



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*

2006

2013

SEA-NET

01/2006 - 06/2009

SEAL

06/2010 - 05/2013



Semiconductor Equipment Assessment for NanoElectronic Technologies Leveraging Innovation

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 and 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

	initial status	final target	Competition	ITRS
General Equipment specifications				
Hardware Interface (loadport, FOUP, FOSB)	Dual/Triple loadport	FIMS	Unchanged	Same
Software Interface (SECS/GEM)	E30,E40,E87,E90,E116	new VID to enable new data upload	Unchanged	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	Unchanged	Same
Max. Batch Size	25		Unchanged	Same
Number of process chambers	NA	NA	Unchanged	NA
Wafer diameter	200/300mm		Unchanged	Same
Wafer edge exclusion	3mm		Unchanged	Same
Handling/cleanliness				

Standardized Assessment approach of prototype equipment from previous project



SEAL

Semiconductor Equipment Assessment Leveraging Innovation

Partners:

Users:

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

Equipment Suppliers:

- Hamatech, Adixen Vacuum Products, Jenoptik Automatisierungstechnik, SUSS MicroOptics, Reinhardt Microtech, SUSS Microtech Lithography, MAPPER, Toppan Photomasks, HQ-Dielectrics, Ion Beam Services
- Nanda Tech, semilab, Fries R&T, Applied Materials, Integrated Circuit Testing, Oxford Instruments, Metryx, PVA TePla, KLA-Tencor, ProTec

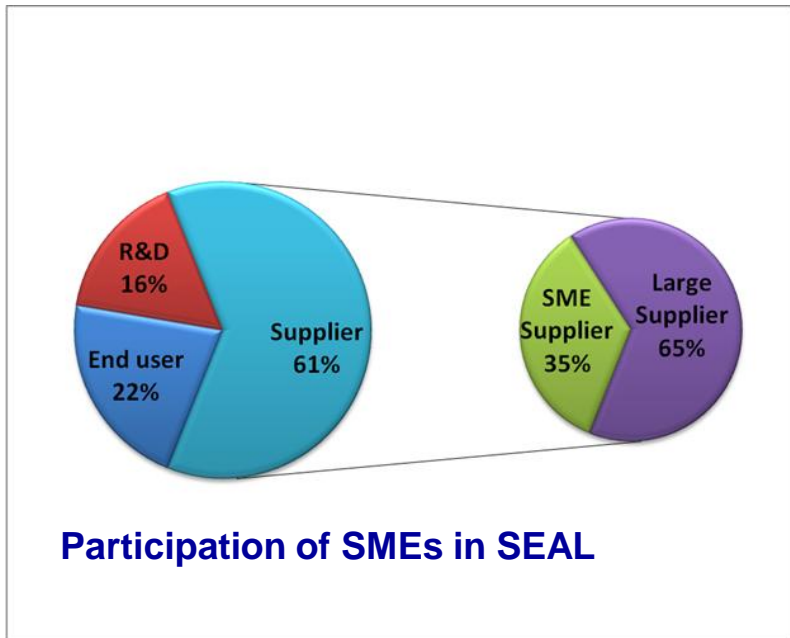
Research Institutes:

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

Budget/Funding:

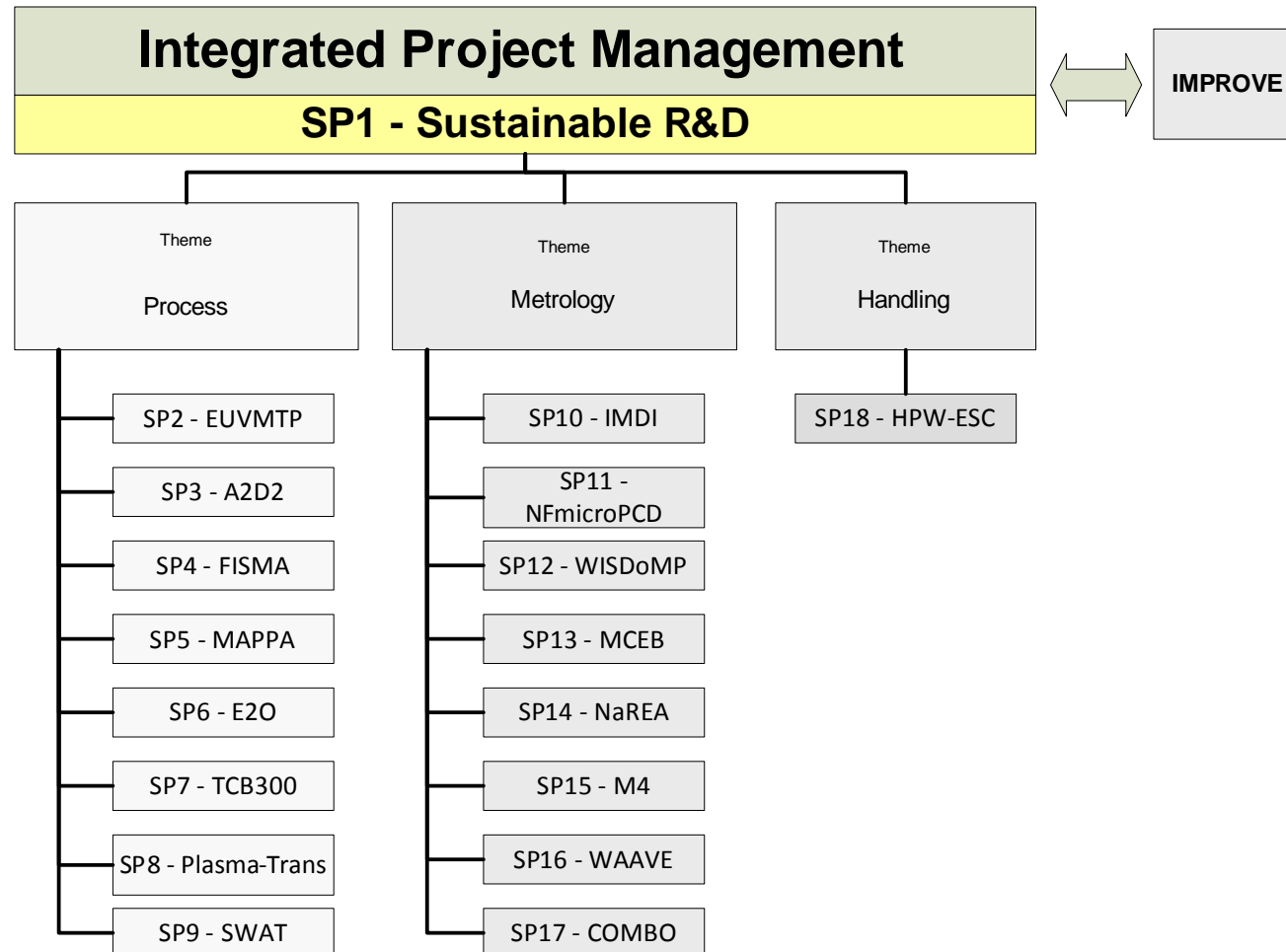
- 14,3 Mio EUR / 9,1 Mio EUR

Duration: June 2010 – May 2013



SEAL

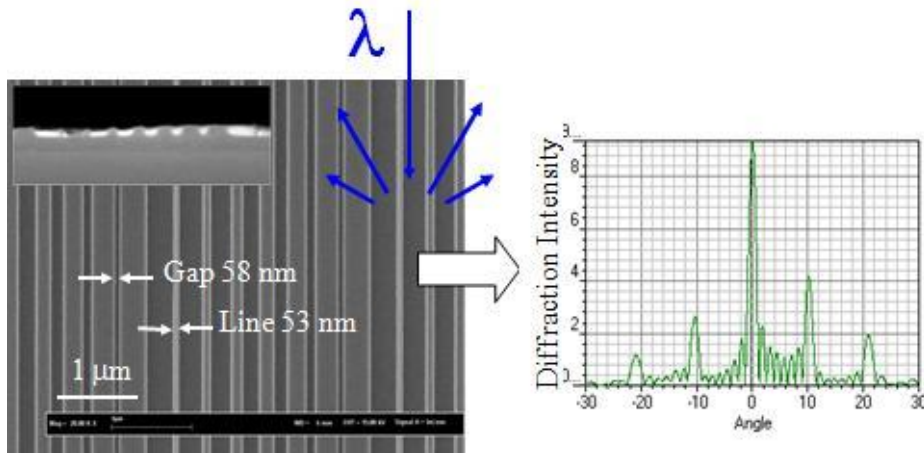
Semiconductor Equipment Assessment Leveraging Innovation



