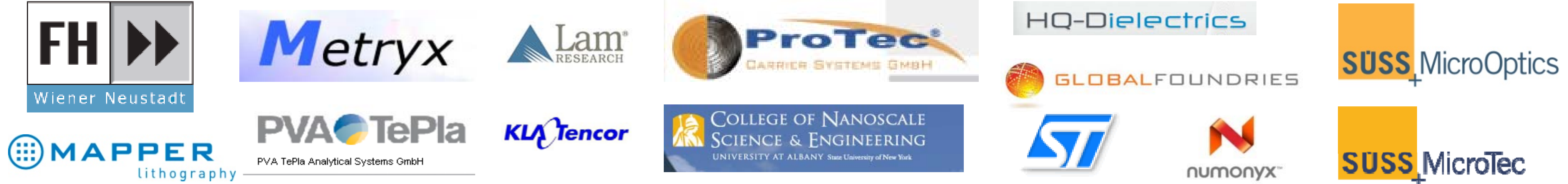


Semiconductor Equipment Assessment Leveraging Innovation

Lothar Pfitzner, Richard Öchsner, Fraunhofer IISB

Outline

- **Introduction**
  History of SEA - Semiconductor Equipment Assessment - in European Programmes
- **Objectives and Partners of SEAL**
- **Introduction of innovative Assessment Activities in SEAL**

History SEA

SEA Projects in IST

Deposition / Growth Processes

- ALCVD for Cu Dual Damascene process — *ATOL*
- Deposition Equipment for FPD Fabrication — *DEPODIS*
- MOCVD ferroelectric deposition 200 mm/300 mm — *FECLAM*
- Low Energy PECVD Hetero-Epitaxy — *LEPECVD300*
- CVD Cluster for Integration of Low K Films — *ACTION*
- High Throughput ALCVD Batch Equipment — *HALE & RAPID*

Lithography

- Advanced lithography using ArF wide field S&S — *ALASCA*
- Photomask resist coater/aqueous developer — *APHRO*
- DUV CD Metrology System — *McDOR*

Etch

- Equipment for deep etching with double etch rate — *I-SPEEDER*
- Microsystems Production Cluster Tool — *MICROSPECT*

Cleaning

- Oxidation and Epitaxy pre Clean — *OXEPICLE*
- FEOL resist and organic residues removal — *NOW*

Analysis / Metrology

- APC for 300 mm plasma processes — *APC 300*
- Defect review via E-beam Auger Microanalysis — *DREAMS*
- In-Line SIMS Assessment — *ILSIMS*
- Microcalorimeter Type EDX System Assessment — *MESA*
- Surface Measurement with integrated TXRF — *SUMMIT*
- Combined XRF / XRR In-Line Analysis — *COMBIMEXX*

Assembly / Test

- Anisotropic Conductive Film die bonder assessment — *AFIDA*
- Low cost anodic bonder for MST products — *ANAB*
- High-Resolution X-ray Laminography Equipment — *EXCEL*
- Flip chip die bonder for ultra-thin silicon — *FLIBUSI*
- Mixed Signal Reliability Test System — *MIDAS*

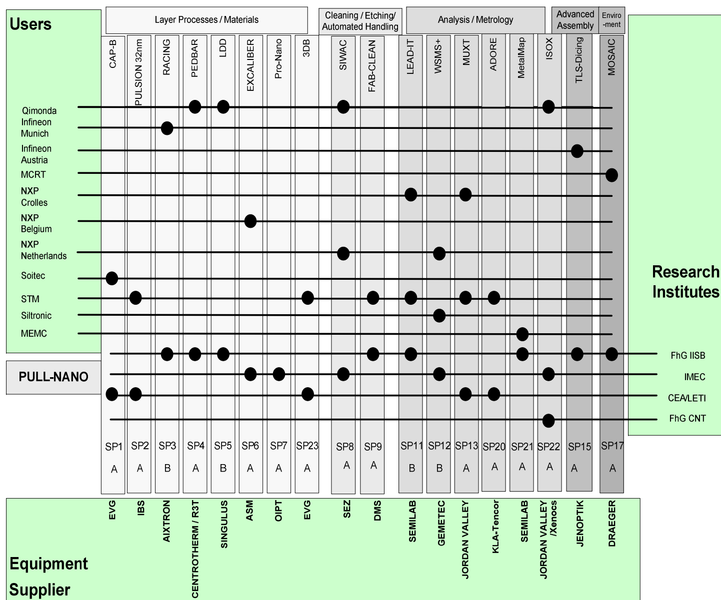
SEA-NET
01/2006 - 06/2009

SEAL
06/2010 - 05/2013

2006

2013

Semiconductor Equipment Assessment for NanoElectronic Technologies Leveraging Innovation



Participation and topics

Objectives:

- **Strengthening** the **European** process and metrology **equipment industry**
- Bring together **critical mass** of research and development power **to form synergies**
- Make **use of the excellent European 300mm research infrastructure** at Fraunhofer IISB, CEA/LETI and imec
- Increase the **chances for SME´s** to get access to IC makers
- Stimulate an approach **to initiate sustaining partner-ships** amongst equipment industry, IC industry and research institutions
- Developing a **common strategy** for key enabling technologies in the EU
- **Stabilize and increase the participation** of European equipment industry in EU FP VII, ENIAC, CATRENE and national programmes etc.

