PROJECT RESULT

Process equipment

T304: Development initiative in advanced metrology and automation for new (IC) technologies (DIAMANT)

New metrology methods measure up to tomorrow's IC technology

The competitiveness of the integrated circuit industry depends on timely development of new technologies and efficient ramp-up to volume production. This in turn demands increasingly sensitive, rapid and automated measurement methods compatible with larger wafer sizes and smaller device feature dimensions. The MEDEA+ DIAMANT project brought together a large consortium of equipment manufacturers, end users and research partners to expand existing analytical techniques and explore new avenues of metrology relevant to the technology road map to keep Europe ahead in the global market place.

Chipmakers rely on in-line metrology on production wafers and off-line characterisation, conducted outside the production area on monitor wafers or test patterns, for technology developments and process control. In-line techniques are almost exclusively stand-alone and based on full-wafer measurement; off-line techniques, although often more powerful, tend to be time-consuming and destructive.

The rapidly evolving nature of the industry demands a constant review of measurement methods to keep pace with new-generation wafers and the constant shrinkage of dimensions. Some current techniques have room for improvement. And in other cases, where methods are reaching their physical limits, alternatives have to be developed.

Achieving competitive time to volume depends on in-line techniques that can measure film properties accurately, reproducibly and rapidly. Factors related to technology maturity and process marginalities need monitoring strategies that are statistically relevant and provide real processing information. Furthermore, when projecting new device technologies in the latest 300 mm wafer environments — where logistics and material flow are entirely automated — integrated metrology becomes critical for production efficiency.

Keeping ahead

The MEDEA+ T304 DIAMANT project set out to provide innovative European-sourced tools for the next two nodes on the International Technology Roadmap for Semiconductors (ITRS). As well as exploring novel metrology concepts, the consortium sought to integrate them at different levels — from stand-alone to fully in-situ for automatic process control. Special attention was paid to clean wafer handling and plant logistics. To realise the ambitious targets, a balanced partnership of European metrology and process equipment suppliers, advanced research institutes and chipmakers was assembled. Although most had co-operated in earlier initiatives, the support of MEDEA+ facilitated the entry of specialist SMEs. DIAMANT was divided into three work packages:

1. Development of techniques and equipment permitting quantitative physical and chemical analysis at chemical and spatial resolutions compatible with sub-100 nm device technologies,
2. Equipment and application developments for fast and accurate in-line metrology, oriented towards measurement on production wafers, and
3. Development of compact but powerful metrology blocks to be integrated in

individual processing tools, together with appropriate workflow and wafer-handling systems, plus data management and control structures for an integrated metrology architecture.

Mixed fortunes

Not all strands reached industrially applicable conclusions within the funded timeframe. Lessons learned about a range of techniques nevertheless provide valuable indications of profitable future directions.

Notable advances were made in transmission electron microscopy (TEM). Once exclusively a sophisticated laboratory technique, TEM has now been brought much closer to the fab environment.

Building on achievements in the MEDEA T618 project, progress has been made in the development of a dual-beam platform for sample transfers. In parallel, a system enabling fragments measuring just a few microns to be extracted from production wafers while leaving the remainder intact for further processing was automated for improved speed and reliability.

Sample removal is by a focused ion beam (FIB) process. A micro-manipulator loads the fragments into a holder, which can be removed from the evacuated sampling chamber and transferred for measurement in a nearby microscope. Such structural imaging could become a routine control operation.

In addition, improvements in scanning transmission electron microscopy and (parallel) electron energy loss spectroscopy (P)EELS make it possible to analyse particles and bonding states at interfaces with a resolution better than 1nm.

The electrolytic metal analysis tool measuring principle was extended to allow high resolution mapping of oxide parameters such as density of interface states, oxide charges and break-down voltage. The vapour phase decomposition technique (VPD) is well established for SiO_2, but there was growing demand for contamination analysis of other materials such as Si_3O_4 and bulk silicon. Hardware and chemistry was developed to extend VPD, and solutions found to measure metal contaminants in oxy-nitride layers.

For in-line metrology, DIAMANT developed a specific system combining IR and UV-visible spectroscopic ellipsometry so that epi-layers in the new SiGe structures can now be measured. And a development of infrared spectroscopic ellipsometry (IRSE) produced a ground-breaking instrument for 3D geometric measurement of devices such as deep trench capacitors.

The feasibility of 3D scatterometry — an optical non-destructive measuring technique — was demonstrated for CD metrology and first results achieved to measure line-width roughness on 50 nm lines.

Overall, tools produced within the project will enable European chipmakers to move quickly towards high yields in new semiconductor processes employing novel material combinations foreseen in the ITRS. Follow-up activities are already underway in the TEM and contamination control fields, as well as in integrated metrology and data management for advanced equipment and process control.

For the SMEs clustered around leading chipmakers, this project offered a unique chance for know-how acquisition and building-up business relations. Together with the strong participation of universities and institutes, there was important co-operation between all target groups within MEDEA+.

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