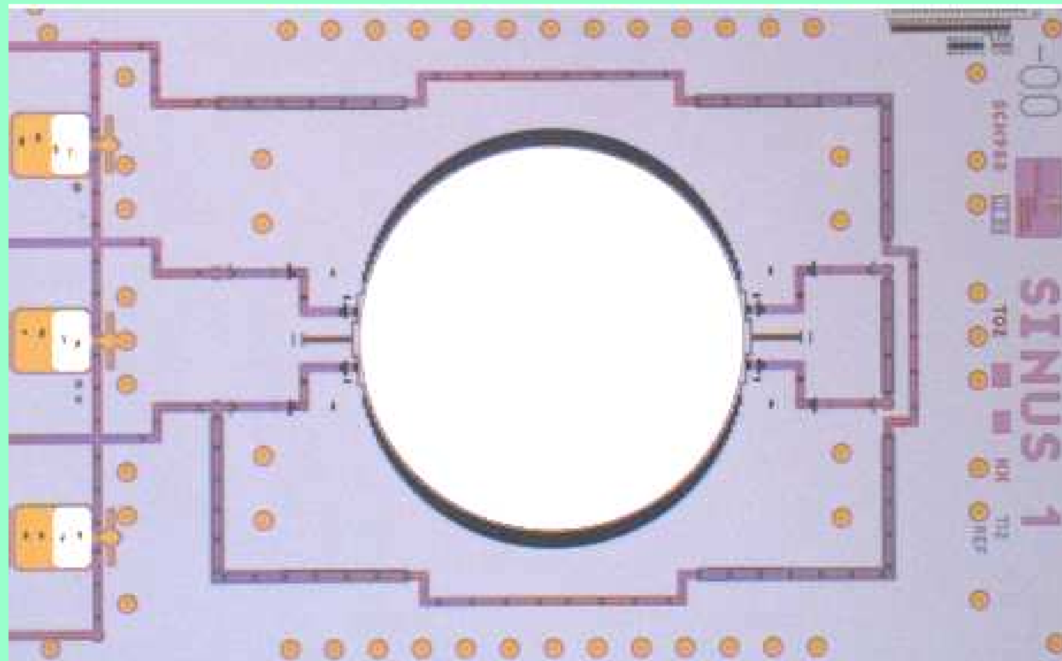
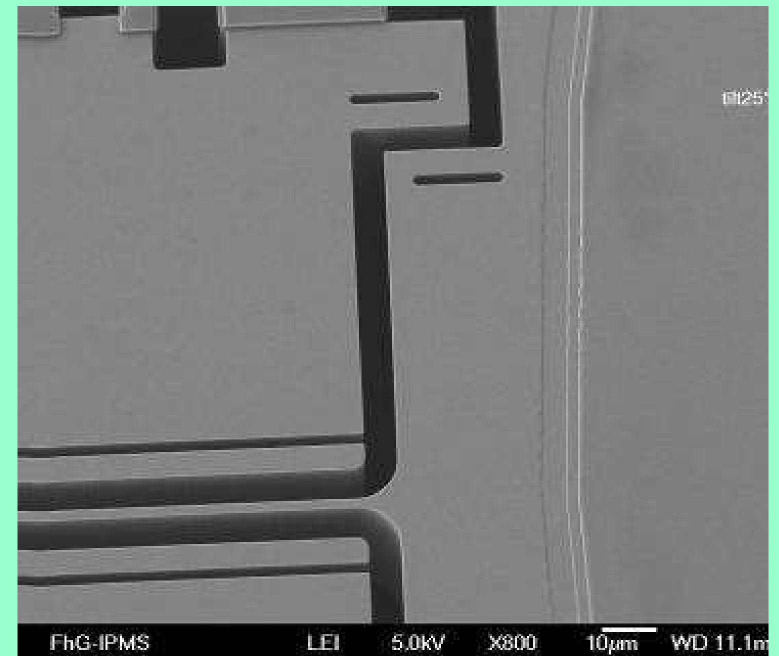
3.: BULK MEMS TECHNOLOGY

Bulk MEMS Technology= Fabrication of sensors & actors out of the wafer's material (bulk) itself





MEMS Scanner



Hinges of MEMS Scanner

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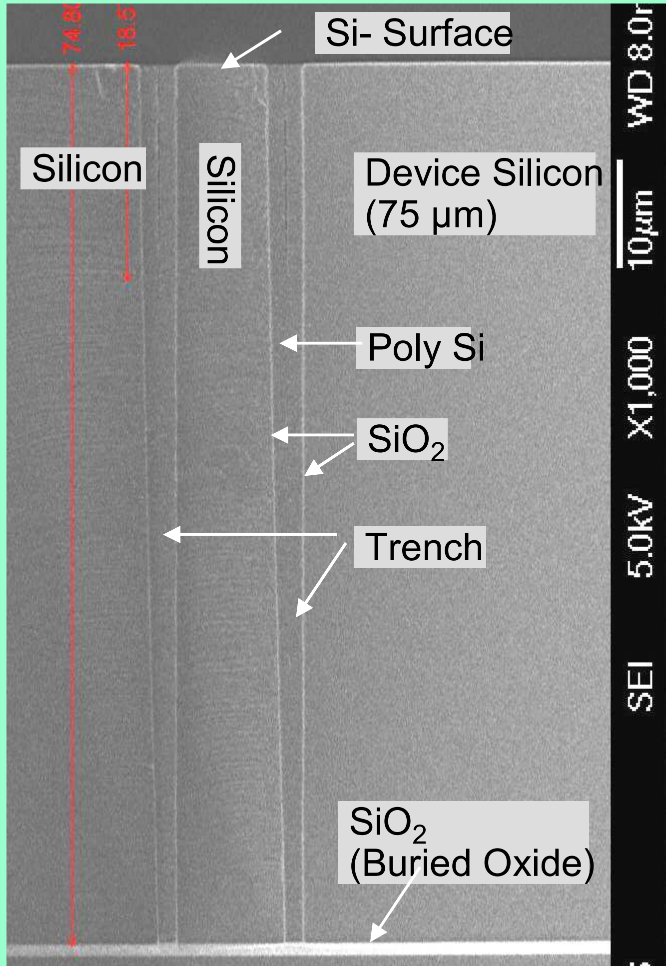
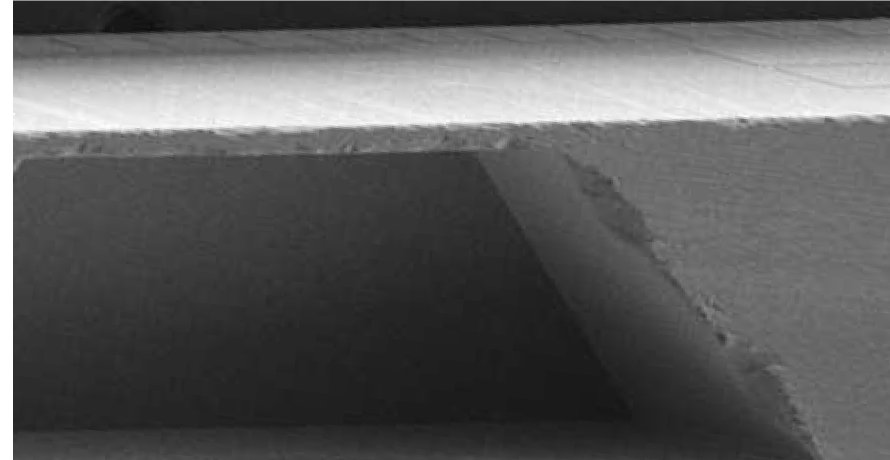
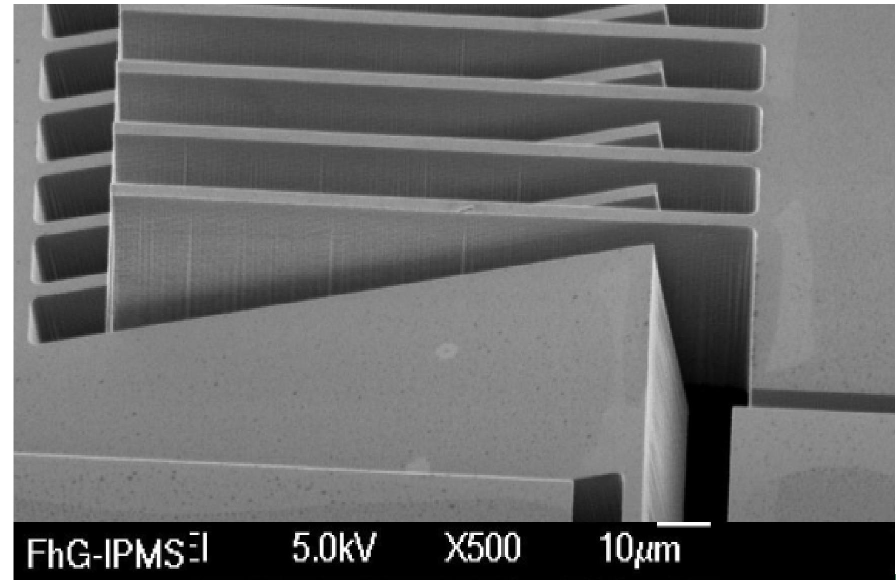
3.: BULK MEMS TECHNOLOGY