Semiconductor Equipment Assessment for NanoElectronic Technologies Leveraging Innovation

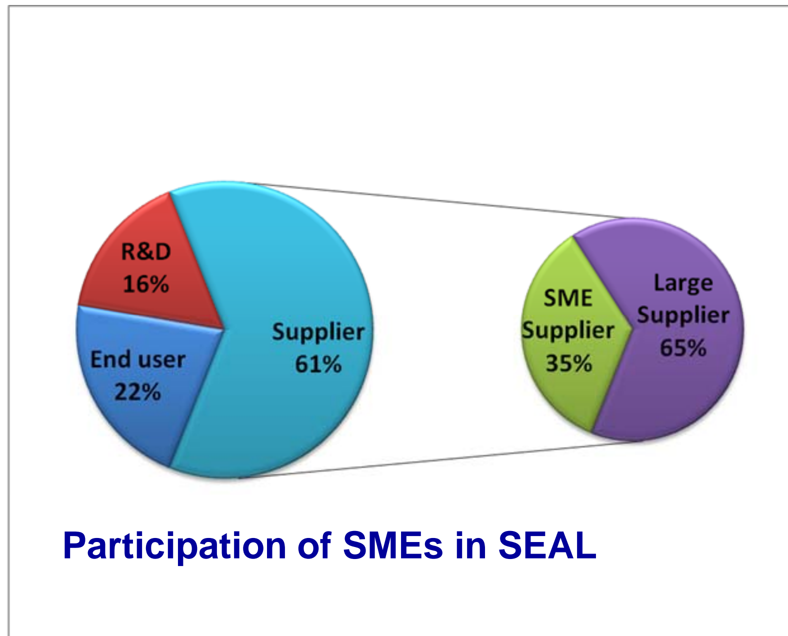
		initial status	final target	Competition	ITRS
General Equipment specifications					
	Hardware Interface (loadport, FOUP, FOSB)	Dual/Triple FIMS loadport	Unchanged	Same	
	Software Interface (SECS/GEM)	E30,E40,E87,E90,E116 Protocols	new VID to enable new data upload	Same	
	cleanroomspace, footprint	2.15 m x 2.80 m	Unchanged	NA	
	Cleanroom class (minienviroment)	Class 1	Unchanged	Same	
	Weight	2600Kg (Dual FIMS)	Unchanged	NA	
	Energy consumption	15A, 250Volts	Unchanged	NA	
	Enviroment (Vacuum, N2 …)	Vacuum (21 to 25 inches Hg (533 to 635 mm Hg; 0.071 to 0.085 MPa), N2 or Dry Air (88 to 96 psi (6.2 to 6.8 Kg/cm2; 0.6067 to 0.6619 MPa)	Unchanged	NA	
	Type of automation (robot, XY table, ...)	Robot	Unchanged	Same	
	Envisaged Feature Size (Technology node)	45/32nm	22nm node	Same	
	Max. Batch Size	25	Unchanged	Same	
	Number of process chambers	NA	NA	NA	
	Wafer diameter	200/300mm	Unchanged	Same	
	Wafer edge exclusion	3mm	Unchanged	Same	
Handling/cleanliness					

Standardized Assessment approach of prototype equipment from previous project

Work Description:

- Assessment of **prototype equipment** and **novel enhancements to existing equipment**, and their application to next generation semiconductor technologies and device architectures
- Main **process themes** include: EUV masks, cleaning front end und back end, lithography (optics and multi e-beam), low temperature oxidation, bonding of thin wafers, plasma immersion ion implantation
- Key **metrology** equipment: full wafer and multi column e-beam inspection, life time measurements, nano-topography, EDS/EDX, mass metrology, acoustic microscopy, overlay metrology
- **Cross-cut R&D**: equipment and process characterisation, equipment simulation, equipment automation, generic equipment topics and assessment, training

SEAL
Semiconductor Equipment Assessment Leveraging Innovation



Participation of SMEs in SEAL

Partners:

Users:

- Global Foundries, Infineon, Intel, LFoundry, MEMC, Numonyx, Siltronic, Soitec, STMicroelectronics Crolles

Equipment Suppliers:

- Hamatech, Alcatel Vacuum, Jenoptik Automatisierungs-technik, SUSS MicroOptics, Reinhardt Microtech, SUSS Microtech Lithography, MAPPER, Toppan Photomasks, HQ-Dielectrics, SUSS Microtec, Ion Beam Services, Lam Research
- Nanda, Semilab, Fries R&T, Applied Materials, Integrated Circuit Testing, Oxford Instruments, Metryx, PVA TePla, KLA-Tencor, ProTec

Research Institutes:

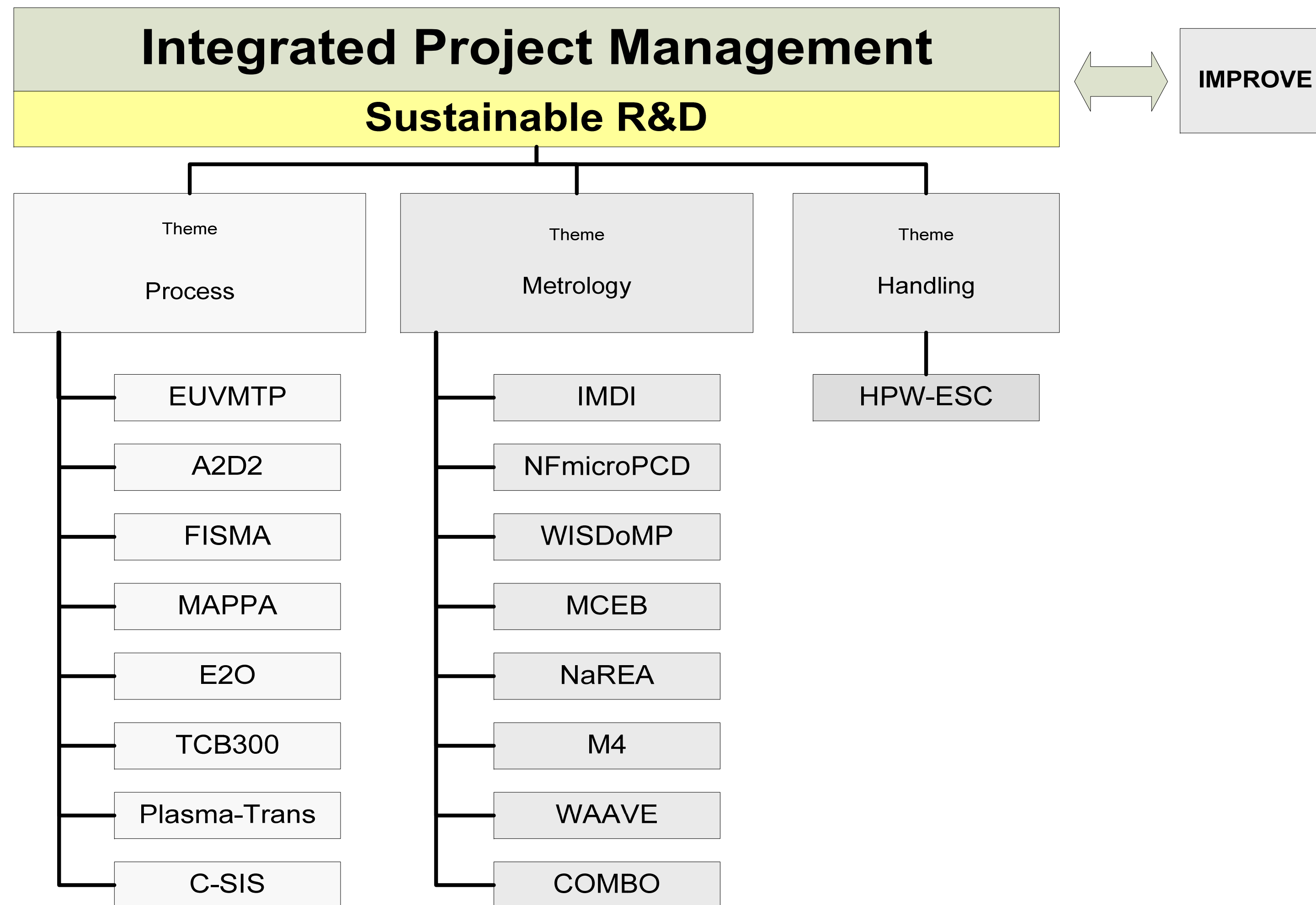
- CEA/LETI, Fraunhofer IISB, imec, UALB, ICN, FHWN

