Coordination Action to enable an effective

European 450 mm Equipment & Materials Network

Enable 450 Newsletter

Issue 5 **September/October 2013**

Enable450 Newsletter

Welcome to the fifth newsletter for the Enable450 project.

If you would like to supply information for publication, please contact the editor at mbryant@futurehorizons.com.

Our website is now up to allow previous issues to be downloaded. Please distribute this document to anyone who might be interested and you may place it on your own intranet if you wish.

Project Membership

There are eleven members of the Enable450 project consortium listed below.

ASM International NV (Coordinator)	ASM	Netherlands
Applied Materials Israel	AMIL	Israel
ASML Netherlands BV	ASML	Netherlands
Commissariat à l'énergie atomique et aux énergies alternatives	CEA-LETI	France
Fraunhofer IISB	IISB	Germany
Future Horizons	FH	UK
Intel Performance Learning Solutions (IPLS)	INTEL	Ireland
Interuniversitair Micro-Electronica Centrum vzw	IMEC	Belgium
RECIF Technologies	RECIF	France
SEMI Europe	SEMI	France
SOITEC	SOITEC	France

Project meetings are held on a three monthly basis and information fed to the EEMI450 consortium.

European Conferences

There were two major conferences in Europe which included presentations on 450mm technology during October.

The first was Future Horizons' IEF2013 conference, this year held in Dublin. The following week SEMI's SEMICON Europa was held in Dresden.

IEF2013

One of the main messages from IEF2013 is that there are a large number of applications still held back by a lack of computing power. For example Alex Butler of Microsoft UK demonstrated a large number of new input technologies to use hand gestures to replace the mouse. His message was that the sensing technology is available but that the computing power required exceeds that of the graphics display system. Thus to implement these approaches requires far more powerful ICs, preferably in a low power handheld device.

Another speaker was Ram Ramamoorthy of Edinburgh University who demonstrated the latest advances in Robotics.

Finally Karlheinz Meier of Heidelberg University who explained the European Commission funded Human Brain Project.

All three speakers were chosen to demonstrate that there is an ongoing demand for ever more powerful processing, often linked to more and better sensors. Thus there is no upcoming falloff in semiconductor IC consumption, either in More Moore or More than Moore technologies.

Several speakers pointed out that 450mm was needed to reduce costs, most bluntly put by John Chen of NVIDIA who pointed out that 450mm was originally due in 2011 and even now he hasn't been given a definite node of introduction. His message was clear – major fabless customers want their products made on 450mm wafers to achieve the next round of cost reduction and they have plenty of innovative products ready to utilise the technology once the foundries introduce it.

One of the main contributions was by European Vice President Neelie Kroes, who though unable to attend due to Council meetings, sent a specially recorded video emphasising that she wants to see Europe taking 20% of worldwide IC production by 2020, and specifically that this should include 450mm technology. This video will soon be available to watch on the Future Horizons website www.futurehorizons.com

SEMICON Europa

The following week, SEMICON Europa included a supplier exhibition where quite a few 450mm wafers were on display. One highlight was a working 450mm FOUP load/unload mechanism, albeit from a Japanese manufacturer. These exhibits did illustrate though that 450mm is for real and no longer a paper exercise.

There was also a day long conference dedicated to 450mm in the largest room. This was crowded throughout the time and a large number of papers were given.

Indeed there were even more applications to speak which had to be turned down, indicating the huge interest 450mm currently has. Indeed the number of speakers was still too many for the time available and there was unfortunately no time for questions. In order to enable more questions in future conferences, the organisers may try to expand the duration over a day and a half, and possibly reduce the number of speakers to enable longer talks.

Paul Farrar of G450C began with a presentation about Supply Chain Collaboration for 450mm. His key message was there are 25 different tools delivered to G450C of which 15 are installed in the NFN cleanroom. This number will grow to 42 onsite and 19 offsite by Q1 2015. He stated Nikon aim to have a working 193i litho machine in 2H 2014 and install one in Albany in 1H 2015. Paul also reported a great improvement in wafer quality which now exceed the expected M76 specification, and prime wafers to the M1 spec should be available in Q3 2014. There has also been good progress on wafer reclaim and it is hoped some wafers can be reused up to 10 times, although at least 3 is the target. Metrology seems to be one of the most advanced areas with 8 different machines already operational. The number of 450mm wafers in their inventory now stands at over 10,000 with these moving between the partners more rapidly.

It was immediately noticeable from Paul's speech that G450C is now recognising the major contribution Europe is making to 450mm and is looking for more collaborations.

