Semiconductor Equipment Assessment – An Enabler for Production Ready Equipment

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ABSTRACT

This paper will present advances in equipment research, in metrology equipment research, in improved collaboration strategies between equipment suppliers and end-users and in better controlled and smart manufacturing.

Keywords: equipment assessment, semiconductor manufacturing, processing, metrology, collaboration

INTRODUCTION

Semiconductor devices today show a ubiquitous presence and are of strategic importance. The manufactured number of transistors per area is still growing along a semi-logarithmic plot over the years. However, Europe‘s position as a supplier of integrated circuits and as a supplier of semiconductor manufacturing equipment and materials has changed significantly over the past decades. The number of IC-manufacturing sites in Europe has remained almost constant - whereas other regions have grown heavily. Concerning products, a strong paradigm shift has occurred. In fact, the number of leading edge IC–manufacturers has globally decreased, not only in Europe. Nevertheless, a new spectrum of devices is rapidly growing and can be summarized under More-than-Moore (MtM) devices, power devices and 3D devices. Such semiconductor devices require a paradigm shift in materials, manufacturing, and equipment development to overcome the valley of death (see fig. 1).

As IC manufacturing is heavily influenced by equipment procurement and operating costs, an effective equipment development, assessment and transfer of new generation equipment into the production lines is required.

SEMICONDUCTOR EQUIPMENT ASSESSMENT

Let’s start with a little background to establish the context. During the 60’s and 70’s laboratory equipment was built by integrated circuit (IC) manufacturers. However, a growing number of equipment manufacturers took over this task and built the tools to the specifications of the semiconductor manufacturers. yA new type of collaboration was needed to progress in this area, a network that linked research, equipment manufacturers, and IC manufacturers. It is also very important to remember that the many actual users of ICs (in computing, communications, manufacturing, transport and medical, to name but a few) rely on innovations that emerge at the equipment level. Linking various parts of the IC chain to foster such innovation is, therefore, a core objective of semiconductor equipment assessment.

COLLABORATION FOR PROGRESS

The Semiconductor Equipment Assessment Initiative (SEA) began in 1996 and lasted until 2004, and offered European equipment and material suppliers a path to develop their product innovations through to fully productive solutions. There were more than 60 SEA projects and more than 40 companies had their products evaluated in SEA. In contrast to the large number of independent SEA projects, the recent European semiconductor assessment projects (SEA-NET, SEAL and SEA4KET) add new values towards cooperation, mutual benefit, innovation and sustainability (see fig. 2). A novel strategy of integration and collaboration between several equipment manufacturers, research institutions, and IC manufacturers for advanced equipment evaluation and assessment of novel and innovative equipment as well as long-term and sustainable equipment research was implemented in order to enable production ready equipment. The recent SEA projects provided the long-needed platform that links relevant parties together and effectively seeks to close the gap between equipment development and its integration into semiconductor production. In addition to processing equipment, metrology is an enabling and indispensable technique for the realization of new semiconductor technologies (see fig 3).

Research and development efforts as well as collaboration on a global level will have to be invested in equipment improvements and innovations addressing key importance areas. Joint equipment assessment may provide large benefit for fast ramp-up, introduction in pilot production, and implementation in high-volume manufacturing.

OBJECTIVES OF SEMICONDUCTOR EQUIPMENT ASSESSMENT

The main objective of semiconductor equipment assessment (SEA) is to validate emerging semiconductor manufacturing equipment for Key Enabling Technologies (KET) based on the SEA program’s proven principle (see fig. 4):

- Take novel, innovative and promising equipment after the R&D phase to integrate it into a joint assessment activity
- Collaboration of equipment supplier, end-user and research institute to perform assessment experiments for one specific equipment
- Bridge the well-known gap between the phase of having an engineered tool and finding the "first user" (see fig. 5).

The advantages that recent SEA projects provided to the industry are numerous. For starters, a valuable framework to enhance development and evaluation techniques and start early collaboration with the semiconductor manufacturers, their potential customers is provided. Furthermore, the programs provide equipment manufacturers with advanced research and facilities, whilst strengthening the European equipment industry by enabling early assessment of emerging tools.

In a wider perspective, the prospects for successful introduction of proven leading-edge European equipment to the global market place for the emerging technology nodes are being enhanced. The European equipment manufacturing industry in an ideal and sustainable way by combining advanced R&D topics with equipment sub-projects involving a wide community of equipment suppliers, users and research institutes. All this provides 'progress beyond the current state-of-the-art' and leads to cost effective equipment development.