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



MaskTrackPro 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

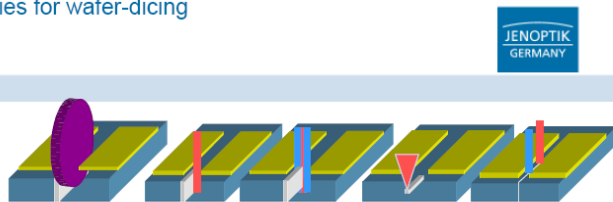
Coordinator: Peter Dreß / HamaTech

Duration: 12 Months

Short description:

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

Known technologies for wafer-dicing



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

TLS +A2D2
😊
😞 / 😊
😊 / 😊
😊 / 😊
😊
😊

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

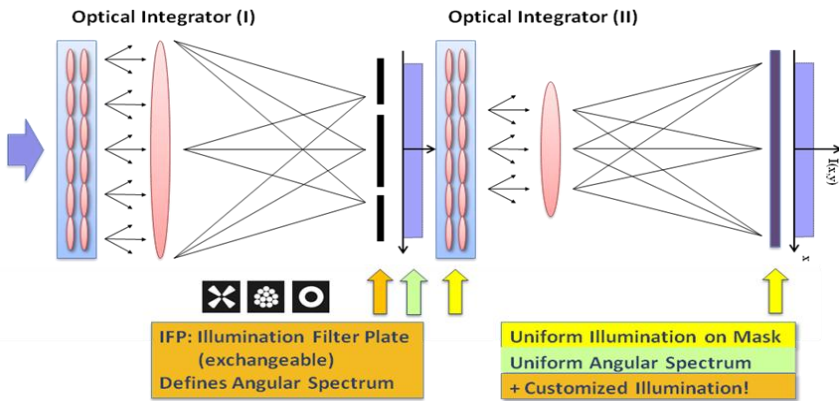
Partners: Adixen Vacuum Products, Fraunhofer IISB, Jenoptik Automatisierungstechnik, ULAB
Coordinator: Magali Davenet / Acatel Vacuum
Duration: 30 Months

SEAL SP4 - FISMA

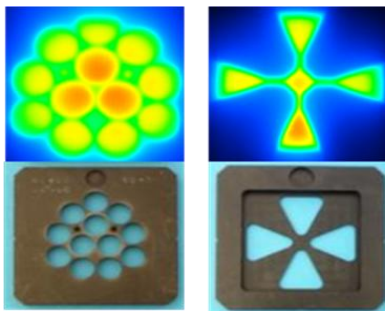
Flexible Illumination System for Mask Aligners

