IntelliSuite

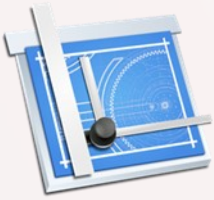
Industry-leading MEMS Software

Intellisense

IntelliSuite

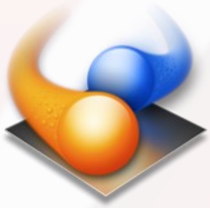
The shortest distance between your MEMS concept & product

IntelliSuite is an end-to-end environment which enables users to seamlessly go from schematic capture and optimization to design verification and tape out. A flexible design flow allows you to start your design at either the schematic, layout or 3D level.



Blueprint
MEMS Design Editor

Clean Room
Your Virtual Fab Process Flow

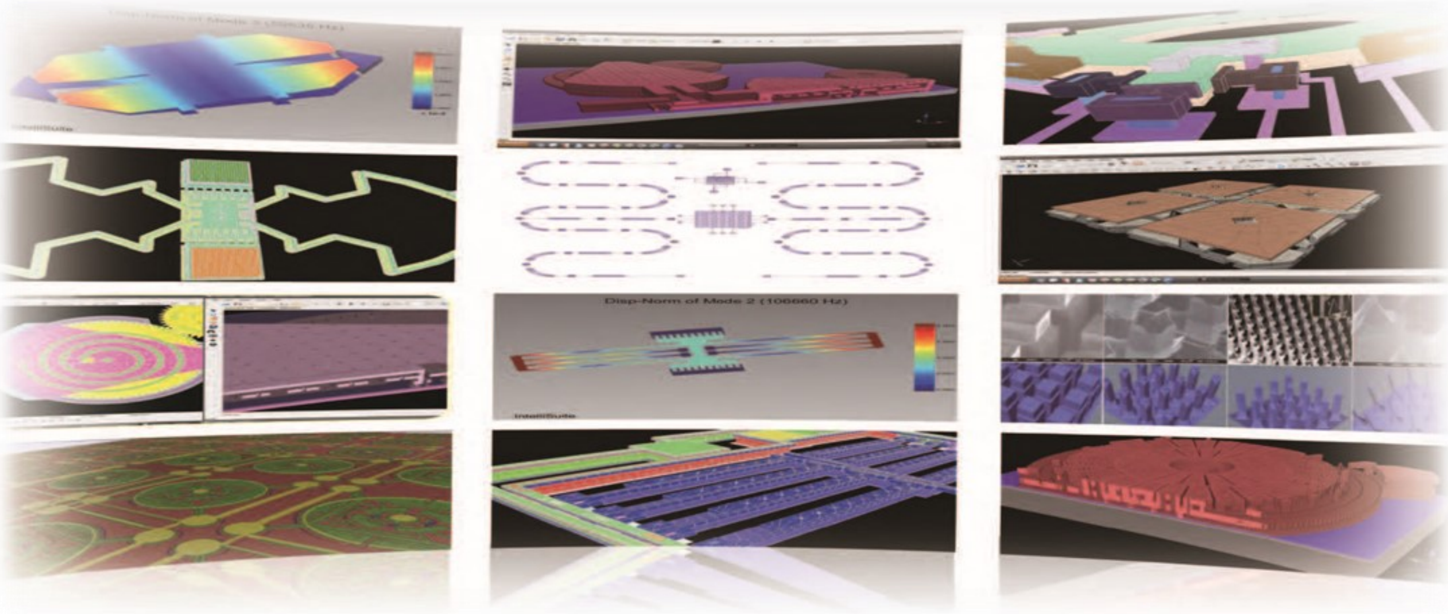


Fast field
Incredibly fast Multiphysics

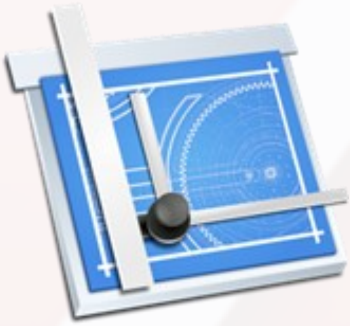
SYNPLE
System Synthesis & Simulation

EDA Linker
Link to your EDA tools

The IntelliSuite software architecture is based upon a unique combination of bottom-up process-driven design and top-down synthesis. Top-down methodology allows you to quickly explore a wide range of design options, while bottom-up design provides the accuracy to produce first-time right silicon. These methods are combined to get you to your designs faster and with fewer process iterations.