Budget/Funding:

- 14,3 Mio EUR / 9,1 Mio EUR

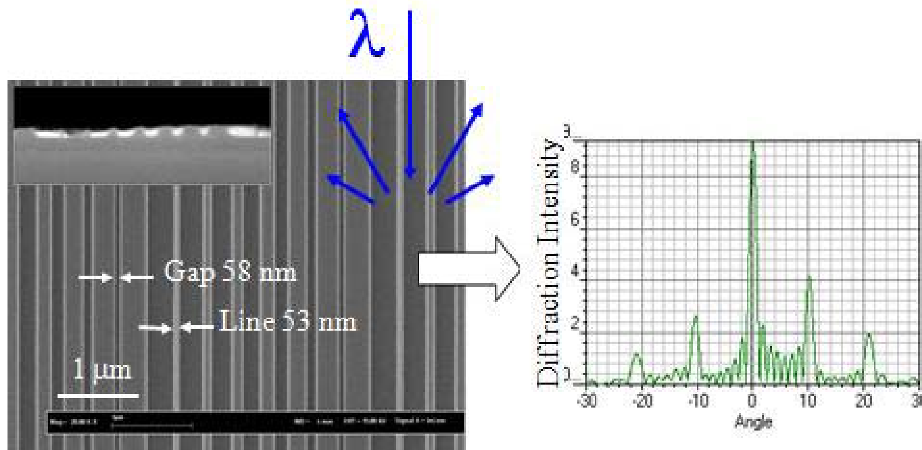
Duration: June 2010 – May 2013

	Process								Metrology								Handling
Users	EUVMTP	A2D2	FISMA	MAPA	E2O	TCB300	Plasma-Trans	C-SIS	IMDI	NFmicroPCD	WISDoMP	MCEB	NaREA	M4	WAAVE (FA)	COMBO	HPW-ESC
GDMOL&CK												●					
IFX					●								●				
Intel	●													●			
LSF																	●
MEMC										●							
NIS																●	
SAG											●						
Soitec															●		
STM Crolles				●		●	●		●								
Research Institutes																	
CEA/LETI				●			●								●		
FhG IISB		●	●		●			●	●	●	●		●				●
IMEC	●					●			●					●		●	
UALB		●															
	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10	SP11	SP12	SP13	SP14	SP15	SP16	SP17	SP18
Equipment Supplier	Hamatech	AVTF / JO-AT	SMO / RMT / SMTL	MAPPER / TPI	HQD	SUSS	IBS	LRA	Nanda	Semilab	FRT / ITL	AMIL / ICT	Oxinst	Metryx	PVA TePla	KLA	PCS



Schematic of the sub-projects and their break down in themes

SEAL SP1 - Cross-Cut
Sustainable Cross-cut Activities in SEAL



Sub-wavelength Diffraction metrology - ICN

Partners: Fraunhofer IISB, imec, CEA/LETI, FHWN, ICN,
Coordinator: Richard Oechsner / IISB
Duration: 36 Months

Topics proposed in SP1:

WP1.1: Support for equipment and process characterization
- Application of integrated metrology
- Potential for advanced process control (APC)
- Methods for implementing predictive maintenance and calculation of an equipment health factor
- Evaluation of virtual metrology and supportive data mining

WP1.2: Equipment simulation
- Equipment simulation and virtual equipment engineering
- Equipment performance analysis and optimization
- Simulation support for lithography and optical metrology

WP1.3: Equipment automation
- Concepts for modular control software, standardized data formats and interfaces
- Robotics and handling systems

WP1.4: Generic equipment topics and assessment
- Cost of ownership studies
- Energy efficiency studies
- Competitive data: benchmarking of equipment
- Equipment assessment metrics and approach
- Related standards for equipment
- Specs for n, n-1, n+1, n+2

WP1.5: Training
- Creation and provision of training material
- Training events, tutorials, courses and workshops

SEAL SP2 - EUVMTP
HamaTech EUV Mask Track Pro

Short description:

- Implementation of cleaning technique for backside contamination on EUV masks
- Assessment of software and hardware for high volume EUV production