Peter Csatary of M&W then dealt with the facilities part of G450C, known as F450C. This group consists of

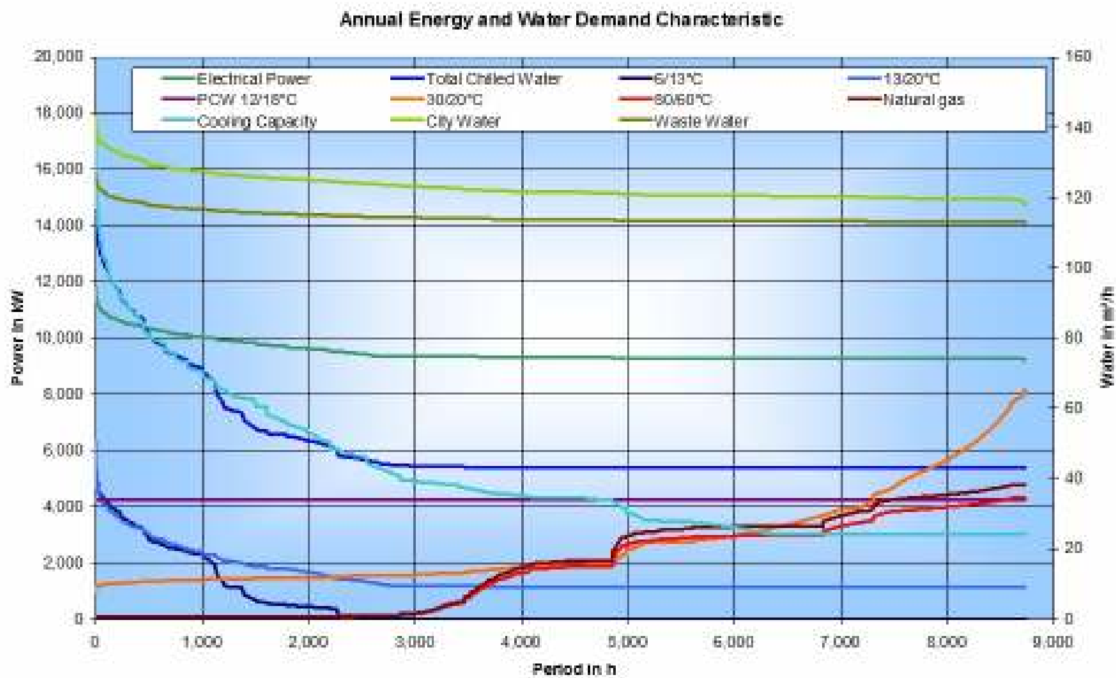
- M&W (co-ordination)
- Edwards
- Swagelok
- Mega Fluid Systems
- Ovivo
- CH2MHILL
- Haws Corporation
- Air Liquide
- Ceres Technlogies
- CS Clean Systems

F450C is seen as streamlining communications with the semiconductor companies and their process tool suppliers. The group will focus on 4 key areas, namely Environmental Footprint, Facility Interface Requirements, Cost and Duration, and Safety and Sustainability.

One interesting point raised was that 450mm equipment is inherently more massive and one suggestion has been that ceiling mounted cranes will be required to install and remove equipment. This of course means that fab roofs would need to be stronger than previously. This topic was discussed at the latest F450C meeting subsequent to this conference and details of that are given later in this newsletter.

Another new concept is that of a few standardised 3D templates and adapter plates to allow fab services to be pre-installed before the equipment is placed.

An interesting point made elsewhere by M&W is that the current preference is to place a fab where there are already other fabs in existence so that the infrastructure to transport products, materials and services is already in place, as are basic utilities such as power, natural gas and water supply. However, the scale of the expected utility demand at 450 mm ups the stakes as for example a large 300 mm facility uses about 4 million gallons of water per day, whereas a 450 mm fab will use almost double that, putting immense strain on a location's infrastructure should there be other fabs in the region. This could affect future site selections. An outcome of this phenomenon is that the reduction, reclaim and reuse of materials will no longer be driven only by the desire to be a good corporate citizen, but will also be driven by cost control and to ensure availability of required resources such as power, water, specialty gases and chemicals.



Bas van Nooten followed with an update on EEMI450 and Global Cooperation. The slide set is being distributed with this newsletter.

Menachem Shoval then gave a speech on Metro450, the Israeli consortium whose members have about one-third of the world market for metrology. He emphasised that metrology is no longer an inconvenient and expensive 'add-on' but a must that needs to be built into process flows from the beginning. He gave some examples of the

performance and costs required to meet industry needs and how the group aims to meet them such as with a new low cost stage with a non-linear servo controller which benefits all. Another issue the group can work on is how many samples are actually needed in production and adaptive sampling is seen as the way forward here. Finally the computing needs have grown massively and Metro450 is trying to specify a standard compute platform for metrology software.