Insulated Silicon

Grooves & Membranes





Movable Silicon

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4.:CMOS & „active“ Silicon

HV-CMOS-Technology

- Double well CMOS process
- Electric strength 45 V
- ILD- Planarization (CMP)
- Application: Control circuit for Micro Mirror Arrays

“Active" Silicon

- PiN- Photo diodes
- FET with Ta_2O_5 and HfO- Gate -> ISFET

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Lithography

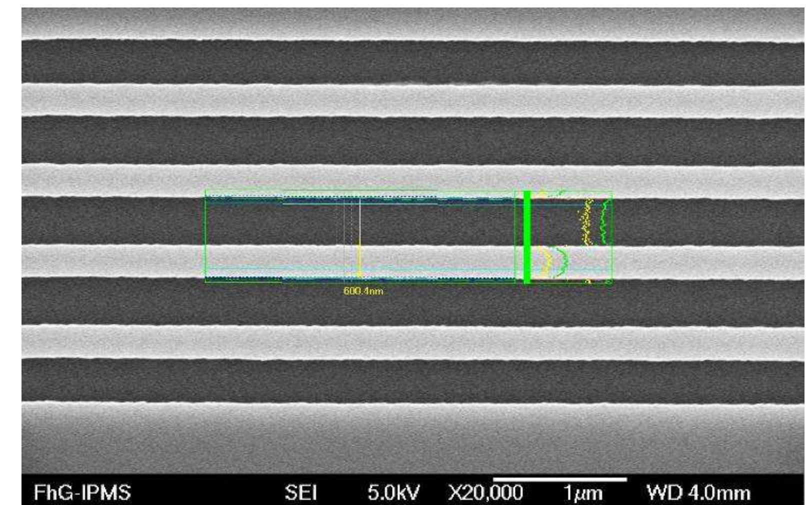
Stepper

- NSR-2205i 14E2/ Nikon
- CD: Lines & Spaces 300 nm, Holes 400 nm
- Overlay: 40 nm (Field Image Alignment (FIA))
- Exposure Field: 22 x 22 mm²

Mask Aligner

- MA 150 BSA/ Suss
- CD: 3 µm
- Front Side & Back Side Processes

Stepper: NSR-2205i 14E2



Resist, Lines & Spaces, Grid= 600 nm

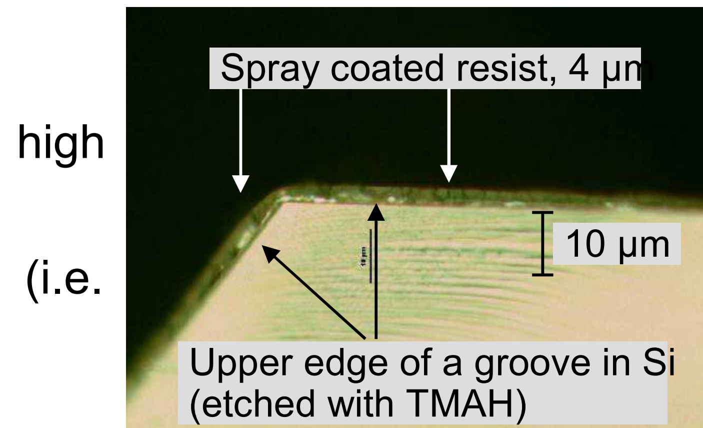
Lithography/ Coating

Spin Coater

- Coater/ Dev-I-line SK-80BW-AVP/ DNS Resists
- Gamma 80 Spin Coater/ Süss Polyimide, BCB

Spray Coater

- Gamma Alta Spray Coater/ Süss
- Conformal resist deposition for high topology
- Lithography in deep structures (i.e. 300 µm deepness)



Spray resist at high topology

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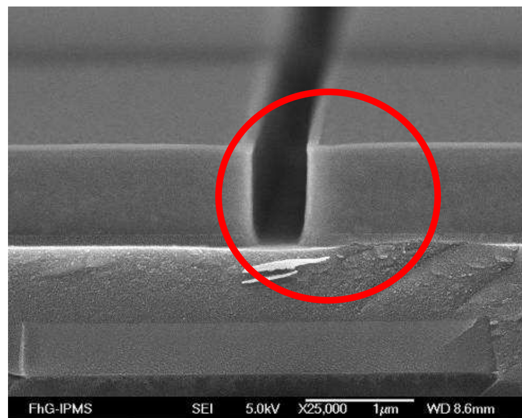
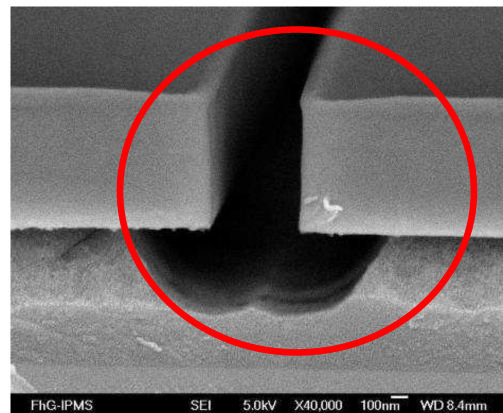
RELEASE PROCESSES