MaskTrack*Pro* installed at imec

Advances proposed in EUVMTP

- MaskTrack Pro for Next Generation Lithography installed at imec to address the **stringent requirements for EUV masks** including; back-side cleaning, preservation of vulnerable layers, avoidance of carbon growth and an EUV-specific load port for Alpha Demo Tool reticles

Main focus

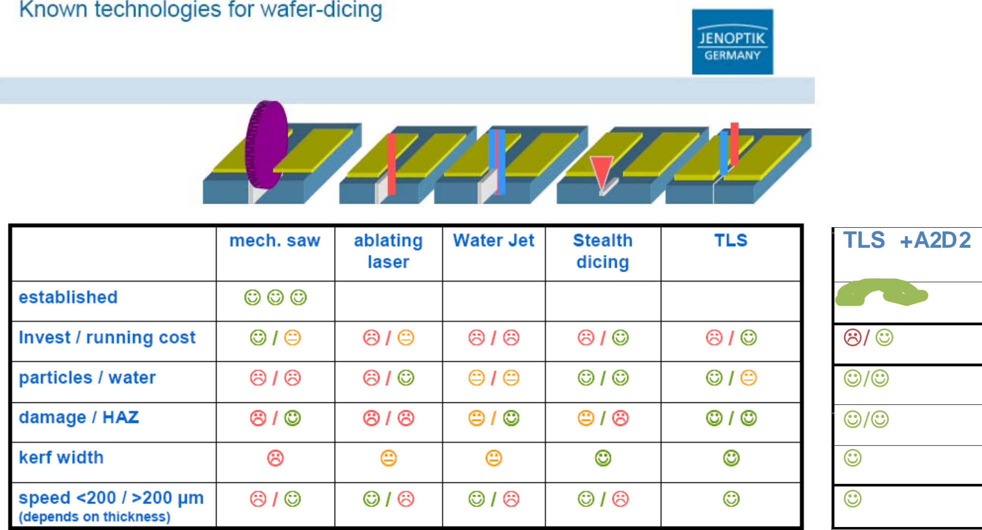
- Intrinsic cleanliness of the MaskTrackPro tool platform
- EUV reticle back-side particle removal process as back-side particles are a specific concern for EUVL to meet the overlay targets;
- Hardware and software reliability verification meeting high volume EUV manufacturing

Partners: HamaTech, imec, Intel
Coordinator: Peter Dreß / HamaTech
Duration: 12 Months

SEAL SP3 - A2D2
Advanced Vacuum wafer Drying for A-TLS Dicing

Short description:

- Evaluation of diced wafers cleaning method
- Integration and assessment of cleaning module in A-TLS tool



	mech. saw	ablating laser	Water Jet	Stealth dicing	TLS	TLS +A2D2
established	☺ ☺ ☺					
Invest / running cost	☺ / 😐	☹ / 😐	☹ / ☹	☹ / ☺	☹ / ☺	☹/ ☺
particles / water	☹ / ☹	☹ / ☺	😐 / 😐	☺ / ☺	☺ / 😐	☺/☺
damage / HAZ	☹ / ☺	☹ / ☹	😐 / ☺	😐 / ☹	☺ / ☺	☺/☺
kerf width	☹	😐	😐	☺	☺	☺
speed <200 / >200 µm (depends on thickness)	☹ / ☺	☺ / ☹	☺ / ☹	☺ / ☹	☺	☺

Advances proposed in A2D2

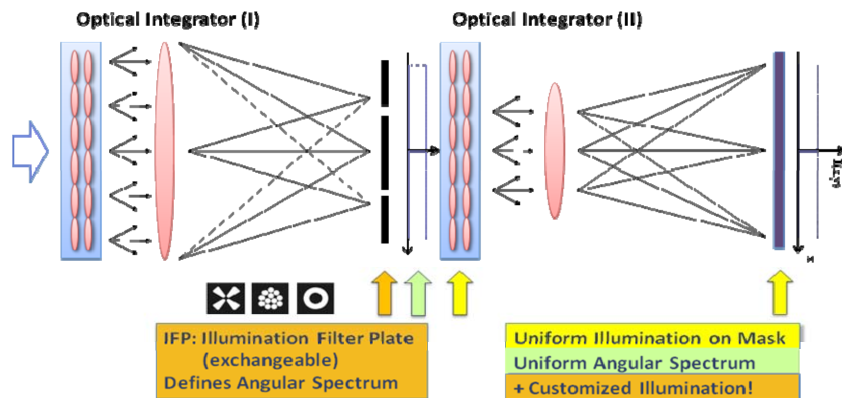
- Incorporate a **vacuum drying module** (an innovative approach)
- Obtain a fully efficient, high quality and short clean drying process.
- Providing; increased functionality, yield and separation of thinner and more flexible products and enhanced dicing speed

Partners: Alcatel Vacuum, Fraunhofer IISB, Jenoptik- Automatisierungstechnik, ULAB
Coordinator: Magali Davenet / Acatel Vacuum
Duration: 30 Months

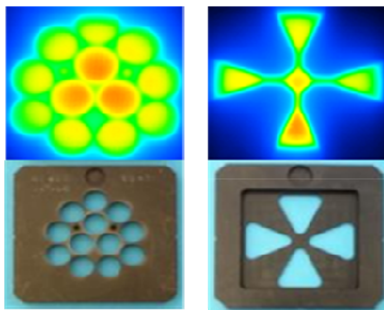
SEAL SP4 - FISMA
Flexible Illumination System for Mask Aligners

Short description:

- Implementation of new illumination optics for mask aligners
- Assessment by simulations and experiments



Operating principle of the new SUSS MicroOptics illumination optics.