Steve Johnston of Intel emphasised that Intel still sees a growing market for state of the art semiconductors and hence the need for 450mm fabs, and saw collaboration as greatly assisting meeting that demand. Unfortunately no information relating to the current D1X second module construction slated for Intel's 450mm pilot line plans was disclosed.

Jochen Kinauer of AIS then spoke on the 450mm cluster within Silicon Saxony. Despite the known feelings of the German federal government, Silicon Saxony is keen on 450mm and would like to be seen as a possible location for Europe's first 450mm production fab. He highlighted the recent MoU with Leuven and the visit to G450C we mentioned in a previous newsletter. Finally he outlined some work on 450mm being performed by Entegris, HAP, Ortner, HSEB, AIS Automation and SYSTEMA both on EC funded projects and elsewhere.

Khalil Rouhana outlined the current thinking on nanoelectronics at the European Commission. The importance of this area and of manufacturing is now well understood and the support for R&D is well placed, with the importance of Cambridge beginning to be recognised though still not at the level those in the UK have hoped the new rules for ECSEL would enable. The current 450mm projects were mentioned but there was no new thinking on how to encourage a fab to be built in Europe.

This was followed by Andreas Wild of ENIAC who showed the gap Europe has at 300mm and some of the plans to fill this and thus hope such technology will transition to 450mm. He also presented some excellent figures on the cost of R&D support under ENIAC and that planned under ECSEL, and some of the welcome changes to the rules so as to avoid companies being forced to non-participate if they cannot get support from their local PA.

Denis Rousset of CATRENE demonstrated a good understanding that 450mm technology is key to Europe's future in semiconductors and that both test beds and pilot lines are crucial to this development.

Malcolm Penn of Future Horizons supported the 450mm rollout in his own inimitable style, pointing out that customers with applications are already there for 450mm wafers and urging the European Commission to financially support the building of 450mm fabs in Europe before it is too late.

Uwe Kreibisch of EVG covered progress of the SOI450 project which has recently achieved the first fully automated 450mm wafer bond, and that the resultant wafers are of good quality.

Alain Jarre of RECIF highlighted that for SMEs collaboration is key as they cannot be in multiple places at the same time, and that a global collaboration is essential to ensure all details are covered enabling 450mm to be rolled out. An excellent example of this was reached at the event between G450C and EEMI450 to align the Demonstration Test Methods between G450C and the distributed Imec pilot line so that test reports will be shared between both organization. This will obviously save a huge amount of time.

Lode Lauwers of Imec underlined the opportunities for ever smaller semiconductor geometries developed under Imec's CMOS, memory and 3D programmes. Progress on EUV was briefly covered followed by an outline of the Imec 450mm pilot line. Some 3D CAD images were given of the cleanroom due to open in Q4 2015 but nothing was labelled, but the timelines were very detailed on when Imec expect to begin each task, all dependent though on the 2H 2015 installation of a 450mm EUV scanner.

Olaf Kievet of TNO looked at the effect contamination will have on the geometries likely to be fabbed on 450mm wafers and some of the programmes they are working on to improve yields.

Markus Pfeffer of Fraunhofer covered the Semiconductor Equipment Assessment (SEA) programme co-ordinated by Fraunhofer and how it is being extended to 450mm in the SEA4KET programme.

Michael Liehr of University of Albany looked at the 450mm transition and some of the other improvements in circuits that need to be achieved to make best use of the new wafer size. A key statement he made was "There are many opportunities to engage CNSE/G450C on 450mm relevant problems".

Frank Bornebroek of ASML noted that concerns remain that there is too little industry support for the transition. Regarding ASML's 450mm design strategy, he stated that for 450mm Immersion tools there is re-use of 33% of parts from 300mm immersion, whilst for 450mm EUV tools there is 74% of commonality of parts with 300mm EUV. The redesign focuses mainly on the larger wafer stage and the wafer handling section.

Jorgen Lundgren of ENTEGRIS looked at the use of advanced polymers to improve the design of FOUPs.

Michael Abraham of Rudolph Technologies dealt with surface, edge and backside inspection of 450mm wafers.

Thomas Dreyer of AIS Automation discussed how to best integrate equipment into 450mm fabs, covering in detail Idle/Green modes and also the huge amount of data that will be created and how this can be used for predictive maintenance.