Release Processes

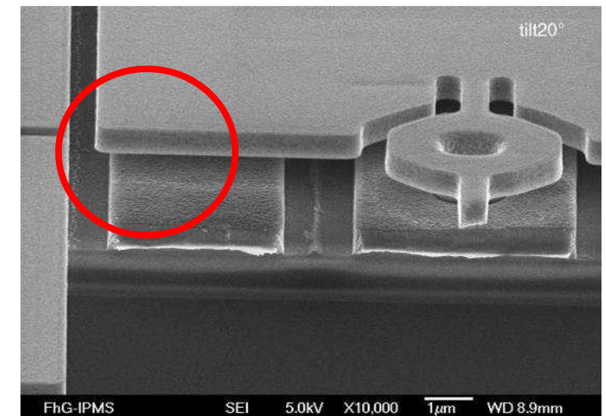
- X-SYS-3B:6/ Xactix: Si etch (XF2)
- MEMS-CET/ Primaxx: SiO_2 etch (HF vapour)
- Application: Release processes in Surface MEMS Technology
- Isotropic etch process
- Vapor etch for sticking free release of microstructures
- High selectivity to Al- Alloys



Before release



After start of release



Release is finished

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CMP

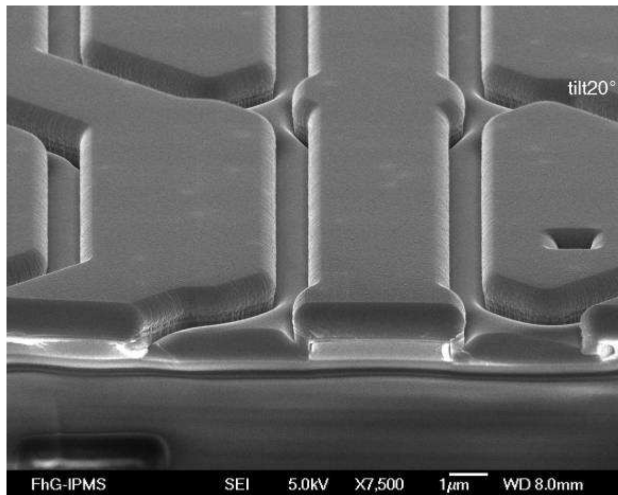
Chemical Mechanical Polishing (CMP)

MIRRA/ Applied Materials

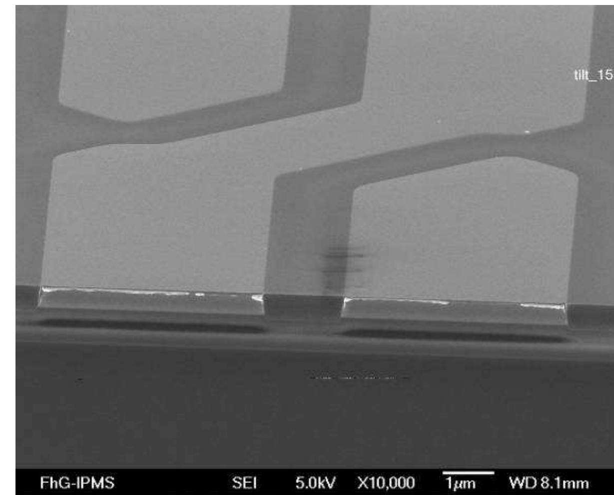
nTrepid/ Strasbaugh

Planarization of surfaces by polishing for:

- Photolithography
- High reliability of metallization
- Smooth surfaces in nm scale for mirrors in UV- applications



a-Si on metal line as sputtered



a-Si on metal line after CMP

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DEPOSITION / PVD

Sigma 204/ Aviza

- Metallization for contact systems
- Al, AlSiCu, Ti, TiN

CS400/ Von Ardenne

- MEMS- Materials
- Al, TiAl, Al-Alloys (Mirror, Hinges)
- SiO2, Al2O3 (Barriers, optical coatings)
- a-Si (Sacrificial layer)
- AlNi (piezoelectric actor)

Alcatel 610/ Alcatel

- Chemical Sensors
- Ta, Ta2O5, HfO2
- Evaporation

PLS 570/ Balzers

- Al, SiO_2, Al_2O_3

Sputter tool CS400

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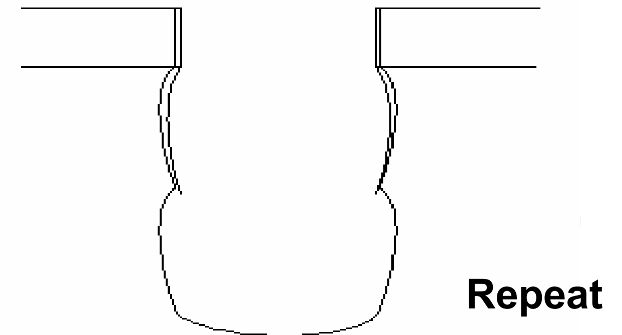
DRY ETCH (Silicon)

Deep Silicon Etch (Bosch Process)

- Omega fxP & Omega I2L/ Aviza
- High density / low pressure

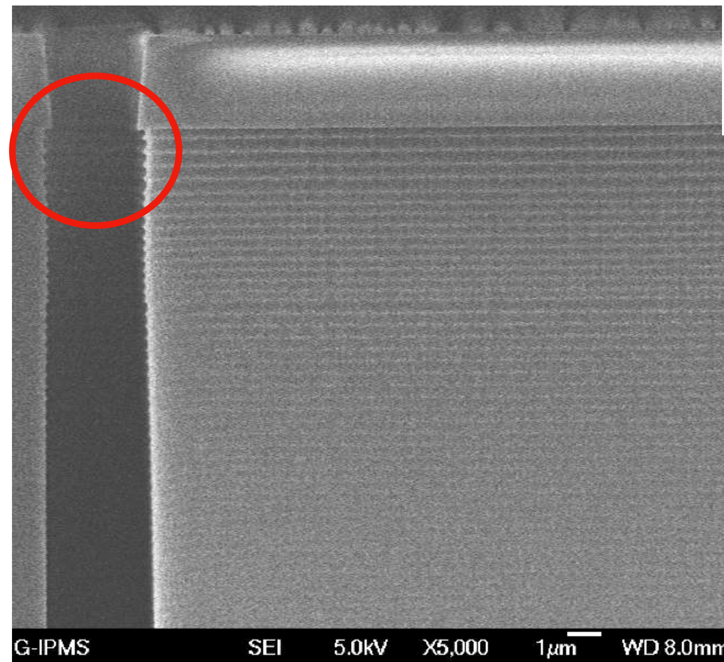
Isotropic Etch Step



Repeat

Etch Process

- Net anisotropic profile
- Scallops on micro-scale
- High aspect ratio



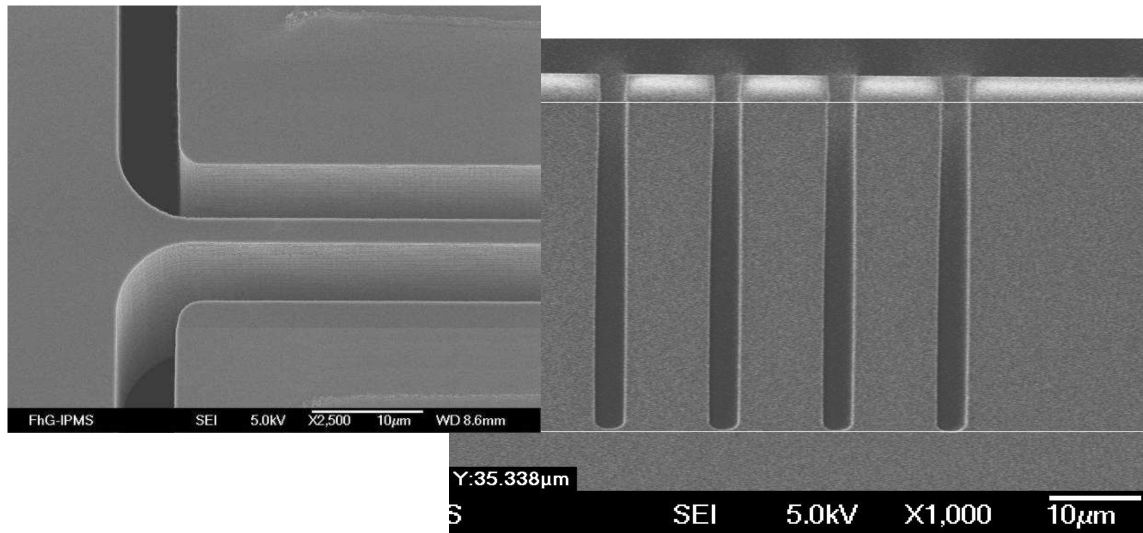
DRY ETCH (Silicon)