Flexible beam shaping by using different illumination filter plates

Advances proposed in FISMA

- Evaluation of **prototype new illumination optics**
- Improved **uniformity of illumination**
- Flexibility for the definition of various illumination geometries for specific applications.
- Predictive Lithography simulation and a methodology that supports the end-users in the definition of the **most appropriate illumination optics**
- Understanding how the performance of the illumination geometry in terms of feature size accuracy, lithographic process window, and sensitivity to variations in source parameters and mask fabrication errors.
- Application of **flexible illumination systems** for more complex layouts

Partners: SUSS MicroOptics, Fraunhofer IISB, Reinhardt Microtech, SUSS MicroTec Lithography
Coordinator: Reinhard Völkel / SUSS MicroOptics
Duration: 36 Months

SEAL SP5 - MAPA
MAssively PArallel electron beam lithography

Short description:

- Assessment by simulations and experiments
- Parallel e-beam lithography for 32nm (22nm logic) node Integration into mask maker
- Assessment of infrastructure (process, data flow and proximity effect correction)

MAPPER tool
@ CEA-Leti

Advances proposed in MAPA

- Multi Beams tools are today under development in the European project MAGIC.
- MAPA will be perfectly aligned with MAGIC allowing the installation and assessment of the Mapper platform in a **production like environment**.
- Tool performance will be upgraded from the **alpha level** (45nm hp, small field, 0.1 WPH) **to Beta level** (32 nm hp, 1 WPH, full field).
- **Infrastructure will be evaluated** for both semiconductor manufacturing and mask making applications.

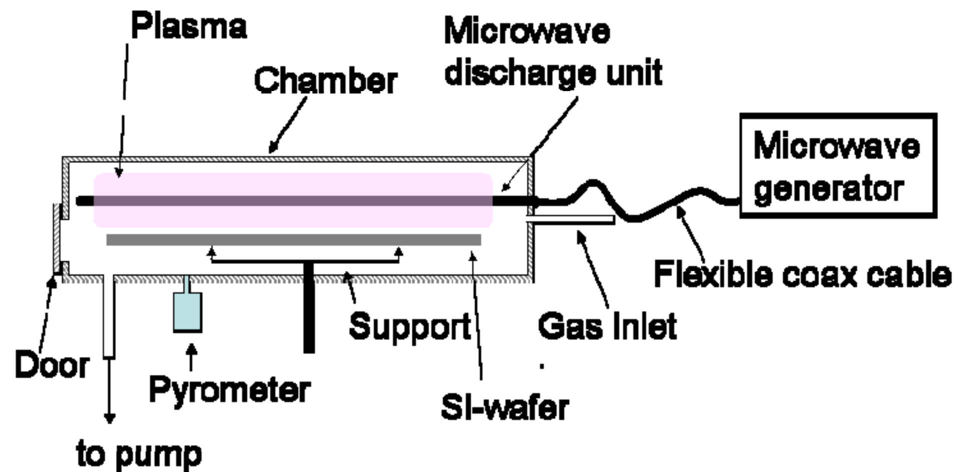
Partners: MAPPER Lithography, CEA/LETI, STMicroelectronics Crolles,Toppan Photomasks
Coordinator: Bert Jan Kampherbeek / MAPPER
Duration: 24 Months

SEAL SP6 - E2O

Electron Enhanced Low Temperature Oxidation for Nano-Electronic Device Generations

Short description:

- Evaluation of low-temperature oxidation technology
- Integration of reactor into cluster platform and assessment of oxide quality



Schematic of the high-density microwave plasma oxidation and in-situ post plasma anneal apparatus

Advances proposed in E2O

- Proposed concept uses **a new electron charge driven method** for enhanced oxidation rate without oxide damage.
- Process has been demonstrated on laboratory scale equipment
- **Transfer to a 300 mm** bridge production tool for equipment assessment

Partners: HQ-Dielectrics, Fraunhofer IISB, Infineon Technologies

Coordinator: Alexander Gschwandtner / HQD

Duration: 24 Months

SP7 - TCB300
New solutions for 300mm temporary carrier bonding

Short description:

- Handling of extremely thinned silicon device wafers
- Processes and equipment assessment

Picture of SUSS 200/300mm wafer bonder XBC300 for temporary and permanent bonding

Advances proposed in TCB300

- Main differentiator: **both bonding and debonding** using **classical thermoplastic glue materials**, as well as a **novel bonding and debonding process**
- Circumvents the **limitations of thermally or light assisted carrier release process**
- Enables the use of cheap **carrier substrates** such as silicon wafers.
- Solution involves:
  - Application of the glue medium by spin-on deposition combined with a CVD deposition,
  - Wafer bonding at very low forces, and
  - Low temperature debonding by peeling
- The **non-thermal nature of the debonding** process widens the scope of application (e.g. memory products, or microbumped devices).
- **Debonding by peeling** as enabled reduces the risk of damaging the device wafer surface.

Partners: Suss MicroTec, imec, STMicroelectronics Crolles
Coordinator: Markus Gabriel / Suss MicroTec
Duration: 24 Months

Plasma Immersion Ion Implantation Tool for Defect Engineering and CMOS image

Short description:

- Extension of application field by tool modification (process control, pressure, temperature)
- Assessment of modified tool

PULSION-nano® tool installed in LETI

Advances proposed Plasma Immersion Ion Implant

- Adaptation and evaluation of the IBS PULSION platform for **defect engineering/gettering**
- **Application** to:
  - CMOS imagers
  - trench doping
  - shallow trench isolation (STI)
  - deep trench doping for power applications
  - shallow junctions with low thermal budget activation for backside doping.
- Modifications for **improved throughput**

Partners: Ion Beam Services, CEA/LETI, STMicroelectronics Crolles

Coordinator: Frank TORREGROSA/ Ion Beam Services

Duration: 24 Months

SEAL SP9 - C-SIS
Cleaning of Sensitive Interconnect Structures

Short description:

- Validation of wet chemical cleans for ≤ 22/28 nm node
- Installation, qualification and beta testing of new cleaning modules

Advances proposed in C-CIS

- Develop **advanced BEoL cleaning technology** for mask, and gate stack residues for the 22 and 28nm nodes,
- Cleaning **without damaging** the new sensitive barrier, cap and dielectric materials utilised.
- Utilise **improved control of gases**, impurities, solvents, and agitation/spray methodologies.
- Enhance the **strict control of the chemical composition** of the customised cleaning media required for the specific applications.