THE SUB-PROJECTS

Hereafter the currently running European assessment project SEA4KET (Semiconductor Equipment Assessment for Key Enabling Technologies) will be described. SEA4KET is led by the Fraunhofer IISB (Institute of Integrated Circuits and Device Technology) which brings together the equipment suppliers, powerful research institutes and semiconductor manufacturers (end user).

SEA4KET contains 12 individual sub-projects (SP). The equipment companies involved include a high proportion of Small to Medium sized Enterprises (SMEs) that will benefit greatly from their involvement with such organizations, from the mutual benefit of cooperation, cross-fertilization and interaction. Also of great importance is the participation of leading IC manufacturers including Globalfoundries, Infineon, Intel and ST Microelectronics. Several key enabling technologies are being addressed; 450 mm process and metrology tools, handling, 3D integration and SiC processing (see fig. 6).

450 mm process equipment

- Single Wafer Critical Cleaning
  - Assess a single wafer cleaning pilot line system
  - In consultation between equipment supplier, pilot line operator and end user, this equipment assessment will focus on test cases related to front end of line wet cleaning and etching processes, relevant to 1x nm technology nodes
- Advanced Batch Processing
  - Assessment of a 450mm Batch Oxidation System for 14nm technology node and beyond
  - Prove general ability for future 450mm production requirements
  - Characterize and understand behaviour of 450mm wafers in thermal processing

Handling

- Critical Wafer Handling
  - Assessment of clean handling technologies for ultra thin 300 mm and 450 mm wafers
  - Evaluation of different end-effector handling concepts: Bernoulli, Ultrasound, Edge-grip and Backside grip.
- Vacuum transportation interface for 450mm architecture
  - Assessment of Vacuum transportation interface for 450mm architecture
  - Studies of this new Handling concept for advanced equipment/fab architecture

450 mm metrology equipment

- 450 mm defects metrology
  - The subproject aims to evaluate 450mm defects metrology for process and materials characterization and qualification
- Metrology Components
  - Set up of an open platform that serves as evaluation stand for different metrology components
  - Evaluation of novel metrology components

3D integration

- 3D Integrated Measurement System
  - Assessment of an Integrated Measurement System for testing 3D dies and die stacks for the engineering and volume-production market. Application-specific test solution, consisting of (1) fine-pitch, low-force probe cards, (2) advanced probe station, and (3) electrical test equipment.
- Direct Covalent Bonding at Room Temperature
  - Assessment of new manufacturing equipment allowing for room temperature covalent wafer bonding.
  - Evaluation of the new processes for applications in the area of engineered substrates, CMOS-MEMS and high vacuum MEMS.
- Inspection for 3D Integrated Photonics Circuits
  - The subproject aims to evaluate the possibility to adapt standard CMOS defectivity tool for KETs application: 3D Heterogeneous integration and Photonics.
- X-ray Metrology
  - Assessment of the latest generation X-ray metrology D8 FABLINE from Bruker AXS

- Assessment of high Brightness X-ray source for MicroHRXD

SiC Process Equipment

- Rapid Electrical Field Driven Processing of Gate Dielectrics on Silicon Carbide
  - Assessement of new equipment for efficient, rapid electrical field driven oxidation resp. nitridation for growing a gate dielectric on SiC at reduced temperatures (<1000°C) and time
  - Evaluation of oxides grown on blanket SiC wafers and SiC test devices for implementation in the production of SiC MOS capacitors and MOSFETs as key emerging devices.
- Thermal Laser Separation for Fast High Quality Silicon Carbide Dicing
  - Assessment of an innovative dicing technology able to fulfill the requirements of SiC volume production

Cross-cut R&D

The equipment sub-projects are supplemented by a cross-cutting sub-project that covers general and sustainable R&D activities:

- Infrastructure to exchange wafers between partners
  - Development of procedures and an infrastrucure to exchange wafers between project partners allowing multi-site processing or characterization

- Identify and solve common problems in respect of manufacturing science and equipment efficiency
  - Research on manufacturing science and equipment efficiency, including the development of APC, VM and PdM modules at equipment level, equipment design and equipment efficiency
  - Investigations to analyze and optimize the energy efficiency of process equipment, metrology tools and supporting systems

- Investigate and provide wafer resizing
  - Evaluation of resizing technologies especially for, but not limited to, 450 mm wafers in order to fit in subsequent process or metrology equipment

- Create and provide learning materials
  - Creation and provision of training material
  - Applica tion of “Best Practice” learning techniques, including the usage of APPS, eBooks and virtual Seminars
  - Set-up and execution of workshops, tutorials and events

GLOBAL COLLABORATION

The European assessment project SEA4KET considers also global collaboration; in particular the 450 mm equipment of one sub-project (Advanced Batch Processing) will be assessed at the facilities of G450C. An alignment of assessment specifications was performed and the applicability of G450C’s Demonstration Test method (DTM) was investigated. G450C utilizes also other equipment and metrology tools in order to complement the SEA4kET assessment activities.