Fine Deep Trenches

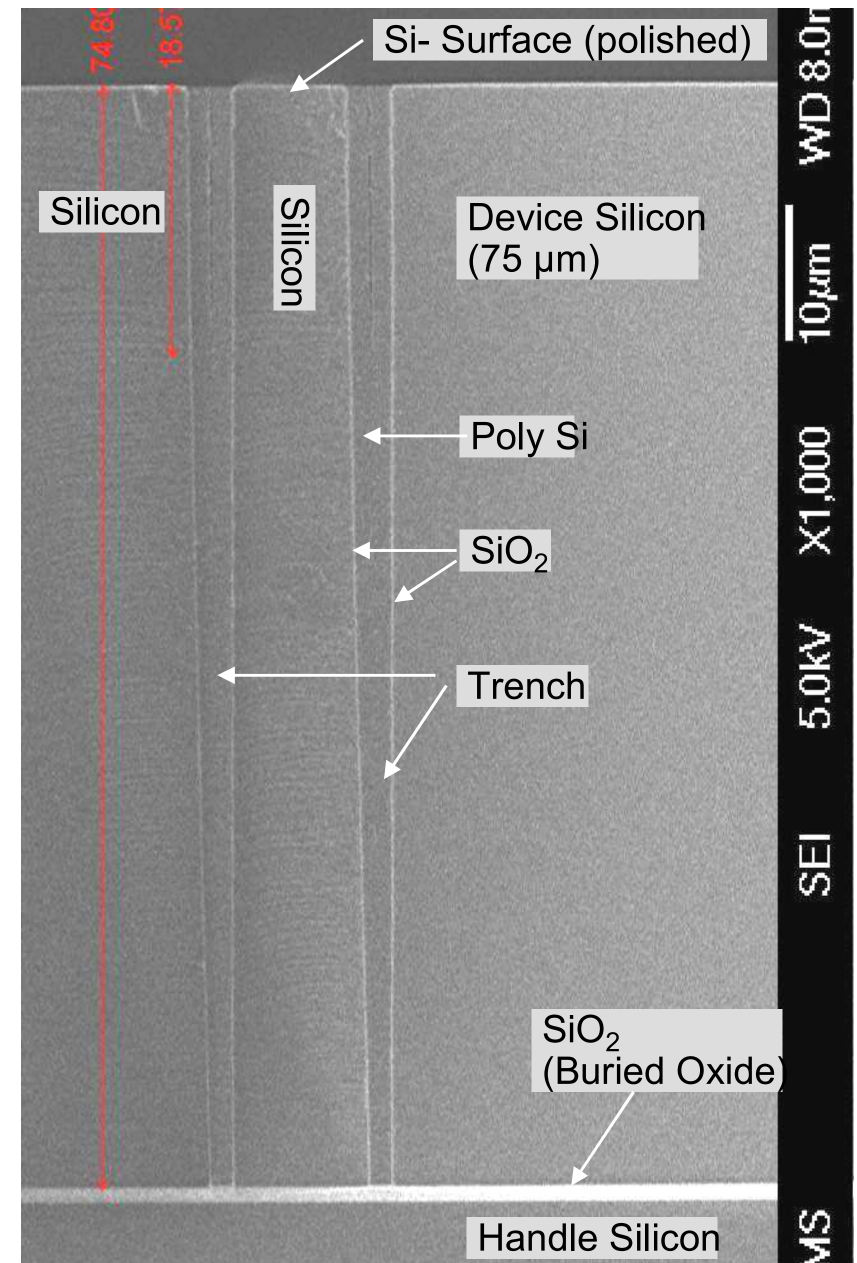
- Isolation trenches (dielectrically insulated Si)
- Free movable Si structures

Grooves

- Membrane etch



Vertical Trenches for movable Si- structures



Insulation trench, positive Profile
2.5 µm wide, 75 µm deep (SOI- Wafer)

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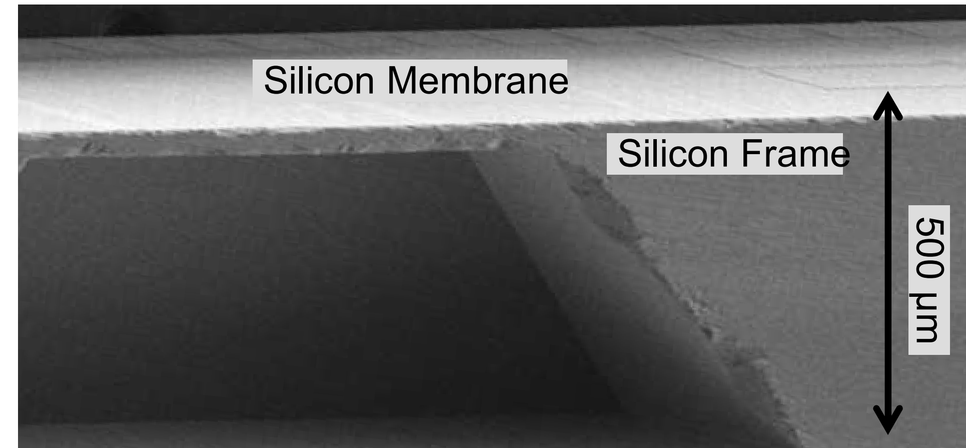
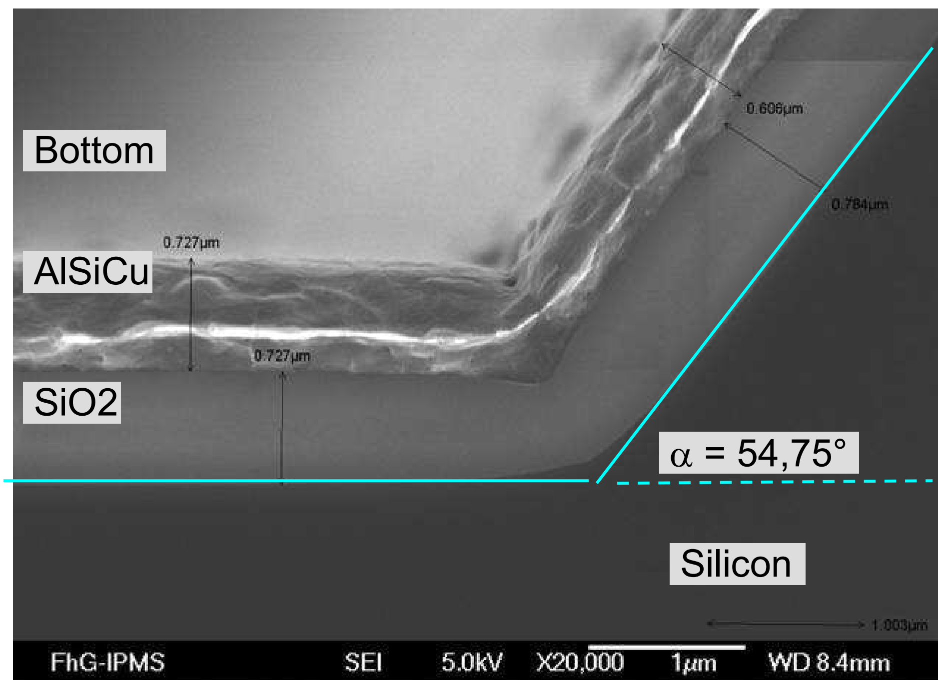
WET ETCH