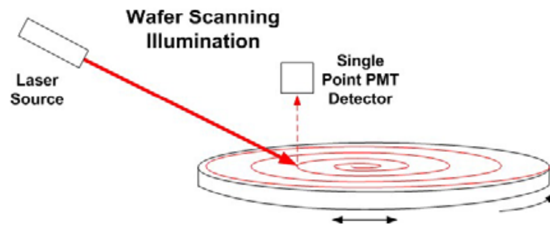
Partners: Lam Research, user not yet defined, Fraunhofer IISB
Coordinator: Harald Kraus/ LRA
Duration: 18 Months

SEAL SP10 - IMDI
Innovative Meso Defect Inspection

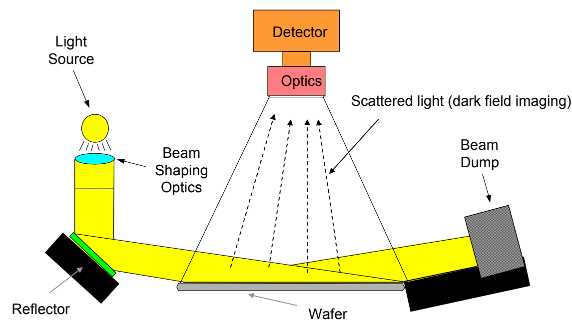
Short description:

- Implementation of new very high throughput and high sensitivity approach for wafer inspection
- Assessment for 3D-Integration (TSV), patterned and un-patterned wafer inspection

Todays Standard Technology:



New Inspection Approach:



Advances proposed in IMDI

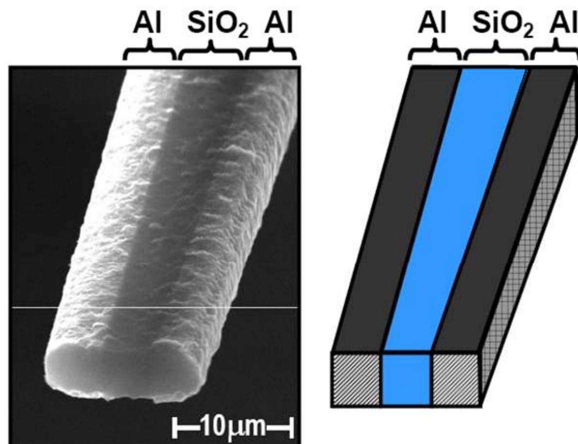
- Combines bright field illumination, dark field illumination with **full wafer illumination without movement of the wafer**
- Bright or dark field images of the full 300mm wafer are captured in one shot at high sensitivity of 1-10µm
- Use of full-wafer imaging permits for a first time to **rapidly inspect** every processed wafer at 100% of the surface
- SW algorithms to extract the defects of interests reliably and to automatically identify defect signatures are being optimized during the project

Partners: Nanda Technologies, STMicroelectronics Crolles, imec, Fraunhofer IISB
Coordinator: Johannes von Borries / Nanda
Duration: 22 Months

SP11 - NFmicroPCD
Near Field microwave photoconductive decay for lifetime measurement

Short description:

- Integration of near field and photo-decay measurement methods
- Assessment of lifetime-measurements with 25µm lateral resolution on product wafers



Advances proposed in NFmicroPCD

- Installation and modification of electronic components in the NeoMetriK tool.
- Creation of software controlling the new hardware set up and to evaluate the signals from the microwave unit.
- Different measurement methods will be tested
- Simultaneously, test structures will be designed and manufactured by the sub-project partners.
- Semilab will decide about the appropriate platform for the measurement tool. The desired mechanical properties (especially regarding vibration isolation) and the level of automation for this platform will be determined
- Some technological risks are associated with the sub-project, since it involves adding a new capability to an already existing instrument.

Partners: Semilab, MEMC Electronic Materials, Fraunhofer IISB
Coordinator: Miklos Tallian / Semilab
Duration: 24 Months

SEAL SP12 - WISDoMP
White-light interferometer system for the development of 300 mm wafer mechanical processes on the nanometre scale

Short description:

- Application of white-light interferometry to assess the full surface topography of Silicon wafers
- Development and assessment of nanotopography concepts

MPR 300 prototype

Advances proposed in WisDoM

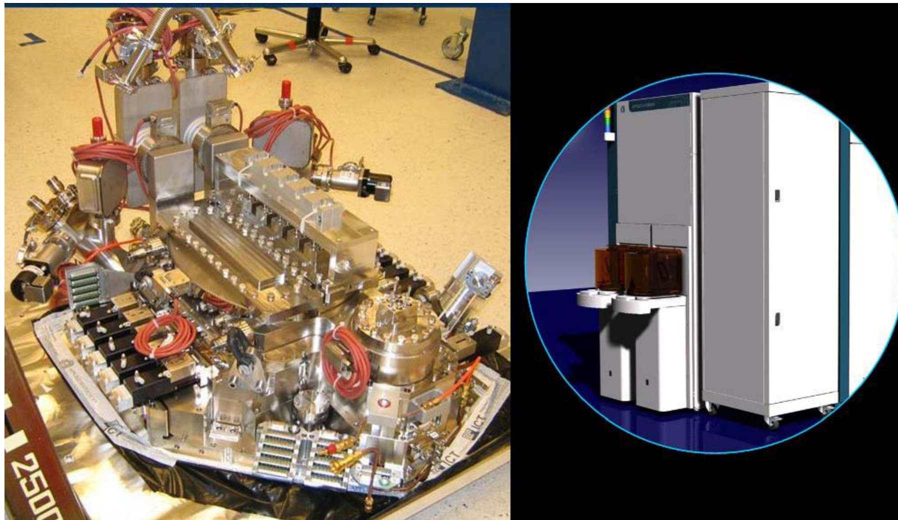
- An interferometric sensor with **90 mm size of field of view**.
- Stitching topography maps will provide **full surface information of 300 mm silicon** wafers.
- High-pass filtering of the surface information will enable **nano-topography assessment**
- **Reliable characterization of large areas** of polished, lapped and ground surfaces.
- Application will not be limited to silicon wafers only.