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

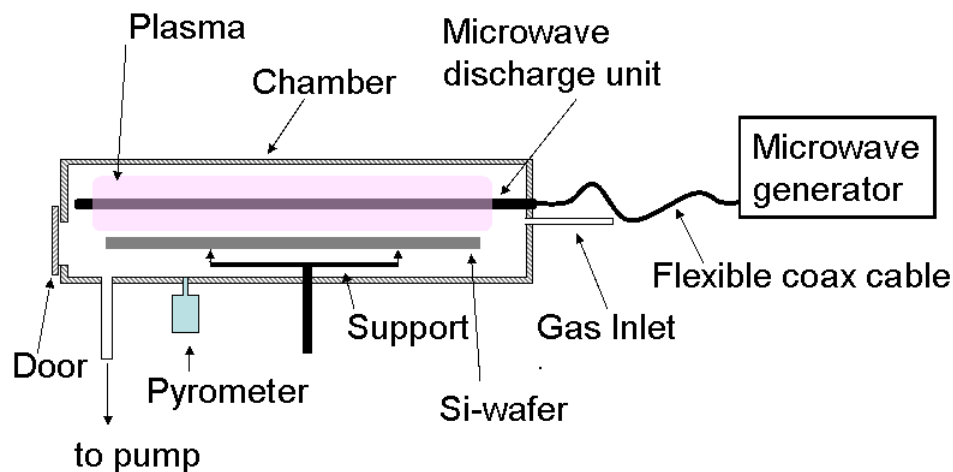
Advances proposed in MAPA

- 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

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

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

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

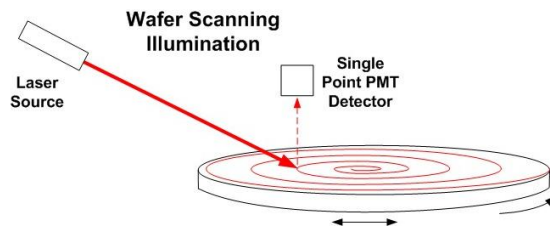
SEAL SP10 - IMDI

Innovative Meso Defect Inspection

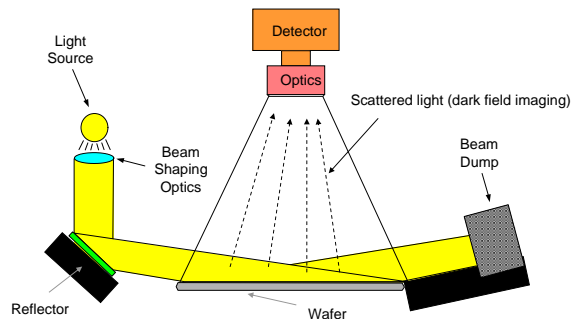
Short description:

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

Today's 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 1-10 μ m
- 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

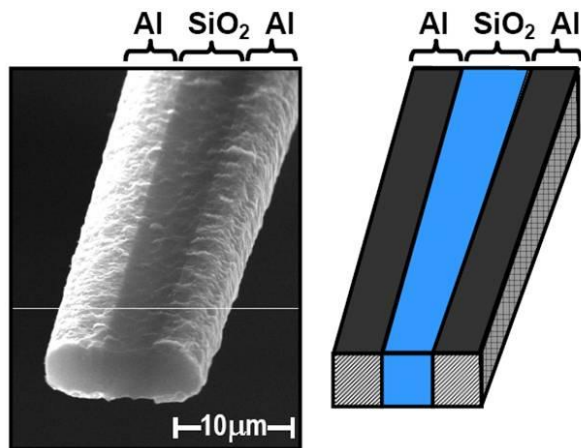
Partners: Nanda Technologies, STMicroelectronics
Crolles, imec, Fraunhofer IISB

Coordinator: Johannes von Borries / Nanda

Duration: 22 Months

Short description:

- Integration of near field and photo-decay measurement methods
- Assessment of lifetime-measurements with 25 μ m 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

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

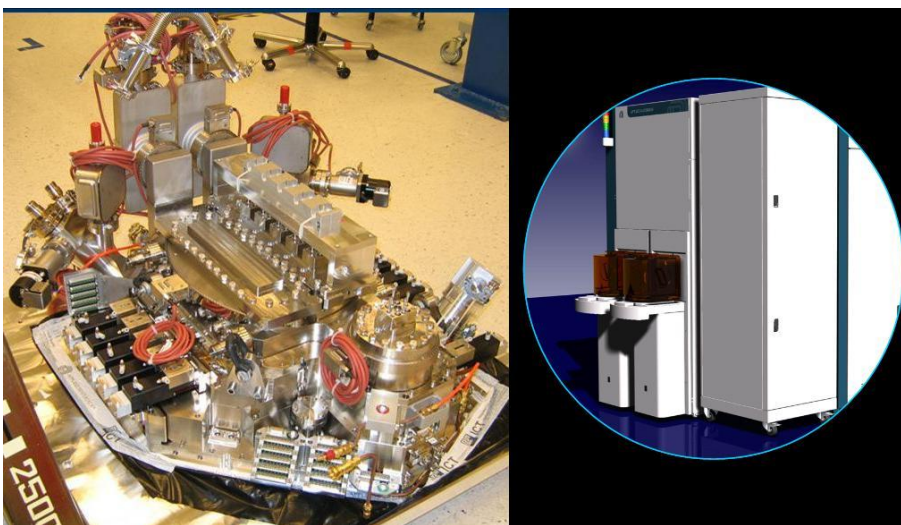
Duration: 16 Months

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

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.