Silicon Wet Etch

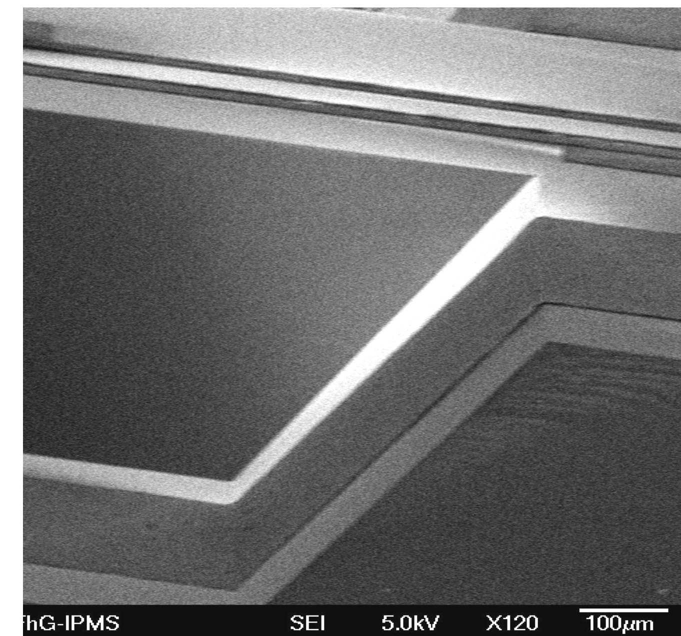
- anisotropic Si Etch: TMAH, KOH
- +/- 3 µm accuracy at 500 µm depth
- Grooves & Membranes



Silicon membrane, KOH etched



Silicon groove, TMAH etched



Metal line in a 200µm deep Silicon groove

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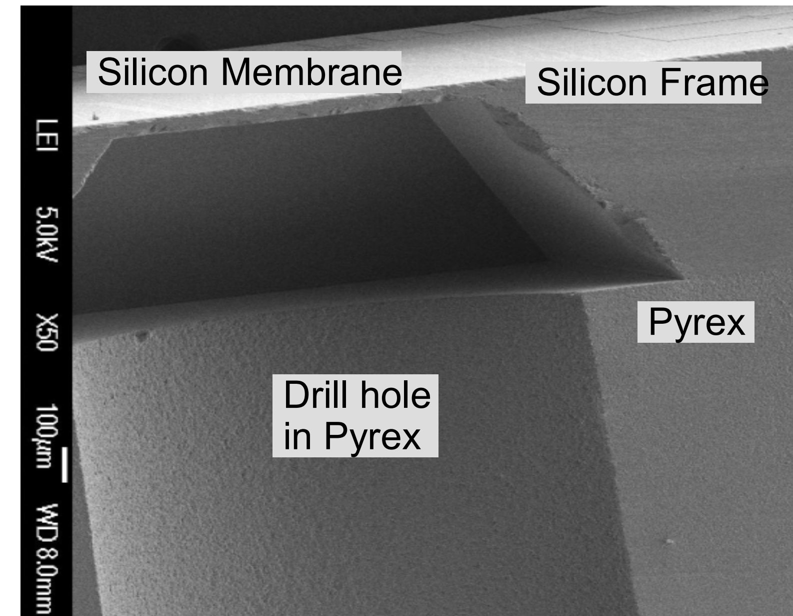
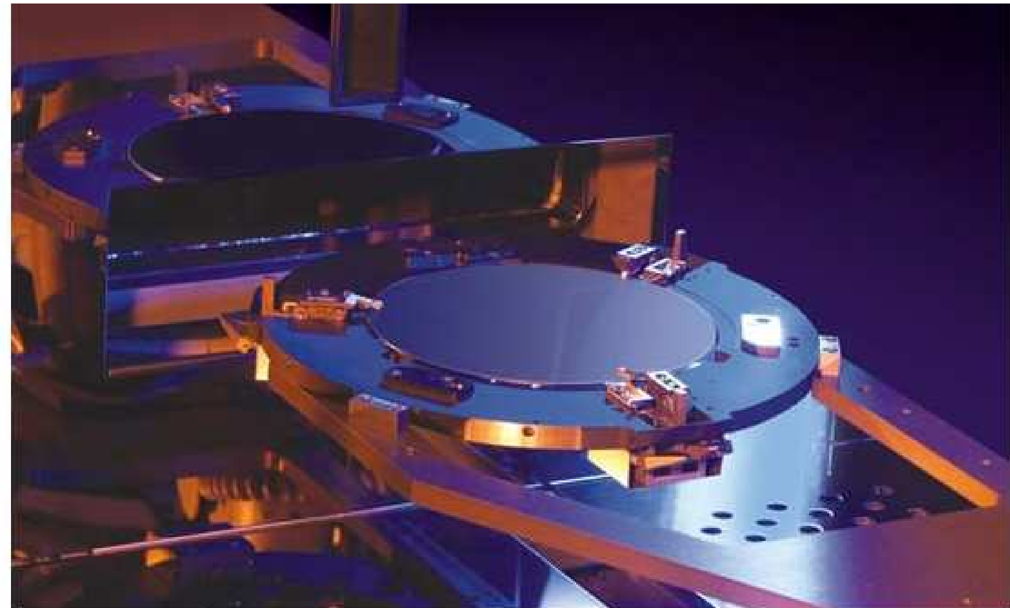
BACK END



Anodic wafer bonding

- SB6 Wafer bonder/ BA6 Bond aligner/ Süss
- Glass (Pyrex, Borofloat) - Silicon- compound
- Performed at 300 … 500 °C with about 1.2 kV
- Stable mechanical connection between
- Silicon and glass due to SiO- bonds
- Application: pressure sensor
- **Wafer dicing tool** DISCO 651
- Dicing of Silicon- Glass- Compound
- Open aluminum MEMS-structures



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AGENDA

- MEMS Services
- Technologiy Toolset
- Selected Processes
- **Solutions (success stories)**
- Detailed Equipment List