Partners: Fries Research & Technology, Siltronic, Fraunhofer IISB
Coordinator: Thomas Fries / FRT
Duration: 16 Months

SEAL SP13 - MCEB (Multi Column E-Beam)
High Resolution Multi Column E-Beam Wafer Inspection – Prototype Assessment at Wafer Fab Production Floor

Short description:

- Assessment of E-Beam inspection technology meeting resolution and throughput requirements of 22nm node
- Tool improvements based on fab feedback



The Elite Multi Column E-Beam inspection tool (right) and the Multi Column module (left)

Advances proposed in MCEB

- A high resolution E-Beam **defect inspection tool** for the 22nm node and below
- Production worthy **throughput** will be reached with a Multi Column E-Beam inspection tool.
- **High resolution** is targeted having the required sensitivity for high capture rate defect detection and will be evaluated for defect monitoring in critical layers

Partners: Applied Materials, Global Foundries, Integrated Circuit Testing
Coordinator: Yoram Uziel / AMIL
Duration:36 Months

SEAL SP14 - NaREA
Nanometre range element analysis with a large angular EDS detector

Short description:
- Assessment of a superior detector for high resolution x-ray analysis
- Qualification of very fast film thickness and chemical composition measurements

Large SDD EDS detector

Advances proposed in NaREA
- New large angular EDS detector concept offers **a multiple times larger signal** yield with respect to the emitted x-ray counts, such that the EDS analysis with very low energy lines is now possible in conventional timeframes with sufficient statistics.
- **No alternative non-destructive methods** exists, that can deliver the same combination of data needed in such a high spatial resolution (nanometre-scale) in one measurement run
- Detector also provides a conservative **analysis for organic coatings** due to the low possible acceleration voltages and low beam currents
- Sensitivity for light elements is sufficient
- It will be possible to carry out many different tasks in the frame of processing of semiconductor layer structures, in FEOL and BEOL applications.

Partners: Oxford Instruments, Fraunhofer IISB, Infineon
Coordinator: Rune Gehrlein / Oxford Instruments
Duration: 30 Months

SP15 - M4
More Mass Metrology for Monitoring

Short description:

- Assessment of fab ready 300mm tool for mass metrology
- Evaluation of new applications like Ion Implantation, Gate Stack, barrier seed layers for BEoL and 3D integration

Advances proposed in M4

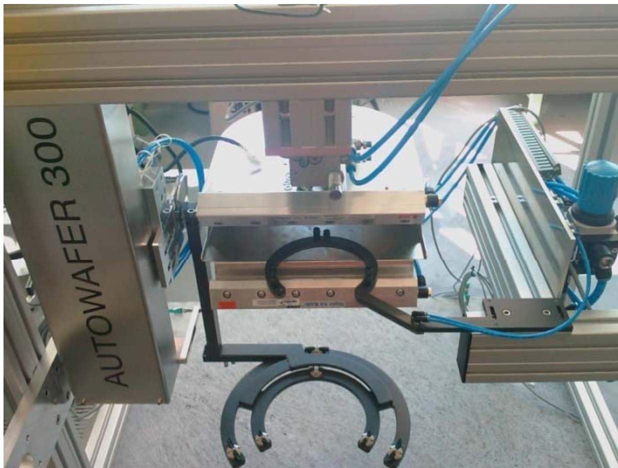
- Assessment of the next generation of mass metrology tools incorporating a high-resolution mass metrology measurement module
- **Resolution improvement** of a factor of 100 to 0.1 micrograms, and a repeatability improvement of a factor of 10 to 8 micrograms.
- Allow the introduction of mass metrology into **new applications**, structures and materials being introduced at the 22nm dimension.
- The advanced modular construction of the tool will also provide the capability of adding **multiple mass modules** with mixed measurement capability, an extendable platform to cope with ever increasing volumes, and the capability of mixed technologies for custom metrology solutions

Partners: Metryx, Intel, imec
Coordinator: Mark Berry / Metryx
Duration: 30 Months

SEAL SP16 - WAAVE
Wafer level Automatic Acoustic VEry high resolution characterization

Short description:

- Assessment of acoustic characterization tool
- Development of new methods for analysis of buried layer and substrate parameters



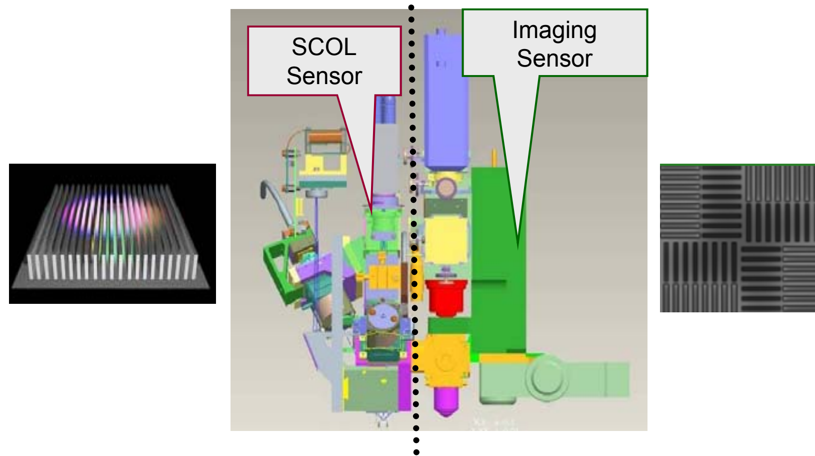
Advances proposed in WAAVE

- Evaluation of an **innovative acoustic microscope** applying multiple transducers inside an automated 200/300 mm device.
- Increasing the frequency will result in an **improved resolution capability** since the frequency is one of the most important parameters impacting the spatial resolution.
- Using longitudinal, transverse and surface wave modes, the estimation of mechanical properties of the **buried layers, interfaces and defects** is potentially enabled (3D integration)
- Performance will be carefully evaluated during the project on **buried interfaces and layers.**