IntelliSuite

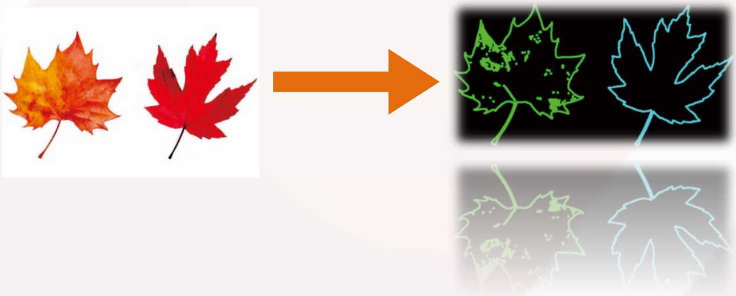


Layout and 3D Structure Meshing Tools

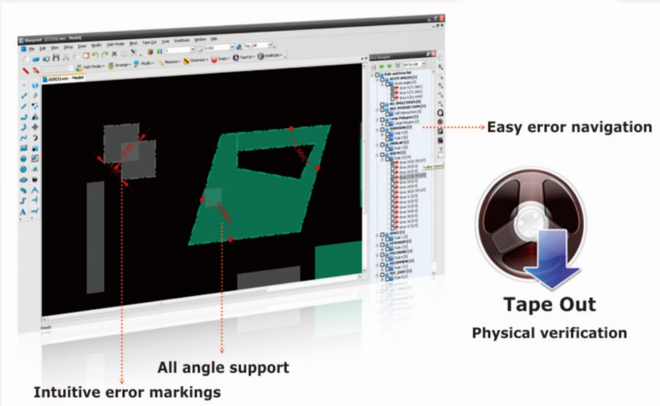
A layout tool specifically designed for the MEMS community.

Blueprint – MEMS Design Editor

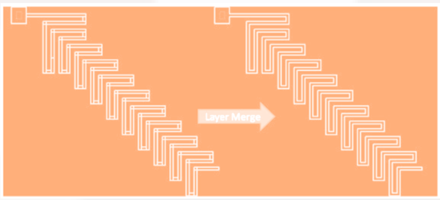
It includes Tape Out, an all-angle Physical Verification (DRC) tool, and a language-independent scripting tool, enabling you to create complex designs through scripting. The built-in Cross-Section Viewer allows you to view mask cross-sections and export them to Power Point. Automated hexahedral meshing techniques can be used to construct robust meshes for analysis.



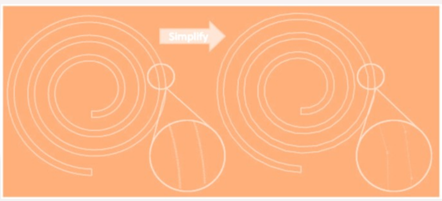
Blueprint supports input/output of several standard mask formats like GDSII, DXF and CIF along with several image formats, including BMP,PNG and JPG.