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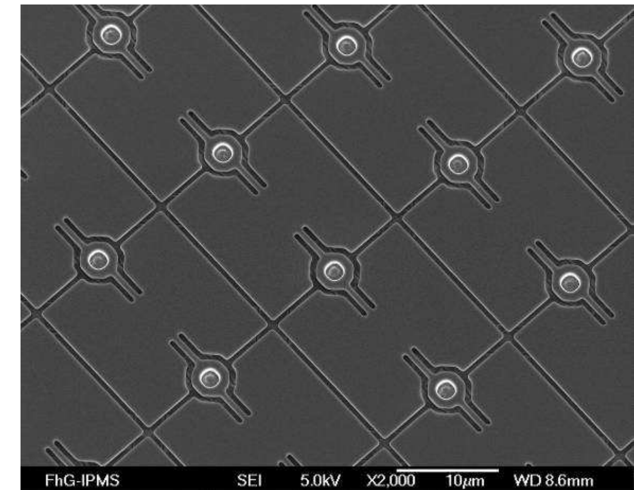
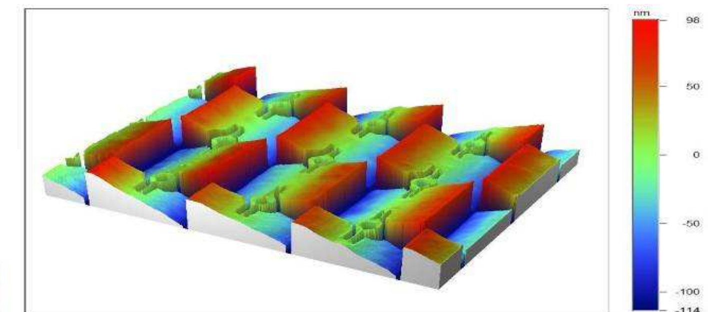
SPATIAL LIGHT MODULATORS



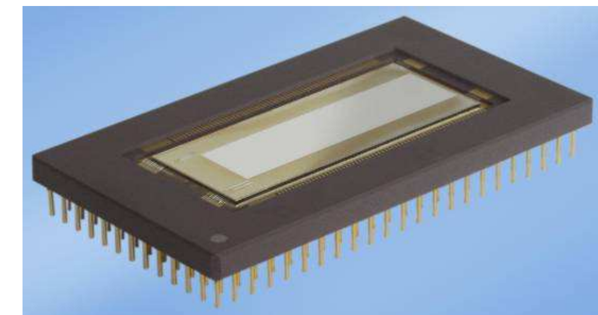
Technology

- CMOS-Back plane: C5090
- Surface micromachining
- Technical parameters
  - 16 µm pitch
  - 2048 x 512 pixel
  - 2 kHz frame rate



Application

- Microlithography
- Structured Illumination



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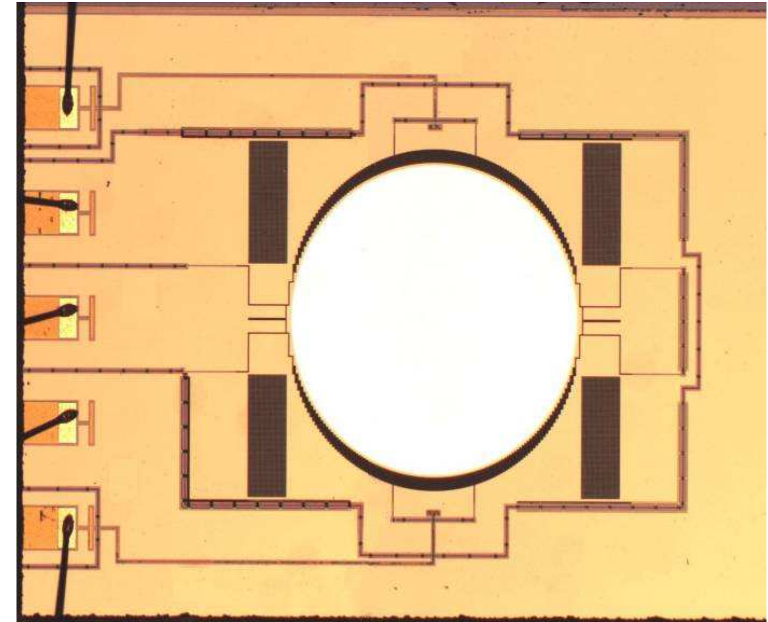
SCANNING MIRRORS

Technology

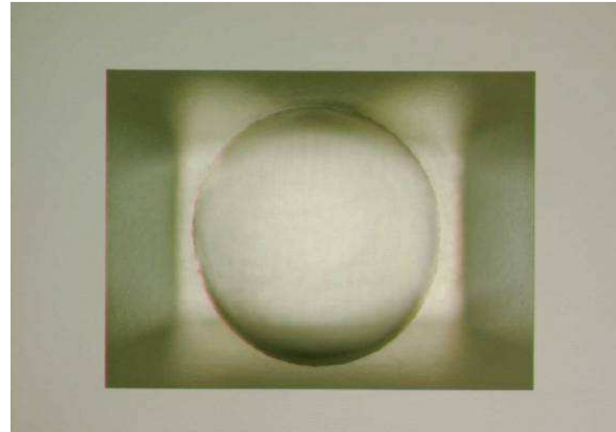
- Bulk micromachining
- 1D-Scanner,..+grid, 2D Scanner
- Frequencies: 0.2 … 35 kHz
- Diameter: 0.5 … 3.0 mm
- Deflection angle: up to +/- 34°
  (136° optical scan range)

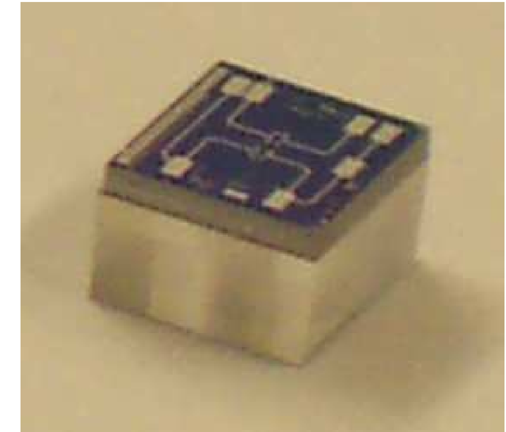


Applications

- Bar code reading
- Spectroscopy
- µ-Projectors (cell phones)

PRESSURE SENSORS





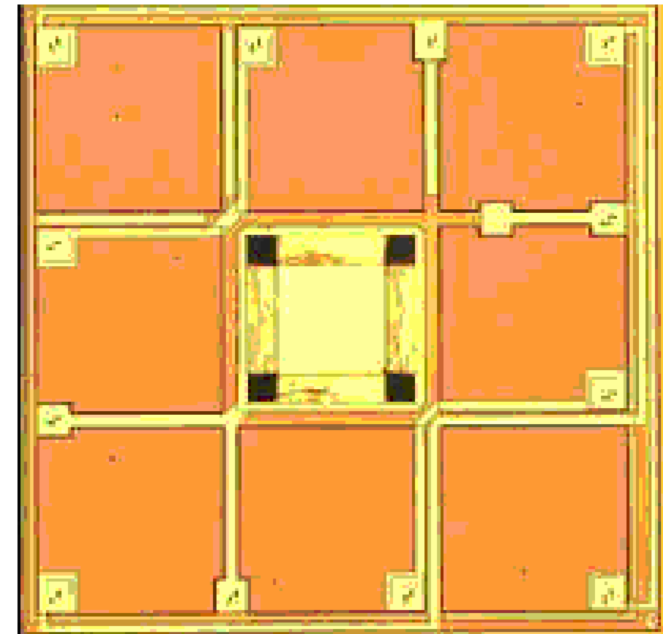
Technology

- Piezo- resistance, SOI (dielectrically insulated resistors)
- Si- Membrane
- anodic bonded Pyrex wafer on wafer back side

Application

- Automotive: Oil pressure in automatic gear boxes
- 0…11 bar, overpressure 60 bar