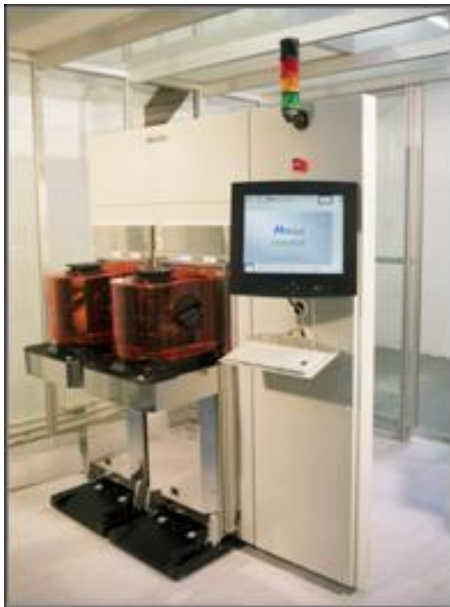
Partners: Oxford Instruments, Fraunhofer IISB, Infineon

Coordinator: Rune Gehrlein / Oxford Instruments

Duration: 30 Months

Short description:

- Assessment of fab ready 300mm tool for mass metrology
- Evaluation of new applications like Ion Implantation, Gate Stack, barrier seed layers for BEOI 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

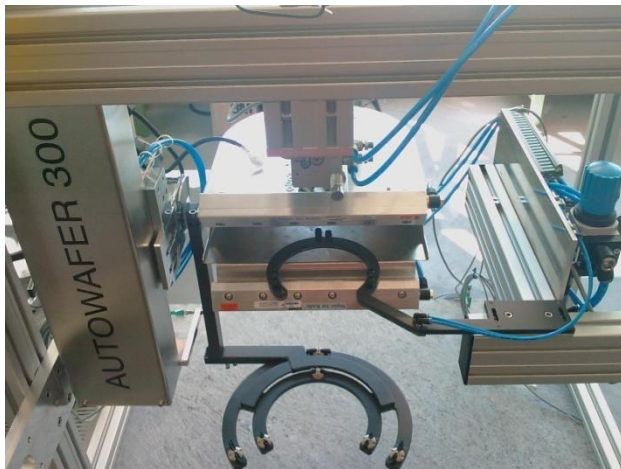
Partners: Metryx, Intel, imec

Coordinator: Mark Berry / Metryx

Duration: 30 Months

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**.

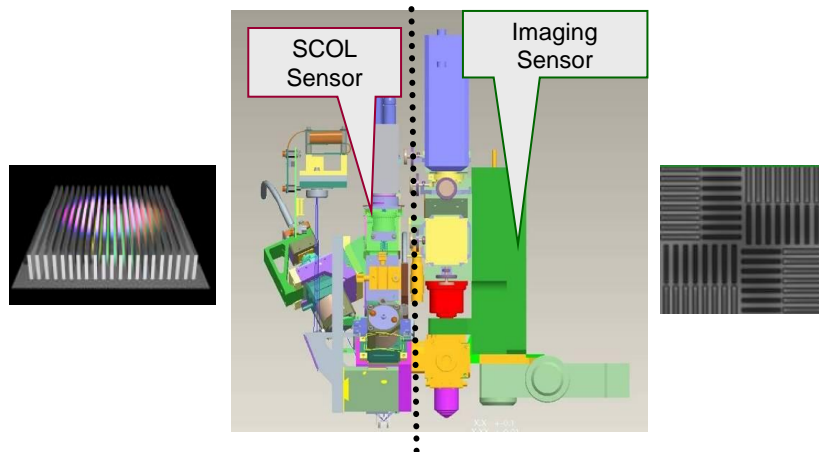
Partners: PVA Tepla Analytical Systems, S.O.I.TEC Silicon on Insulation Technologies, CEA/LETI