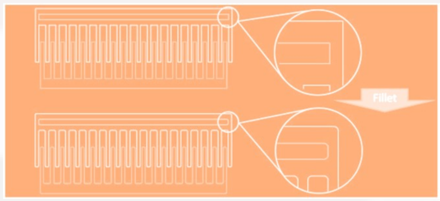
Design rule check



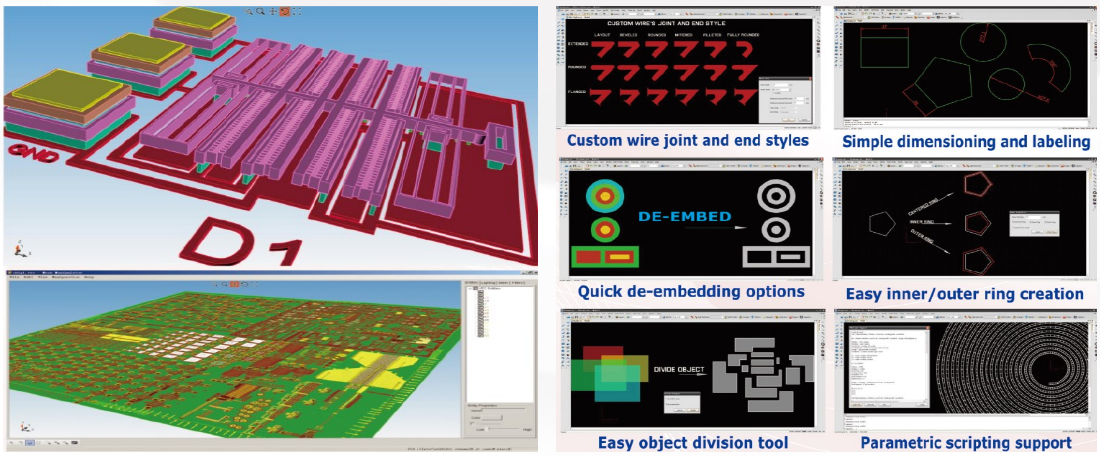
Layer Merge



Simplify



Fillet

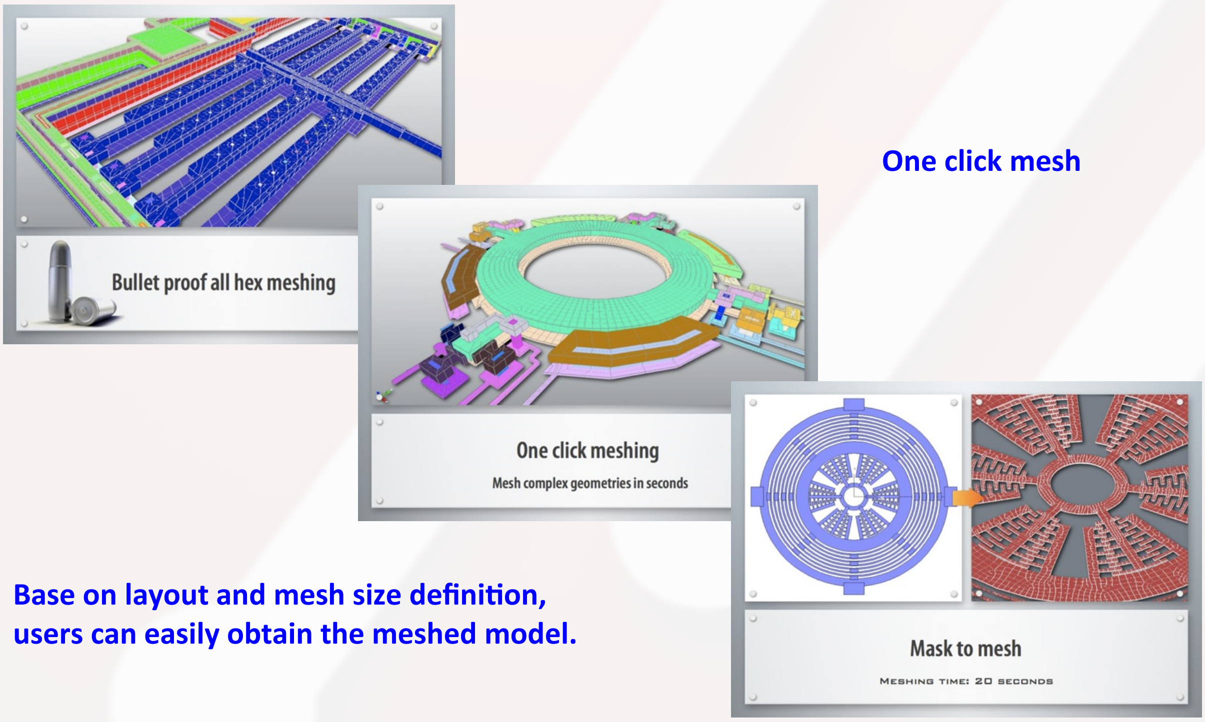


Quick 3D View

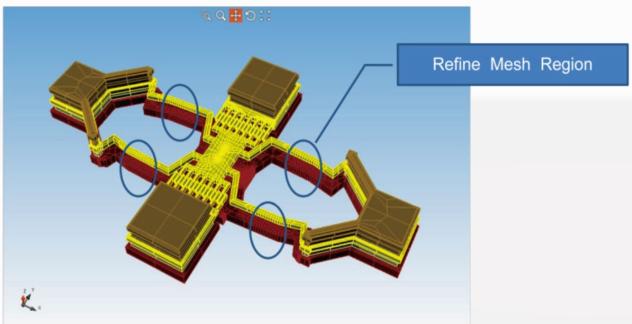
3D Builder™ / Hexpresso™

IntelliSuite's state-of-the-art automeshing tools are again updated with cutting edge advancements. Material properties can be automatically applied when a 3D meshed model is generated. New adaptive meshing and mesh refinement settings