Furthermore, general topics like 450 mm notch less wafers, 450 mm implementation time line, standards etc. were discussed between SEA4KET, G450C and the Israeli Metro 450 consortium.

SUMMARY

A detailed presentation of history, recent and current projects in the area of Semiconductor Equipment Assessment in Europe were presented. The topics and objectives of the ongoing equipment assessments within the SEA4KET framework were described. The importance on a horizontal and vertical collaboration in a global perspective was elaborated.

The work has been performed within the EU projects SEA-NET and SEAL and is currently being performed within SEA4KET.

REFERENCES

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Pictures:

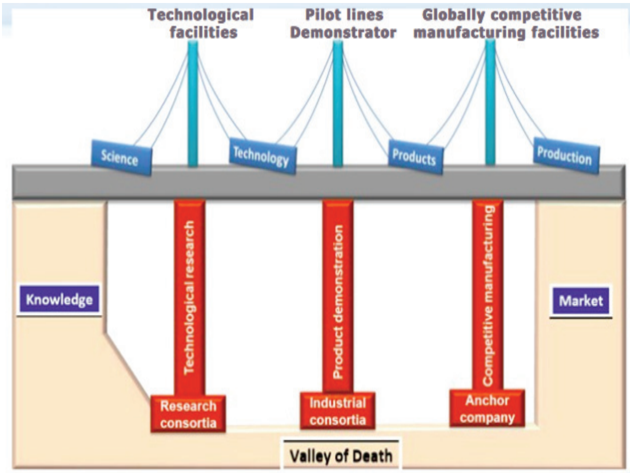

Fig. 1: Valley of death.

Fig. 4: Proven principle of Semiconductor Equipment Assessment (SEA)

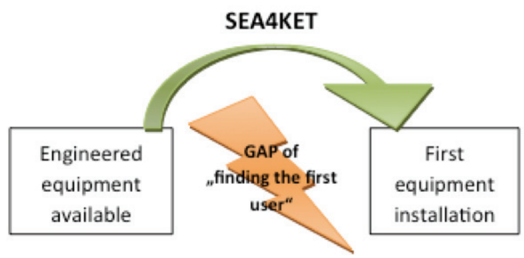

Fig. 5: Bridge the gap of finding first user

Fig. 2: History of SEA

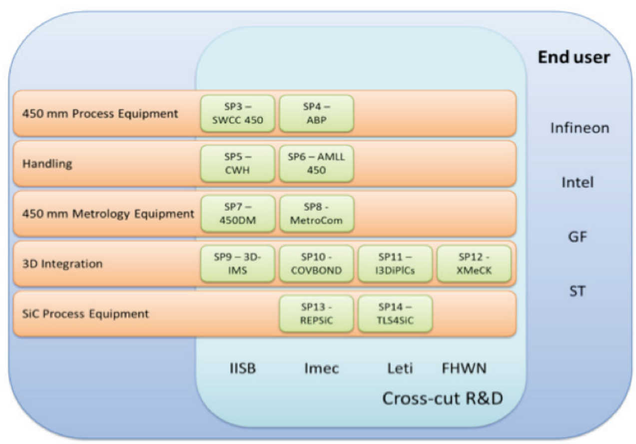

Fig. 6: Structure of the SEA4KET project

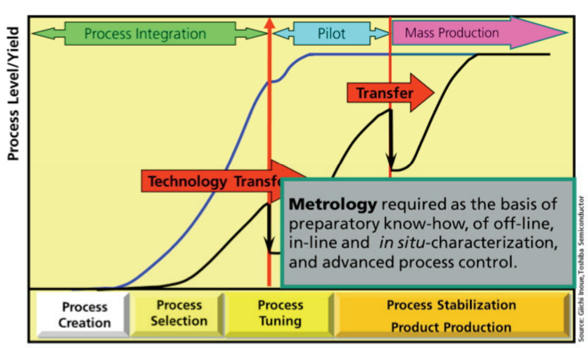

Fig. 3: Metrology in the production ramp curve