Coordinator: Peter Czurratis / PVA Tepla

Duration: 24 Months

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

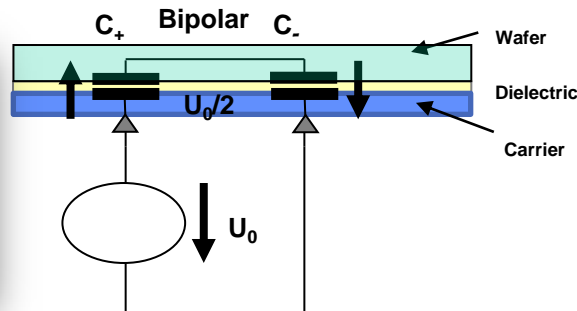
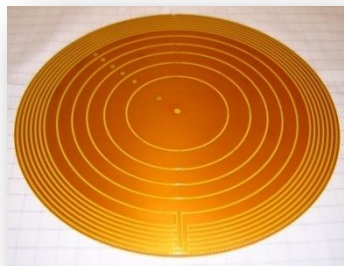
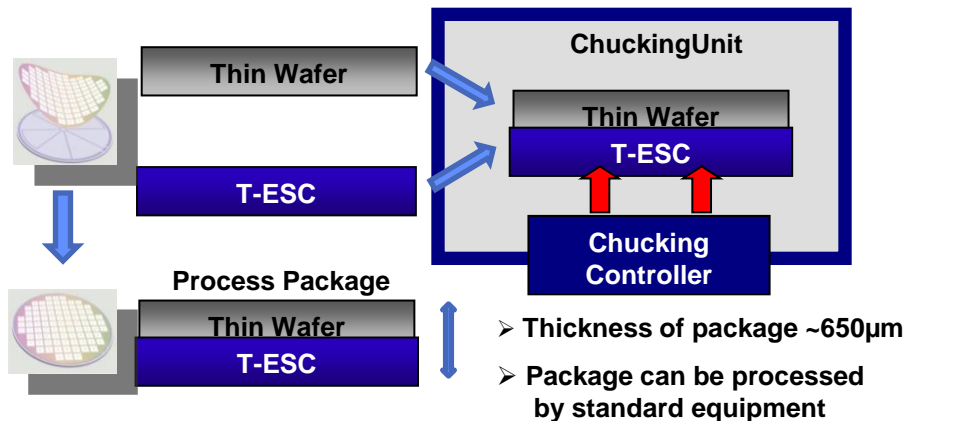
Partners: KLA-Tencor, imec, Numonyx

Coordinator: Daniel Kandel / KLA

Duration: 18 Months

Short description:

- Assessment of electrostatic 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



Participant of the kick-off meeting at Fraunhofer IISB

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

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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
- INTERUNIVERSITAIR MICRO- ELECTRONIC CENTRUM VZW (**imec**), Belgium
- PVA TePla Analytical Systems GmbH (**PVA TePla**)/Germany
- Siltronic AG (**SAG**), Germany
- Fries Research & Technology GmbH, FRT (**FRT**), Germany
- Oxford Instruments (**Oxinst**), Germany
- Infineon Technologies AG (**IFX**), Germany
- HamaTech APE GmbH&Co.KG (**Hamatech**), Germany
- Intel Corporation (**Intel**), United States
- STMICROELECTRONICS CROLLES 2 SAS (**STM CROLLES**), France
- Nanda Technologies GmbH (**Nanda**), Germany
- Applied Materials Ltd. (**AMIL**), Israel
- Integrated Circuit Testing GmbH (subsidiary of Applied Materials) (**ICT**), Germany
- Metryx Ltd (**Metryx**), United Kingdom
- GLOBALFOUNDRIES Dresden Module One LLC & Co. KG (**GDMOL&CK**), Germany



SEAL: Partners

- ION BEAM SERVICES (**IBS**), France
- Jenoptik Automatisierungstechnik GmbH (**JO-AT**), Germany
- NUMONYX ITALY S.R.L. (**NIS**), Italy
- KLA-Tencor Israel (**KLA**), Israel
- College of Nanoscale Science and Engineering (**UALB**), United States
- Reinhardt Microtech AG (**RMT**), Switzerland
- SUSS MicroTec Lithography GmbH (**SMTL**), Germany
- MAPPER LITHOGRAPHY B.V. (**MAPPER**), Netherlands
- TOPPAN Photomasks (**TPI**), France
- Protec Carrier Systems GmbH (**PCS**), Germany
- HQ-Dielectrics GmbH (**HQD**), Germany
- SUSS MicroOptics SA (**SMO**), Switzerland
- Adixen Vacuum Products (**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

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Thank you!