Juergen Niess of HQ-Dielectrics talked about low temperature plasma oxidisation being essential to processing modern semiconductor structures.

Finally Kirk Hasserjian of AMAT gave a speech on the Challenges in the Transition to 450mm. He saw this being defined by three vectors – When, Who and What, and also by another three – Macro Economics, Technical Complexity and Transition Economics. On Macro Economics he saw no reason for silicon demand not to carry on expanding at its current rate. Technical Complexity needed to be addressed but no actual roadblocks, whilst also offering more opportunities for standardisation than occurred at 300mm. Transition Economics was harder though with only 3 to 5 customers and this being the first transition not driven by memory, but solely by logic (i.e. Intel) and Foundry. Finally he stated his 450mm Transition Requirements as

- Timeline Synchronisation – customer timelines need to be synchronised to maximise R&D efficiency.
- R&D Funding – consortia, government and IC maker funding needed to share cost and risks.
- Standardisation – further standardisation needed across the industry to lower costs.
- Process Performance – pilot tool performance needs to meet the 7/5nm node requirements for a successful transition.

Biographies and abstracts of the speeches are available to all at

http://www.semiconeuropa.org/node/2216/

A few speeches for which we have copyright clearance are distributed with this document. Other speeches are on the SEMI website although access may be restricted.

Outside the conference room, discussions with the representatives of Marcy from New York revealed they intend to issue bonds to pay for the subsidies necessary to attract the three 450mm fabs they hope will be built there. However they did acknowledge it is unlikely three of the four major IDMs and foundries would be willing to have their fabs co-located with their competitors as there would be too much leakage of confidential information as employees moved job. Europe may need to consider this factor in its attempts to attract new fabs to Europe. The legality or otherwise within Europe of issuing bonds for funding could be investigated with the European Investment Bank though.

In conclusion both conferences showed that 450mm is now well recognised as being a key part to Europe’s future success.

EEMI450

SEMICON Europa was followed with a General Assembly meeting of EEMI450. It was immediately noticeable that much of the same material had been used at the 450mm session of SEMICON and after some administrative actions and as time was short the agenda was swiftly culled by chairperson Bas van Nooten.

As mentioned before it was noticeable in Paul Farrar's speech that G450C is now recognising the major contribution Europe is making to 450mm and is looking for more collaboration and this view was echoed by Frank Robertson in his presentation to the EEMI450 GA.

Alignment on 450mm Tool Testing

- In the spirit of global coordination, EEMI450 participants the Fraunhofer Institute, IMEC and Metro450 have agreed with G450C to align on using the G450C Demonstration Test Methods as the means of characterizing 450mm equipment
- By standardizing on the same approaches to testing, common data collection tools and report content outlines, the outputs of such testing will have the same scope, consistent format and comparable data regardless of where the work is done and Suppliers will not have to accommodate multiple testing regimes
- This alignment enables the organizations to exchange reports in a complementary fashion, asking the Suppliers to perform only one such demonstration per tool and increasing the information flow to the members of each program
- This collaborative effort provides value to all stakeholders by moving the 450mm transition forward in a cost-effective and timely manner