allow users to have full control over the automated meshing process. Meshing is now faster and more robust than ever before.

One click mesh

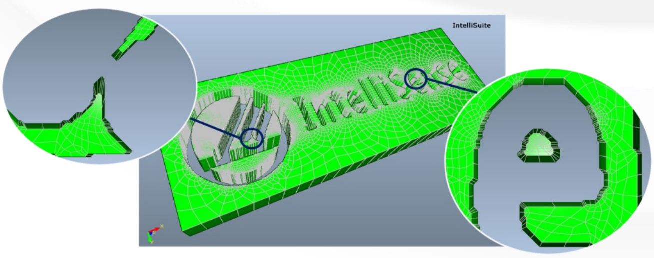


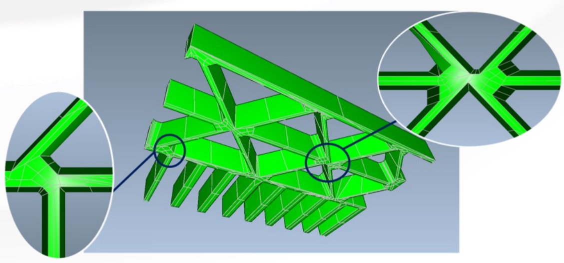
Base on layout and mesh size definition, users can easily obtain the meshed model.



Refine mesh

The features allow users to easily define an adaptive mesh region. With a desired mesh size (smaller than global mesh size), the chosen region will have a refined mesh.

