Fraunhofer IISB

FRAUNHOFER INSTITUTE FOR INTEGRATED SYSTEMS AND DEVICE TECHNOLOGY IISB

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 318458.

European Project SUPERTHEME

PROCESS VARIATIONS

- Equipment-induced inhomogeneities of process results – e.g. layer thickness across wafer
- Uncertainties / drifts of equipment settings – e.g. distance between last lens and illuminated area in lithography
- Stochastic variations of process results due to granularity of matter – e.g. random dopant fluctuations (RDF)

IMPACT OF PROCESS VARIATIONS

- Process variations are propagated through the fabrication process

⇨ Variations of device (e.g. threshold voltage) and circuit properties (e.g. static noise margin) – reducing yield

STATUS IN SIMULATION BEFORE SUPERTHEME

- Device simulation based on simple assumptions for only some process variations – esp. RDF
- Most process variations (e.g. variations of gate length and width) not considered

SUPERTHEME PROJECT

- Close critical gaps: Simulate variations from their source (largely at equipment level) up to device and circuit level
- Include electro-thermal-mechanical effects
- Complement commercial software with tools from consortium
- Funded by European Union within FP7 from Oct. 2012 to Dec. 2015, grant agreement no. 318458

CONSORTIUM

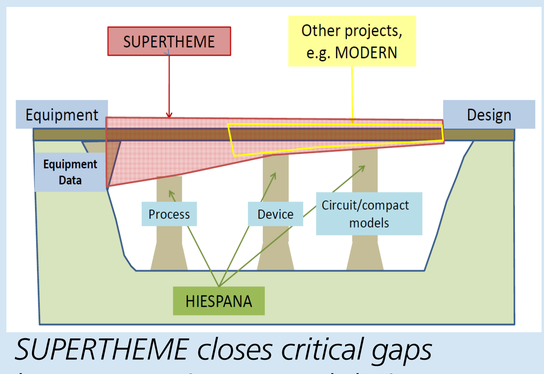
- Semiconductor company: ams
- Equipment companies: ASML, HQD, LASSE (Excico), IBS
- Software house: GSS
- Research institutes: Fraunhofer IISB (coord.) and IIS/EAS
- Universities: Univ. Glasgow, TU Wien

MAIN RESULTS

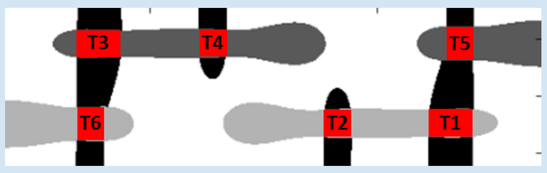
- Simulation system for impact of process variations
- Process aware compact models
- Appplication to several MM and MtM benchmarks
- Commercialization via SUPERTHEME partner GSS

SUPERTHEME

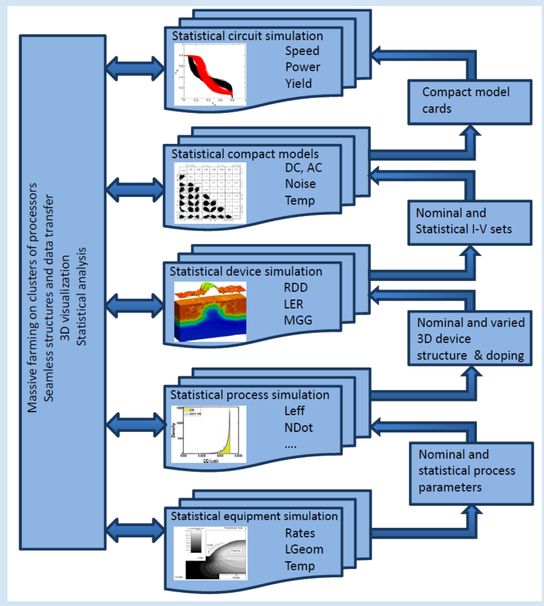
www.supertheme.eu



SUPERTHEME closes critical gaps between equipment and design
(© Fraunhofer IISB)



Layout of the SRAM cell studied
(© Fraunhofer IISB)



Levels of simulation being addressed by SUPERTHEME
(© GU / Fraunhofer IISB)