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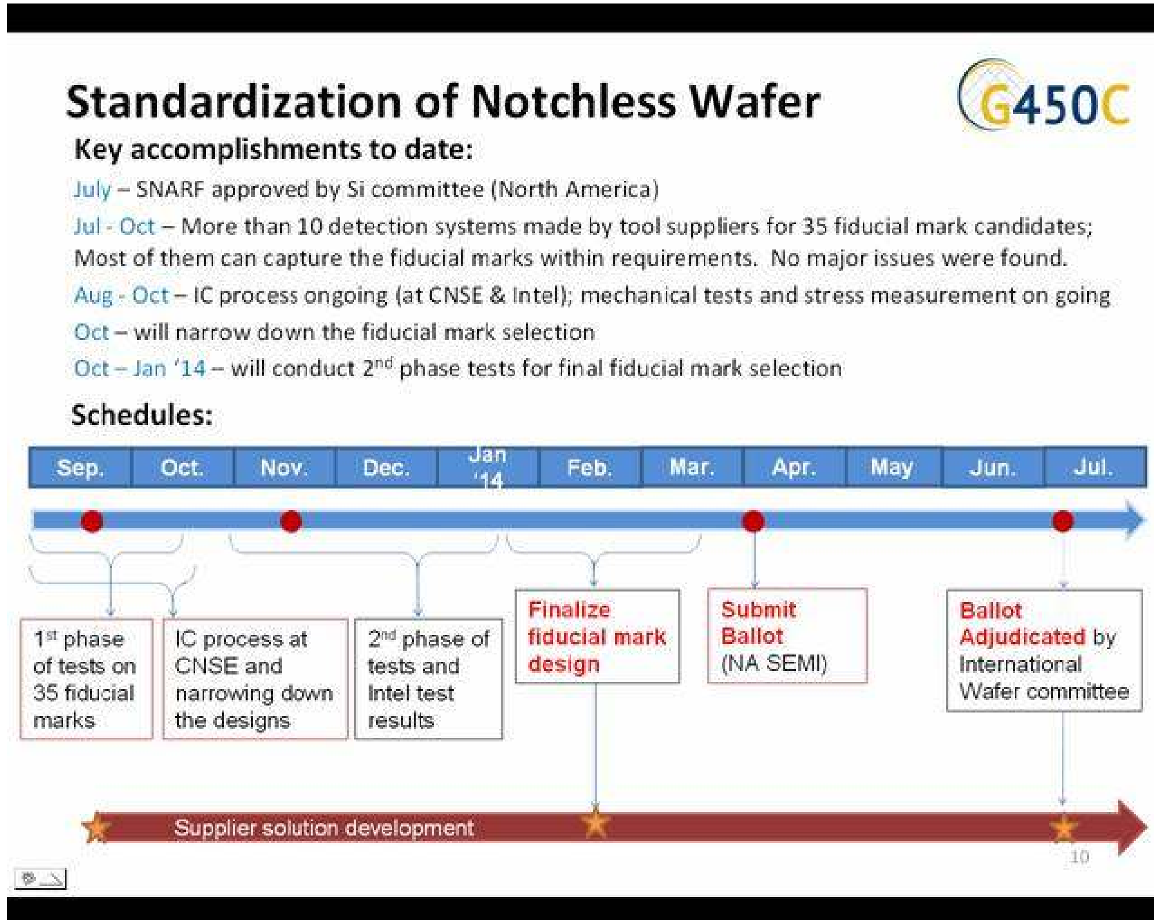
Frank also gave an updated schedule for the standardisation of Notchless Wafers which was less aggressive than previous suggestions.



New information was given on some of the projects such as E450PR and SOI450. Members of EEMI450 can consult the website for updates.

F450C

A meeting of F450C was held at the latest Albany workshop on October 23rd.

As mentioned earlier in this newsletter, 450mm equipment is inherently more massive and one suggestion has been that ceiling mounted cranes will be required to install and remove equipment. This of course means that fab roofs would need to be stronger than previously. However the F450C Workshop clearly stated that this option would not be preferred option for enabling heavy lifting during tool install and maintenance procedures in HVM fabs. Therefore, tool OEMs are currently working together to explore suitable alternatives that do not hinder fab layout, and improve safety and ergonomic aspects of the tasks.

Many other issues were discussed and some may result in new collaborations or projects.

- Maintaining 450 equipment, including how to lift heavy machine parts with minimal need to have special tools and extra footprint, or constraints on the fab infrastructure.
- Dealing with performance matching of 450 process and process control equipment. Cost of mismatch will jump and which standards and common solutions can be investigated to resolve this expected problem. As wafer diameter increases, non-uniformity, thermal effects and others, will increase tool and process induced shift and errors. Possible collaborations can focus on
  - Adaptive tools recipes for optimal matching.
  - Excursion monitor.
  - Automated tool / process diagnostics.
- More work on eliminating molecular contamination
  - In situ molecular contamination sensors.
  - Immediate lab methods to detect molecular contamination.
  - Design a tool better than the current ability to measure cleanliness.

European Funded 450mm Projects

Any company interested in taking part in future 450mm European projects is asked to first join EEMI450 whereupon they will be able to receive full details of new project proposals.

An overview of the projects to date were given in the second edition of this newsletter. The new projects beginning this Autumn are :

E450EDL

European 450mm Equipment Demo Line

This is a ENIAC KET (Key Enabling Technology) pilot project to continue the engagement of the European semiconductor equipment and materials industry in the 450mm wafer size transition, and will build the second phase of the 450mm pilot line at Imec. It began in October 2013 and will last 3 years.

The project is coordinated by ASML of the Netherlands and includes 41 partners from 11 countries. 867 person-years of effort will be expended at a cost of €205 million with ENIAC funding of €30.6 million and national funding of €30.2 million.

