PROJECT RESULT

Lithography

2T302: Masks through users supply chain: leadership by excellence (MUSCLE)

Lithography mask supply chain improvements speed new product introductions

The MUSCLE project developed a sensible photo mask supply chain model linked to manufacturing execution software. This model enables direct calculation of cycle-time changes over the full mask supply chain resulting from incremental modifications. To improve cycle time and cost of quality, data and mask-material flows were scrutinised and standard methodologies for mask-defect management and characterisation developed. Impact on cycle time was continuously verified using the model. Resulting demonstrators of the project have been integrated in the real production environment of project partners.

Lithography is a critical process in semiconductor production. It determines minimum device feature size, strongly impacts die costs and is the basis for the emergence of new device generations. Lithography mask sets play an essential role in imaging performance and strongly contribute to costs, quality and yield of the process. Short cycle times through the mask supply chain are crucial for early product availability.

Average mask-set costs increased from € 160,000 for 120 nm technology to between € 1.2 and € 2.4 million for 45 nm technology with global mask sales of € 2.5 billion in 2006. Roughly 30% of costs can be attributed to logistics and related in-line management in a non-standardised mask supply chain, leaving substantial room for savings.

Complex network

Most of the many in-house mask shops, with short internal supply-and-order lines and direct control by their chipmaking owners, were spun off at the end of the 1990s. Only some large industry leaders can still afford their own mask shops and this for strategic reasons. Apart from protecting new competitive product designs, the complexity of dealing with an external multi-party supply chain, including exorbitant data flows and lack of direct control over quality and cycle time, is a major reason.

Critical performance indicators for a mask supply chain are quality, cycle time and costs. The MEDEA+ 2T302 MUSCLE project addressed output quality on several levels:

- Correlation between mask blank-making and mask-making processes;
- Mask defect characterisation and management;
- Mask defect printability and related data standardisation;
- Influences of manufacturing, environment and transport on reticle lifetime; and
- Methodologies to overcome/minimise defect sources.

A cycle time of up to 1000 hours is common for a critical mask, taking account of all the steps in the supply chain from mask design data preparation to use on the stepper in the wafer fab, and including the dynamic effects of rework and yield. Information- and material-flow automation with related standardisation were studied to cut this time. Mask costs are influenced by yield – quality of output – and cycle time; both were considered.

The final major issue was to verify the impact of proposed improvements on a real life process. A sensible supply chain model was developed, taking into account all incremental mask-manufacturing process steps and their quantitative relation to cycle time and costs.

Multitude of protocols

MUSCLE analysed the data flow throughout the mask supply chain, concluding that data sets for similar tasks between various parties were different. This results in a multitude of different communication protocols between suppliers and customers for identical orders.

Standardisation proposals were submitted to international associations. Demonstrators for all parts of the supply chain were developed, complying with the proposed standards and implemented on partners' production lines. A mask result demonstrator – as last in line – showed generation of a mask result file based on combined parameters from all previous demonstrators.

Mask-material flow including transport and mask carriers or pods was carefully analysed. Airborne molecular contamination (AMC) was found to impact reticle quality and lifetime. AMC levels of various pods from different suppliers were benchmarked using a specifically developed analytical tool with low detection limits for all AMC species. This tool has been successfully commercialised. Storage and transport recommendations were worked out on best pod materials and results shared with partners and pod suppliers.

An obvious remedy to contamination is cleaning. Processes to reduce the impact of the environment on sensitive masks were studied. Removal of surface cations and anions was found to be most effective in a multi-step ultra-cleaning process. In addition, a specific vacuum-decontamination process was developed to out-gas carrier material and reduce AMC levels. Finally the carrier-related work results were translated into international standards proposals aimed at reducing the number of carriers in use and potential mask damage by particles and molecular contamination.

A mask-tracking system was developed for mask control in the wafer fab. This gathers all photo-mask quality and metrology data, and makes it available at the required points in the fab. The programme could be successfully standardised.

Following a printability study with special test reticles and assessment of the results, a sophisticated standard methodology for classifying defect printability was advised, common metrology criteria agreed and a prototype built. Implementing the standards can lead to 20% reduction in engineering time, cutting overall mask cycle time.

The most synthesizing outcome was an operational photo-mask supply-chain model that allows calculation of the impact of all supply-chain changes on overall cycle time. It analyses six key process indicators in 53 steps. A cycle time reduction of around 10% was demonstrated at the end of the MEDEA+ project. Evenly applied to all masks consumed in the EU, this could save European chipmakers some € 50 million a year.

Concerted action essential

Optimising and standardising a complex supply chain needs concerted action by all participants. The strong MUSCLE consortium combined members from all European companies active in mask manufacture and use. The results of the work are already being implemented throughout the supply chain, enabling European chipmakers to reduce overall mask costs and shorten product time to market.

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ASML
Atmel
CEA-LETI
De Clercq Engineering
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KEY PROJECT DATES:

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