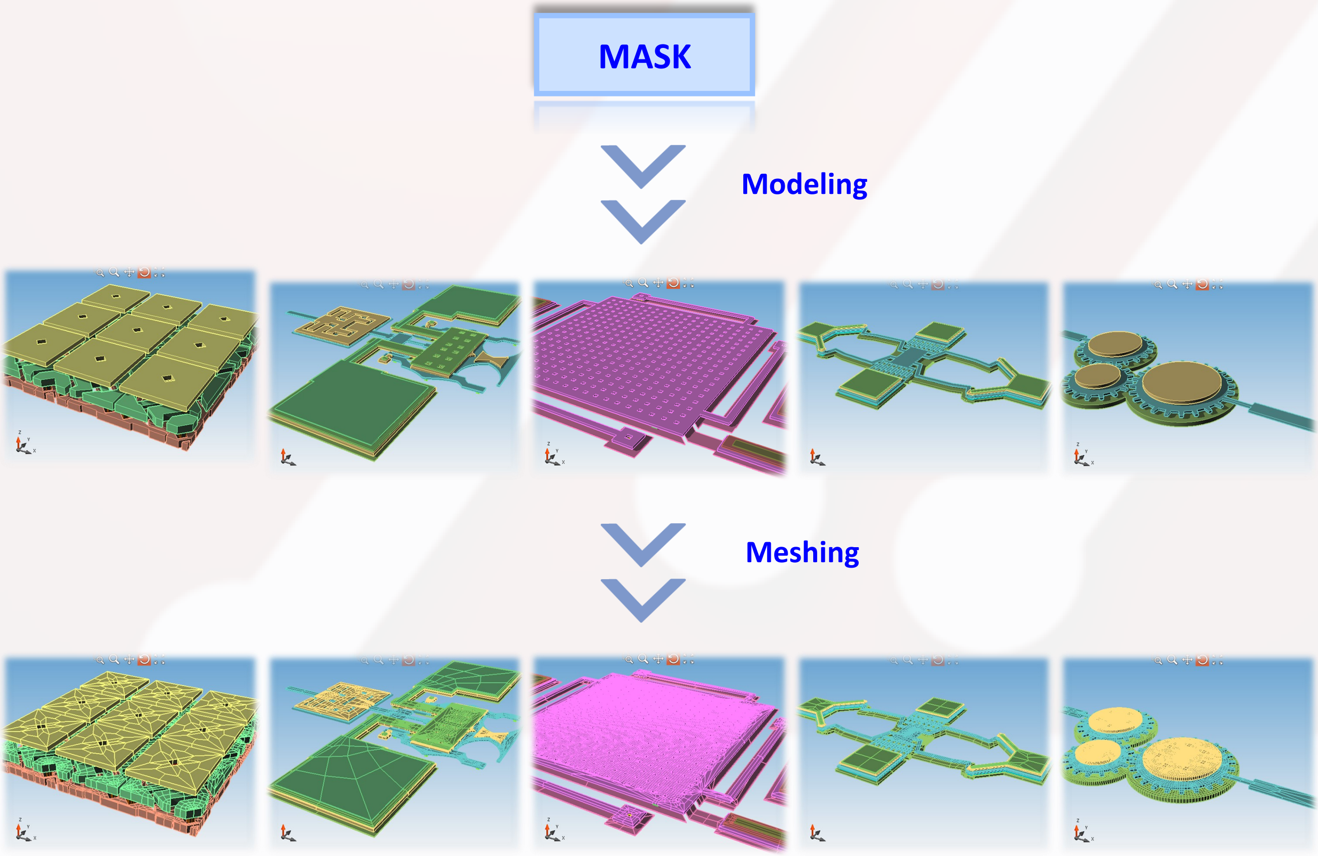




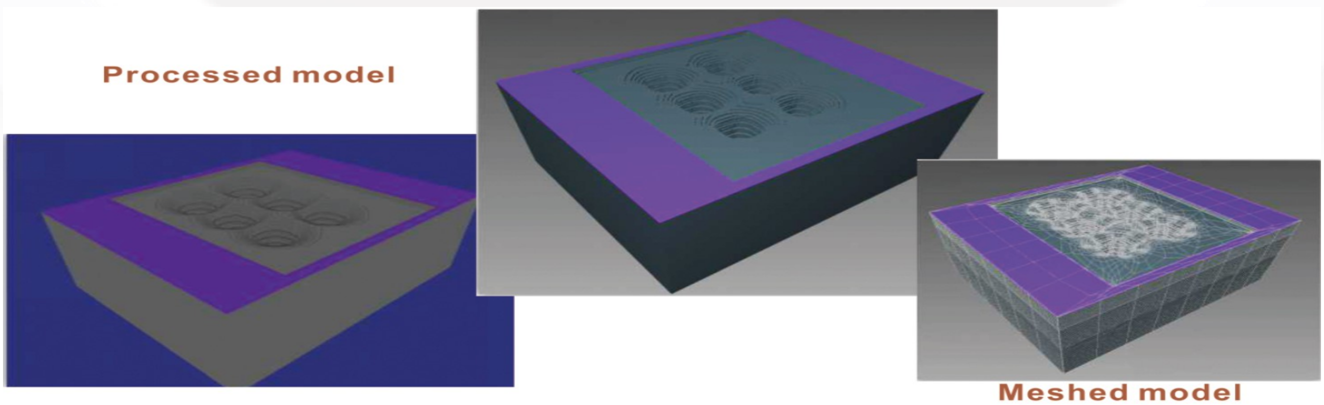
MeshManip

MeshManip is a mesh operation tool with which the user can view, rotate, translate, zoom, scale or hide some parts of the meshed model in the 3D viewer. Furthermore, the user can perform element/entity edits in MeshManip.