MEMS/MOEMS Products at IPMS / Photodiodes

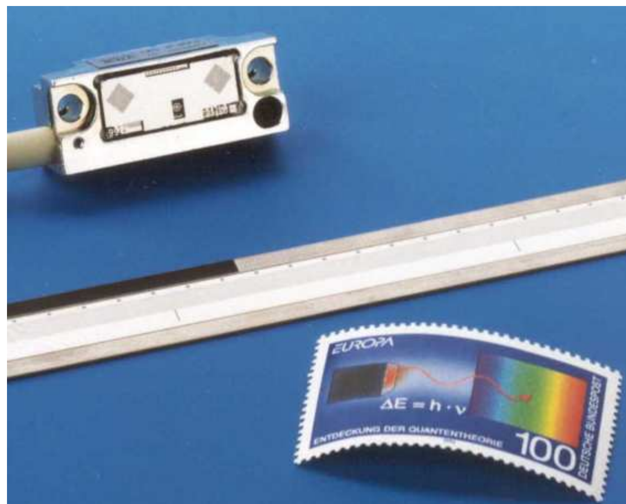


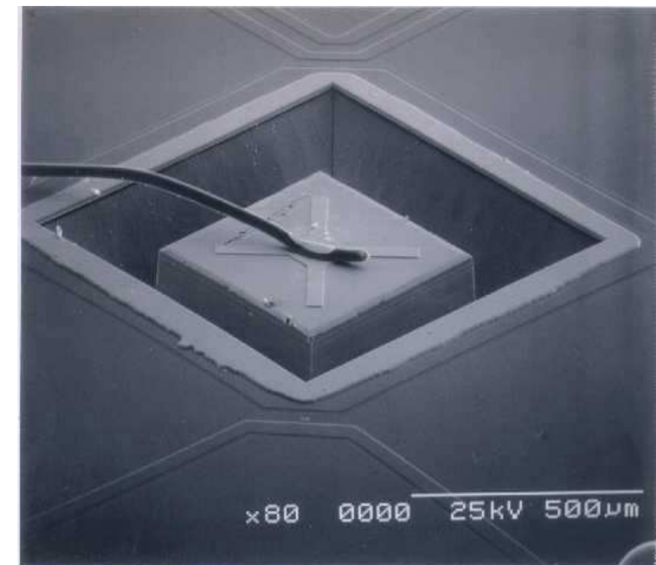
Technology

- PIN-Diode
- Metallised Groove (Depth: 220 µm)

Application

- Linear measurement systems for machine tools (0.1 µm resolution)





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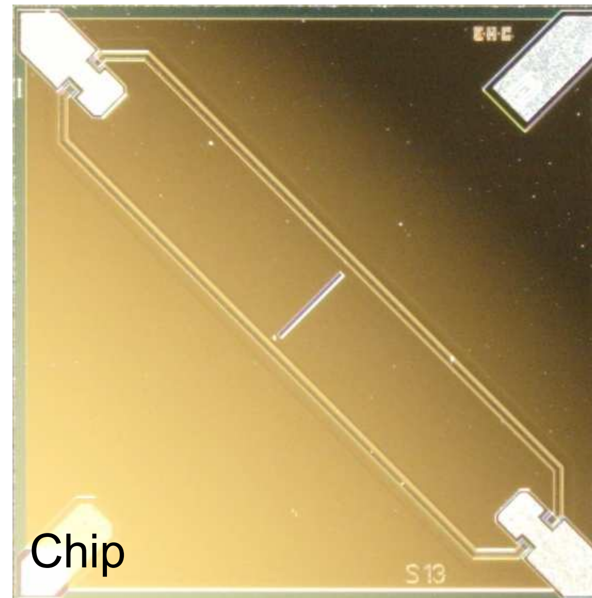
ION SENSITIVE FET (ISFET)

Technology

- p- MOS
- Ion sensitive interface: Ta_2O_5
- Resist Lift- off

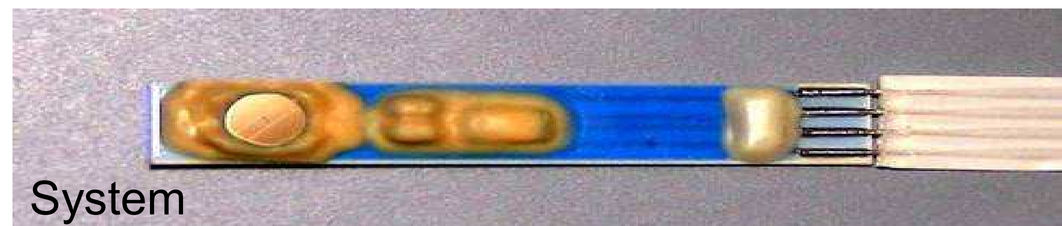
Application

- Measurement of H^+ concentration in hydrous liquids
- pH- Measurement (environment, instrumentation, medical)



Chip

Electrode


System

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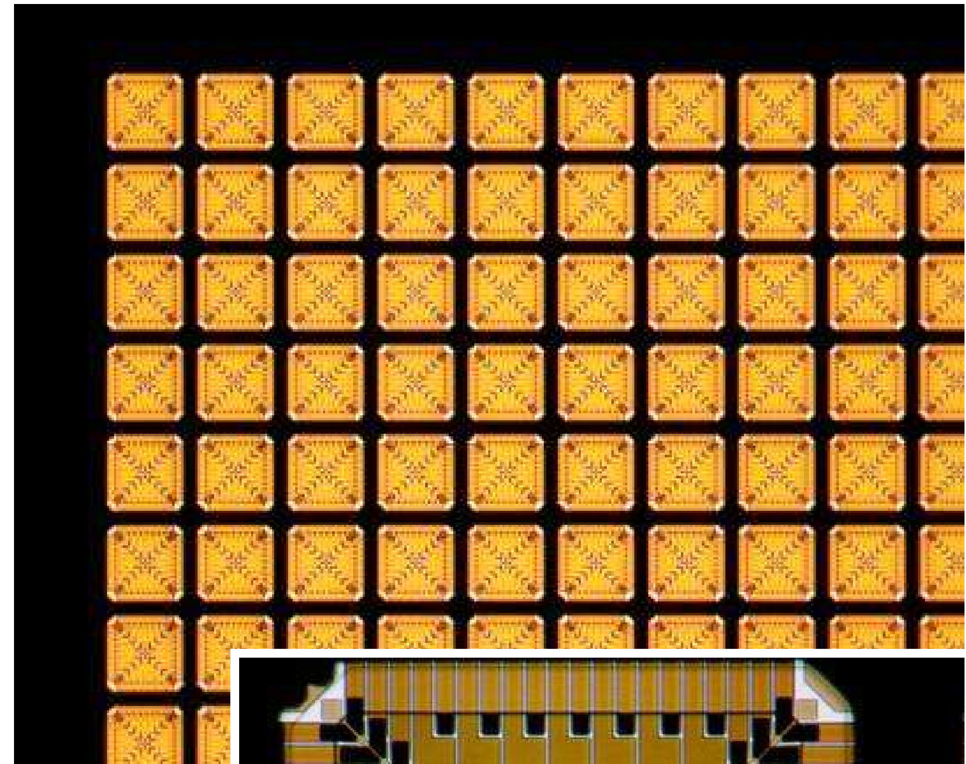
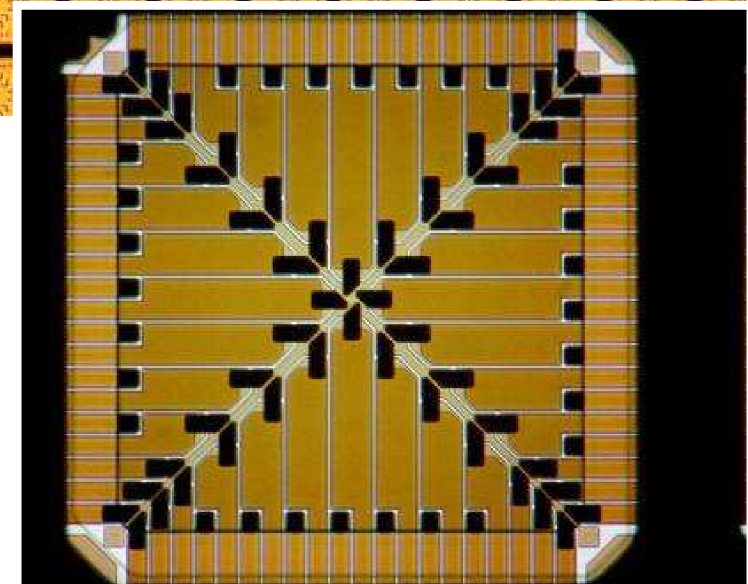
FOUNDRY SERVICE (1)