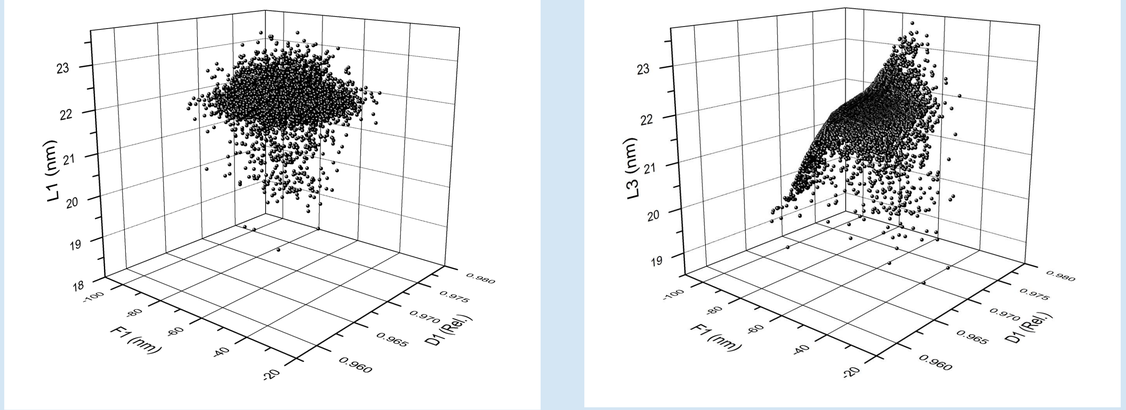
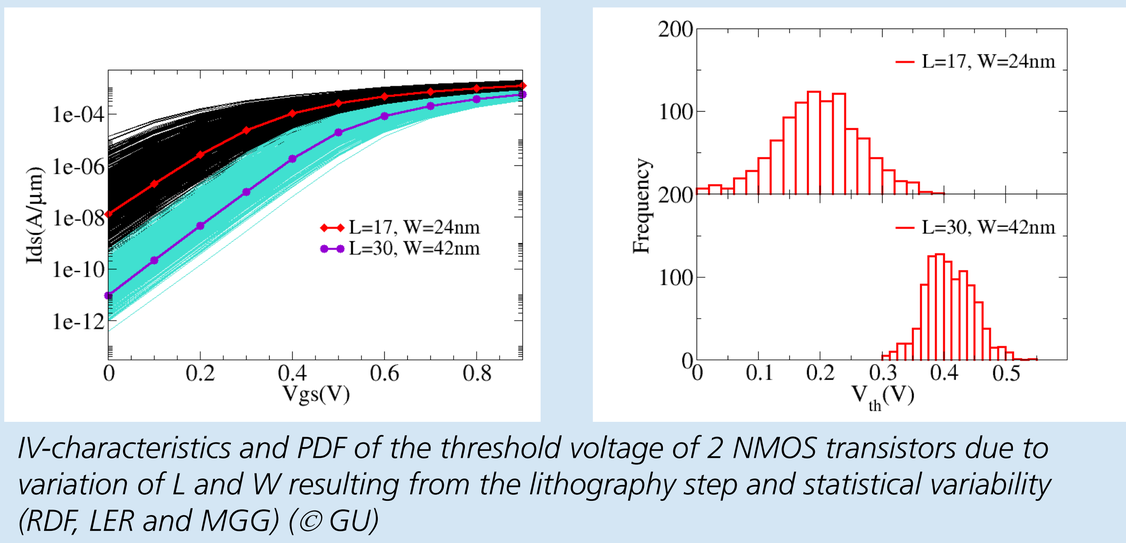
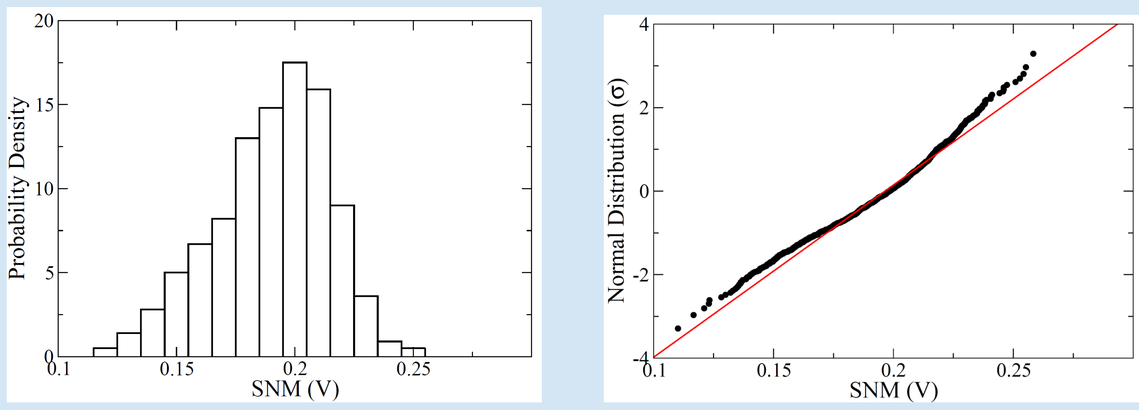


Illustration of randomly selected variations of focus (here F1) and dose (here D1) in the three lithography steps: Length L1 of transistor T1 does not correlate with F1 and D1 (T1 not patterned with the first lithography step – variations in steps 2 and 3 lead to spread); right: Length L3 of transistor T3 correlates strongly with F1 and D1 because T3 patterned with the first lithography step.