The E450EDL project will enable first critical process module development in a distributed pilot line, allowing participation in the world first 450mm integration studies, sustaining the leadership position of the European industry. This continues the engagement of the European semiconductor equipment and materials industry in the 450mm wafer size transition that started with the ENIAC JU EEMI450 initiative and proceeded with subsequent projects such as NGC450, SOI450 and EEM450PR.

The demo line resulting from this project will be such that it will enable first critical process module installation by combining with the Imec infrastructure. In the particular case of equipment which is very expensive or complex to operate, tools may remain at the site of the manufacturers to form a distributed pilot line. Multisite processing will allow partners to participate in the world first 450mm integration studies and will be enabled by the controlled exchange of 450mm wafers between different sites.

The project is organized in five technical work packages and a work package on management and coordination.

In the work package on integration and wafer processing first critical modules will be developed and will demonstrate the feasibility of processing on 450mm wafers.

The main objective in the work package on lithography is to develop a wafer stage test-rig, which can be implemented into the pilot line system.

In the work package on front end equipment several tools will be developed such as a plasma ion implant module, a plasma dry etch module, a RTP system and a single wafer cleaning system.

In the dedicated work package on metrology 450mm metrology tool types will be developed for amongst others dielectric film thickness and composition measurements, defect inspection, defect review and analysis, optical critical dimensions (CD), overlay (mask and wafer) and 3D metrology.

Finally, from the work package on wafer handling and automation a set of equipment will be provided to support the demo line operations, and facilitate the R&D dedicated to process and metrology modules.

The partners are :

- ASML Netherlands B.V. (co-ordinator)
- adixen Vacuum Products
- AIS Automation Dresden GmbH
- Applied Materials Israel Ltd.
- artemis control AG
- ASM Belgium N.V.
- ASYS Automatic Systems GmbH & Co. KG
- CEA-Leti
- DEMCON
- Entegris Cleaning Process (ECP) S.A.S.
- EV Group E. Thallner GmbH
- FEI Czech Republic, s.r.o.
- FEI Electron Optics B.V.
- IBS ion beam services
- Integrated Dynamics Engineering GmbH
- IMEC Interuniversitair Micro-Electronica Centrum VZW
- Intel Performance Learning Solutions Ltd
- Institute of Scientific Instruments of the ASCR, v.v.i.
- Jordan Valley Semiconductors LTD
- KLA Tencor Corporation Israel Ltd.

- LAM Research AG
- Levitech B.V.
- M+W Products GmbH
- Metryx Ltd
- MFA Research Centre for Natural Sciences - Institute for Technical Physics and Materials Science
- Mogema B.V.
- Nanoplas S.A.S.
- Nova Measuring Instruments Ltd
- Prodrive B.V.
- Recif Technologies S.A.S.
- Reden
- Riber
- Semilab Semiconductor Physics Laboratory Co. Ltd.
- Semilev GmbH
- Soitec S.A.
- SUSS Microtec AG
- TNO - Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek
- Delft University of Technology
- VDL Enabling Technologies Group Eindhoven B.V.
- Xycarb Ceramics B.V.
- Zeiss SMT GmbH

SEA4KET (FP7, partly 450mm)

Semiconductor Equipment Assessment for Key Enabling Technologies

This is an FP7 project that partially deals with 450mm issues. It begins in November 2013 and will last 3 years.

The strategic objective of SEA4KET project is to effectively combine resources and expertise into a joint assessment of novel equipment for key enabling technologies to foster and accelerate the successful transfer of novel European equipment into the world-wide market.

It is coordinated by Fraunhofer IISB of Germany and includes 26 partners from 7 countries

Bridge450

Bridge450 is a new work program defined under the Objective FP7-ICT-2013-11. It is listed under Objective ICT-2013.3.1 Nanoelectronics and specifically Topic d: International Co-operation : One support action to develop a European strategy which addresses the challenges in manufacturing for 450 mm in dialogue with G450C and with the US, Korea and Taiwan.

The FP7 Coordination Action Enable450 began in 2012 to assist European 450mm programmes with data collection, standards, G450C liaison, dissemination of 450mm topics and other activities. The Bridge450 Support Action seeks to run in parallel with Enable450 to expand its scope with more focus on Asian semiconductor manufacture.

Bridge450 will support the European E&M companies and specially the SMEs to become aware of and understand Asian technical requirements and to develop solutions to address this market. To assist the information flow, a Semiconductor Manufacturers Board will be set up which is aimed to include representatives of Asian semiconductor IDMs and foundries.

A second objective of Bridge450 will be to establish the possibilities of 450mm semi-manufacturing in Europe and what would be needed to facilitate such an operation, which will be vital for the future of advanced nanoelectronics in Europe.