Partners: PVA Tepla Analytical Systems, S.O.I.TEC Silicon on Insulaton Technologies, CEA/LETI
Coordinator: Peter Czurratis / PVA Tepla
Duration: 24 Months

SP17 - COMBO
Combined image-based and diffraction-based overlay metrology for the 22nm technol

Short description:
- Platform assessment for overlay measurements to meet 22nm nodes requirements.
- Performance evaluation for image and diffraction based techniques



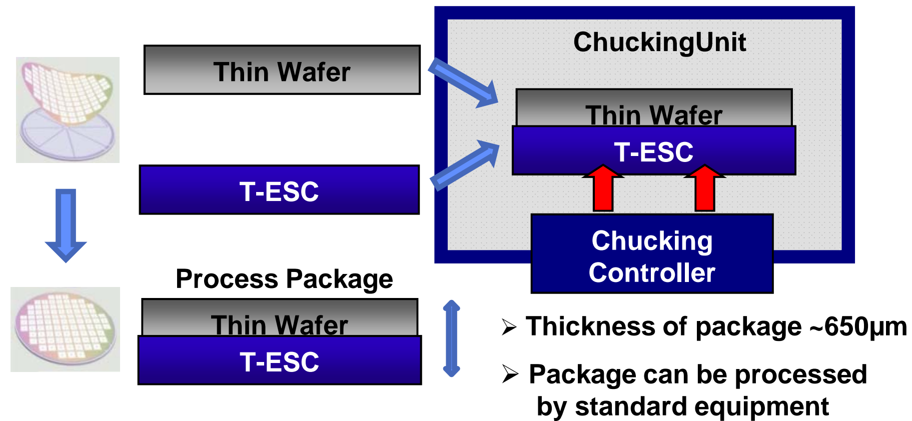
Archer equipped with SCOL head
The tool combines two sensors: an imaging sensor and a spectroscopic ellipsometer.

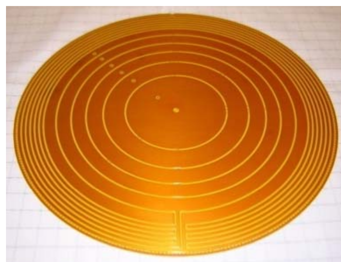
Advances proposed in Combo
- Development, demonstration and qualification of the **two sensor concept** (imaging sensor and spectroscopic ellipsometer)
- **Test on several stacks** for which tight specifications are required

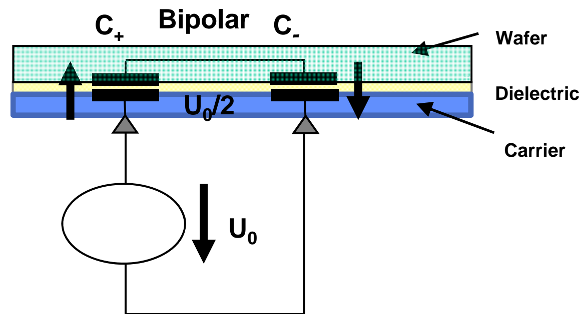
Partners: KLA-Tencor, imec, Numonyx
Coordinator: Daniel Kandel / KLA
Duration: 18 Months

SP18 - HPW-ESC
Handling and Processing of Ultra-/Thin Wafers by Transferable Electro Static Carrier Technology (T-ESC®)

Short description:
- Assessment of electro-static carrier technology for handling ultra-/thin wafers
- Optimization of carrier parameters to meet wafer processing requirements







Power electrodes can hold the wafer without the presence of a grounding electrode

Advances proposed in HPW-ESC
- To make the technology **mature for mass production**, incl. automation,
- To prepare for **future requirements**, such as ultra thin substrates < 50µm up to a size of 450mm.
- To optimise the design to get a **robust carrier**, which can be used in various process applications **without changing between different carrier** types for different processes

Partners: ProTec Carrier Systems, Landshut Silicon Foundry, Fraunhofer IISB
Coordinator: Arno Wehner / ProTec
Duration: 12 Months

SP19 – Project Management

Short description:

- To perform the management of the Integrated Project on the level of the Project Management and on the level of the Sub-Project Management.
- Management is done by the coordinator Fraunhofer IISB.
- Management Board in support by the Steering Committee especially in strategic issues and technical road mapping.

Partners: Fraunhofer IISB
Coordinator: Lothar Pfitzner
Duration: 36 Months

SEAL: info

Coordinator
Lothar Pfitzner

Fraunhofer-Institut für Integrierte Systeme und Bauelementetechnologie

Germany

Partners
See next page

Duration: 36 months

Start date: June 1st 2010

End date: May 31th 2013

Project's website:
http://www.seal-project.eu/

SEAL: Partners

- Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. **(FhG IISB)/**Germany
- Semilab Félvezeto Fizikai Laboratórium Zrt. **(Semilab)/**Hungary
- MEMC Electronic Materials SpA **(MEMC)**/Italy
- COMMISSARIAT A L' ENERGIE ATOMIQUE **(CEA)**/France
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- PVA TePla Analytical Systems GmbH **(PVA TePla)**/Germany
- S.O.I.TEC Silicon on Insulator Technologies **(Soitec)**/France
- Siltronic AG **(SAG)**/Germany
- Fries Research & Technology GmbH, FRT **(FRT)**/Germany
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- HQ-Dielectrics GmbH **(HQD)**/Germany
- SUSS MicroOptics SA **(SMO)**/Switzerland
- Alcatel Vacuum Technology France **(AVTF)**/France
- Landshut Silicon Foundry **(LSF)**/Germany
- Fachhochschule Wiener Neustadt **(FHWN)**/Austria
- Phononic and Photonic Nanostructures Group Catalan Institute of Nanotechnology **(ICN)**/Spain

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- www.seal-project.eu
- www.sea-net.info
- www.anna-i3.org

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Thank you!