IV-characteristics and PDF of the threshold voltage of 2 NMOS transistors due to variation of L and W resulting from the lithography step and statistical variability (RDF, LER and MGG) (© GU)



Histogram and QQ plot for Static Noise Margin of SRAM Cell subject to focus and dose variations in the three incremental lithography steps, together with RDD, LER and MGG. Correlations resulting from some transistors being patterned with the same lithography step are included.(© GSS)

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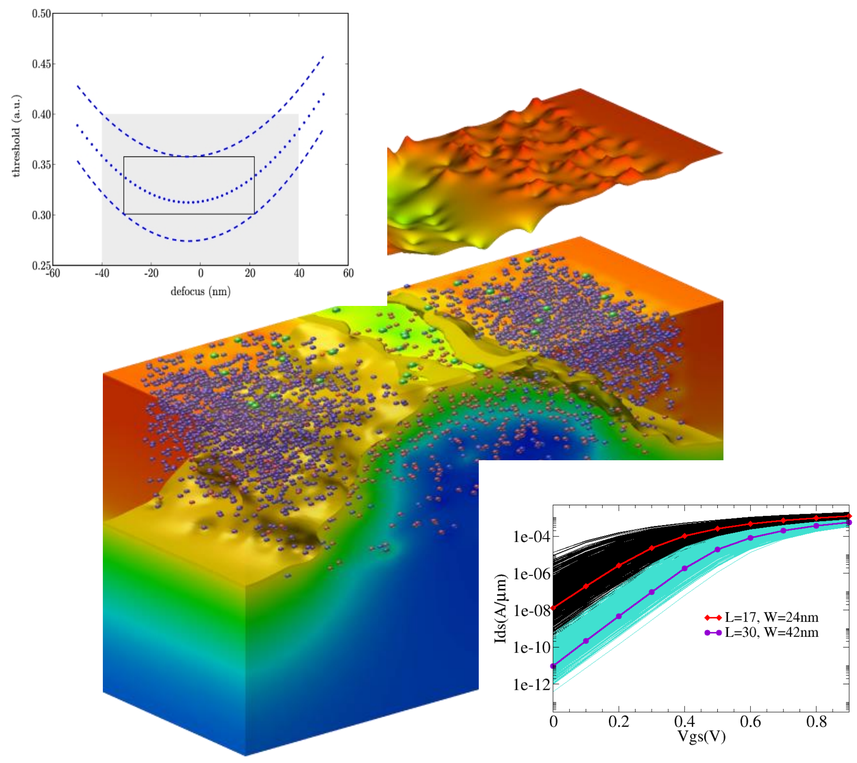
SUPERTHEME

Circuit Stability under Process Variability and Electro-Thermal Mechanical Coupling

General description

Process variations and their interactions with electrical, thermal and mechanical effects are getting more and more critical both for advanced *Moore Moore* and *More than Moore* devices and circuits. Effects from various sources of process variations, both systematic and stochastic, influence each other. Correlations are of key importance because they drastically affect the percentage of products which meet the specifications. Modelling and simulation (TCAD) offer the unique possibility to predefine process variations and trace their effects on subsequent process steps and on devices and circuits fabricated. Within SUPERTHEME, the most important weaknesses which limit the use of current TCAD software to study the influence of both systematic and stochastic process variability and its interaction with electro-thermal-mechanical effects will be removed, and the study of correlations will be enabled.



Left to right: feature size variations due to focus/dose variations in optical lithography; random dopant variations in 45 nm transistor; drive current variations due to some statistical process variations for two different transistor sizes

Goals / Objectives

- Development and demonstration of a full chain of software tools for the simulation of the impact of systematic and statistical process variations
- Development and enhancement of simulation modules as needed
- Quantification of process variations at their source
- Demonstration of the software system via *Moore than Moore* and *More Moore* benchmarks
- Transfer of results to exploitation via software house partner Gold Standard Simulations and at other industrial partners

Societal impact / Results

The software suite developed in SUPERTHEME enables the assessment and minimization of the impact of process variations on advanced *Moore than Moore* and *More Moore* devices and circuits. This helps to optimize fabrication processes, device and circuit properties, and finally yield in semiconductor fabrication, and contributes to enabling further applications of micro and nanoelectronics.

- Integrated variability simulation from equipment through process and device up to circuit level has been enabled and demonstrated
- Methodology and tools for the extraction of process variation aware compact models have been developed and demonstrated
- The tools have been applied to equipment and device optimization
- Commercialization of results has been successfully started

Looking ahead

Future developments are planned in three main directions:

- Internal use of SUPERTHEME software at partners' sites for the development and optimization of equipment, processes, devices and circuits
- Exploitation of the software developed via commercial offer of the SUPERTHEME partner Gold Standard Simulations
- Further extension of the SUPERTHEME software to sub-10 nm devices within a follow-up project

Partners

- Fraunhofer IISB, Erlangen, and IIS/EAS, Dresden
- ams AG, Graz
- Gold Standard Simulations ltd, Glasgow
- University of Glasgow
- Technische Universität Wien
- ASML Netherlands B.V., Veldhoven
- HQ-Dielectrics GmbH, Dornstadt
- IBS ion beam services, Rousset
- Laser Systems & Solutions of Europe, Genneviliers

Countries involved

- Germany
- Austria
- France
- Netherlands
- United Kingdom

Additional information

More information is given at www.supertheme.eu .

This includes among others

- three highlight presentations
- public deliverables; posters, list of software tools
- currently 24 publications on SUPERTHEME results

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