Thus this could be considered a sister project to Enable450 with many of the same companies involved as listed below.

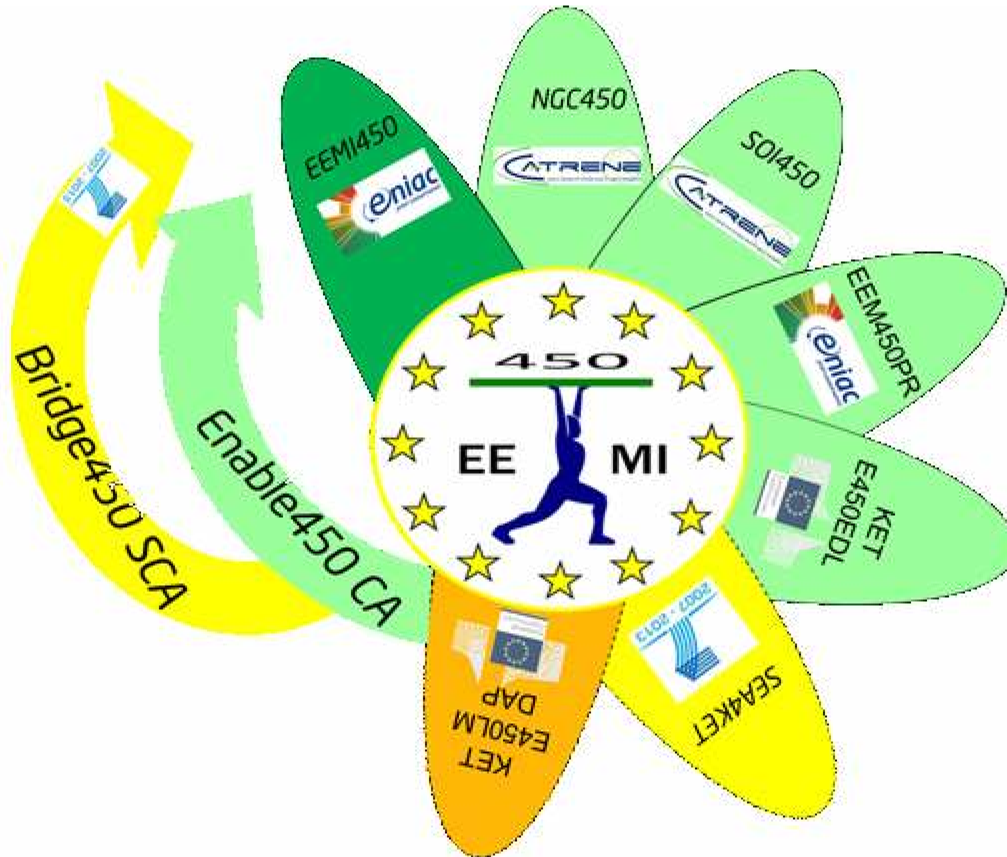
Participant no.	Participant organisation name	Part. Short	Country

		name	
1	ASM International NV (Coordinator)	ASM	Netherlands
2	Future Horizons Ltd	FH	United Kingdom
3	Interuniversitair Micro-Electronica Centrum vzw	IMEC	Belgium
4	Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung E.V.	IISB	Germany
5	Applied Materials Israel Ltd.	AMIL	Israel
6	RECIF Technologies	RECIF	France
7	Artemis Control AG	ART	Switzerland
8	SEMI Europe-Grenoble Office	SEMI	France
9	M+W Germany GmbH	M&W	Germany
10	AIS Automation Dresden GmbH	AIS	Germany

European SMEs are often in competition with suppliers from the US and Asia and it is essential that their existence is recognised by IDMs and foundries. Bridge450 will attempt to research by visits to Asia and the US, what opportunities exist for European SMEs, whilst simultaneously presenting the abilities of European SMEs to the IDMs and foundries. Obviously if we discover that it is possible to source all requirements for a 450mm fab within Europe, this will also assist in promoting Europe as a suitable place for such a new fab to be constructed.

The kick off meeting for the project will be on November 13th but if you are a European based SME of any size with an interest in 450mm processing in any form whatsoever, please contact Bas van Nooten or Mike Bryant who will be glad to discuss how this project could assist you.

The current active and proposed projects are shown in this picture below.



10/100/20

One of the first initiatives under Horizon 2020 is the 10/100/20 initiative announced by Neelie Kroes earlier this year. This aims to achieve 20% of world semiconductor production within Europe by 2020. As a first step towards this the European Leaders Group held their first meeting in Brussels on October 16th.