- Membrane etch for IR- Sensors
- Test substrates for bumping
- Deposition of stress compensated stacks
- Deposition (PE-CVD, Oxidation, …)
- OLED/ OFET- Substrates





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FOUNDRY SERVICE(2): test and characterisation

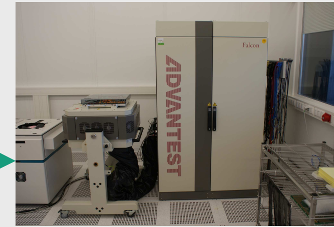
currently services:

•transponder calibration

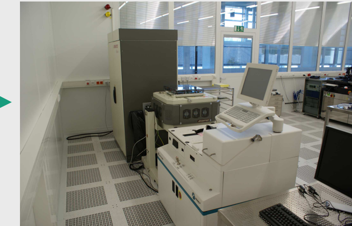
•characterisation MOEMS

•end test diced wafers

Mixed signal test system
- FALCON M3670_GL

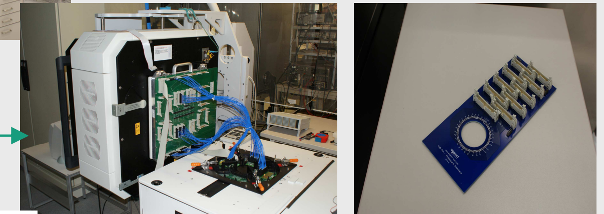


Waferprober
- EG4090µ+



Substratprober
- PA300

Probecard + cabel-interface



switchboard
- Keithley 4200-UL-LS-72

colorimetry sensor/camera
- LMK 98-4

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AGENDA

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- **Detailed Equipment List**

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THANK YOU FOR YOUR ATTENTION!

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EQUIPMENT (1)

Lithography	Stepper	NSR-2205i 14E2 | Nikon
	Mask aligner	MA 150 BSA | SUSS
	Nano Imprinting Stepper	NPS 300 | SUSS
	Coater / Dev-I-line	SK-80BW-AVP | DNS
	Spin Coater (Polyimide, BCB)	Gamma 80 Spin Coater | SUSS
	Spray Coater (high topology)	Gamma Alta Spray Coater | SUSS
	Spray Coater (high topology)	EV101 | EVG
	UV-Stabilizer	Fusion 200 PCU Polo | Axcelis
Deposition	PE-CVD (USG, PSG, BPSG, Silicon nitride)	P5000 | Applied Materials
	PE-CVD / SA-CVD	Centura | Applied Materials
	LP-CVD (Poly-Si, SR nitride, TEOS, Oxynitride)	E1550 HAT 320-4 | Centroterm
	PVD Sputtering (Al, TiAl, SiO2, Al2O3, a-Si, HfO2)	CS400 | Von Ardenne Anlagentechnik
	PVD Sputtering (Al, AlSiCu, Ti, TiN)	Sigma 204 | Aviza
	PVD Sputtering (Ta, Ta2O5, HfO2)	Alcatel 610 | Alcatel
	Evaporation (Al, SiO2)	PLS 570 | Balzers

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EQUIPMENT (2)

Furnaces	Horizontal Furnace Anneal	Interterm
	Horizontal Furnace Oxide	Interterm
	Horizontal Furnace POCl3 Doping	Interterm
	Horizontal Furnace Reflow	Interterm
	RTA	Heatpuls 8108 | Metron
Dry Etch	Etch (Oxide, Nitride, Poly-Si, deep Si)	Omega fxP | Aviza
	Etch (Al alloys)	TCP 9600 | LAM
	Etch (deep Si)	I2L | Aviza
	Etch (deep Si)	ASE | STS
	Resist Strip	BobCat 208S | Axcelis
	Resist Strip	Plasma System 300 | PVA Tepla
	Resist Strip	Type1 | Axcelis
Wet Etch and Cleaning	Wet Etch (Silicon oxide, Silicon nitride, Al)	Tauchbeckenlinie | Ramgraber
	Wet Etch (anisotropic Si: TMAH, KOH)	Tauchbeckenlinie | Ramgraber
	Wet Strip	Solvent Spray Processor | Semitool
	Wafer Cleaning	Automatic Tool | Ramgraber
	Cleaning processor (High velocity spray, scrubber)	3300ML | SSEC

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EQUIPMENT (3)

Category	Equipment	Model / Manufacturer
Chemical Mechanical Polishing (CMP)	CMP (Silicon oxide, Polyimide, a-Si)	MIRRA | Applied Materials
	CMP (Silicon oxide, Poly-Si, a-Si)	nTrepid | Strasbaugh
	Scrubber	DSS 200 On Track | LAM
Vapor Etch for MEMS Release	Si Vapor Etch (XeF2)	X-SYS-3B:6 | Xactix
	SiO2 Vapor Etch (HF)	Primaxx
Analysis / Metrology	Film Thickness Measurement System	NanoSpec 9100 | Nanometrics
	Film Thickness Measurement System	NanoSpec 8000 X | Nanometrics
	Scanning Electron Microscope	JSM-6700F | Jeol
	Atomic Force Microscope	Nanoscope D3100 | Veeco
	Ellipsometer	VB-400 | Woollam
	X-Ray Diffractometer	D5000 | Siemens
	Scanning Near-field Microscope SNOM	MV4000 | Nanonics
	FTIR Microspectroscopy System	FTIR6700+Continuum | ThermoFischer
	Tunable Diode Laser System	TLB | NewFocus
	White-light Interferometer	NT8000 Wyko | Veeco
	White-light Interferometer	NT1100 | Veeco
	White-light Interferometer	NV7300 | Zygo
	Surface Scan	µScan | Nanofocus
	Twymen-Green-Interferometer	µPhase | Fisba

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EQUIPMENT (4)

Masks	E-Beam Writer (5“, 6“, 7“ blanks)	ZBA31 | Vistec
	Mask Cleaner	HMR900 | Hamatech
Packaging	Wafer Saw	DISCO 651 | Disco
	Bonder (Anodic and Adhesive Bonding)	SB6e | SUSS
	Bond Aligner	BA6 | SUSS
	Dispenser	Schiller
	Wire Bonder	Bondjet 810 | H&K
Test and Characterization	Mixed-Signal Tester	ST-M3650 | SZ
	Sensor Actuator Test System	AP200 | SUSS
	Automatic Inspection System	SUSS
	Electro optical Test system	several
	Pressure burst testsystem	several
	Vibrometer	MSV 300 | Polytec

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