Members of the ELG are :

Ben Verwaayen, formerly of BT and Alcatel

Carlo Bozotti of STM

Reinhard Ploss of Infineon

Rutger Wijburg of Globalfoundries

Rick Clemmer of NXP

Hubert Lakner of Fraunhofer

Mike Muller of ARM

Peter Wennink of ASML

André-Jacques Auberton-Hervé of SOITEC

Luc van den Hove of Imec

Jean Therme of CEA

Eamonn Sinnott of Intel

This is a reasonable mix of 'More Moore' and 'More than Moore' advocates so it will be interesting to see what they submit to Ms Kroes by the deadline of the end of December 2013. Certainly in all the calculations Future Horizons has performed it appears impossible to meet the target without several new 450mm or 300mm upgradeable to 450mm state of the art fabs being built in Europe.

European NanoElectronics Forum 2013 in Barcelona

This annual event takes place this year in Barcelona and is organized by FP7, ENIAC and CATRENE. In previous years this has been an excellent forum to attend if you are interested in seeing the broad spectrum of European research as the speeches are supported with a very large poster session covering almost every funded project. There are also a number of awards for the most innovative projects and for the best presentation at the exhibition.

Of course ENIAC is soon being replaced by the Electronic Components and Systems for European Leadership (ECSEL) Joint Technology Initiative (JTI) which will operate under Horizon2020, the official name for the Eighth Framework Programme. It is a merger of the ARTEMIS embedded systems JTI and the ENIAC nanoelectronics JTI both set up in 2008 operating under FP7. Khalil Rouhana of the European Commission spoke at both IEF2013 and SEMICON Europa to explain the plans in more detail, and we expect further information will be presented at at the upcoming European Nanoelectronics Forum being held in Barcelona from November 27th to 28th.

There are also many Europe-wide projects of interest which are funded directly under FP7 rather than by ENIAC. Hopefully the future of nanoelectronics projects funded in this manner will be clarified at the forum as this is generally the preferred way universities like to participate in funded projects.

Meanwhile the CATRENE initiative will proceed in its second phase until the end of 2015 and details should be given of progress to date, and possibly of some of the latest approved projects in the latest call for projects.

Those interested in attending will need to request an invitation and then register at :

http://www.nanoelectronicsforum.org/

WaferNet 450mm Particle Monitor Specification

We were given the current specification of wafers manufactured by Sumco which is published here for interest.

Category	Items	Particle Monitor
General Characteristics	Growth Method	Cz or MCz
	Crystal Orientation	<100>
	Conductivity Type	p
	Dopant	B
	Wafer surface declination in respect to crystal orientation	no specification
Electrical Characteristics	Resistivity	0.005 - 100 ohm-cm
	Radial Resistivity Variation	no specification
Structural Characteristics	Slip	no specification
	Twin Boundary	no specification
	Swirl	no specification
Wafer Preparation Characteristics	Wafer ID marking	OCR or SEMI T7
	Edge surface conditions	Polished
	Back surface conditions	Polished
Dimensional Characteristics	Diameter	450+/-0.2mm
	Notch Dimensions: Depth Angle	1.00+0.25 -0.00 mm
	Orientation of Notch axis	<110>
	Edge profile	Front edge width:120 - 508 µm Back edge width 120 - 508 µm
	Thickness	925 +/- 25um
	GBIR, less than	10µm
	Bow, max	no specification
	Warp, max	no specification
	Flatness/SFQR (26 * 8 mm2 site size)	no specification
	Nanotopography (2 x 2 mm)	no specification
	Near Edge Geometry	no specification

Front Surface Chemistry	Sodium	< 1 x 10E10 / cm2
	Aluminum	< 1 x 10E10 / cm2
	Potassium	< 1 x 10E10 / cm2
	Chromium	< 1 x 10E10 / cm2
	Iron	< 1 x 10E10 / cm2
	Nickel	< 1 x 10E10 / cm2
	Copper	< 1 x 10E10 / cm2
	Zinc	< 1 x 10E10 / cm2
	Calcium	< 1 x 10E10 / cm2
Front Surface Inspection Characteristics	Particles	<250@>0.045um (LPD)
	Scratch	no specification
	Pits (COP)	no specification
	Haze	Comparable to 300mm monitor wafer
	Localized Light Scatteres	No specification
	Edge Chips	None
	Dimples	no specification
	Orange Peel	no specification
Back Surface Inspection Characteristics	Edge Chips	None
	Edge Cracks	None
	Contamination/Area	no specification
	Stains	no specification
	Scratches	no specification
	Back surface brightness	no specification