MeshManip supports import/export of such standard format files as parasolid, ANSYS cdb, OBJ, IGES, STL, STEP, Patran Neutral, etc. And it fully supports IntelliSuite .save, .solid and .vec file formats. In particular it can import a vec file as a solid model and apply meshing on it by invoking Hexpresso.



directly meshing a process model



IntelliSuite

CleanRoom Process Suite

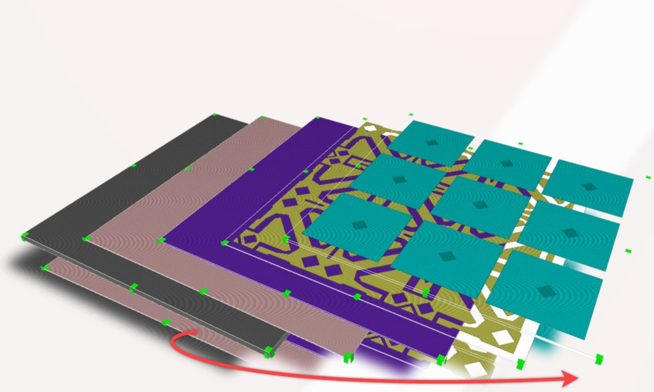
IntelliSuite CleanRoom is the industry-standard for process simulation. With IntelliFab and FabSim, quickly simulate and visualize complex, custom process flows or select one of our many commercial process design kit (PDK) templates. With IntelliEtch, rapidly simulate anisotropic etching of silicon or quartz using the power of your PC's GPU.

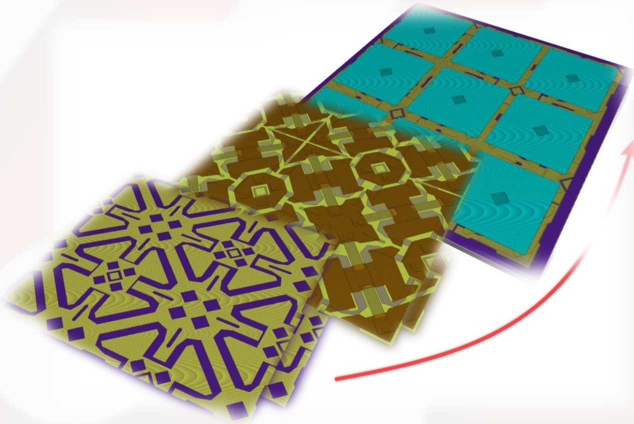
IntelliSuite CleanRoom features a comprehensive material database which allows you to understand material properties like conductivity, film stresses and mechanical strength as a function of processing parameters. Subsequently, this enables you to produce much more realistic models.

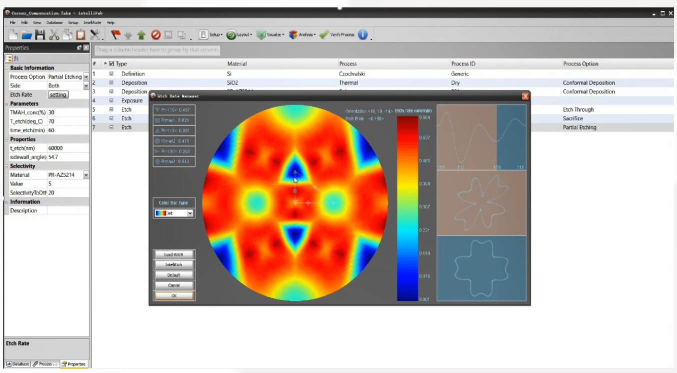
IntelliFAB™ - Process Parameter Calibration

IntelliSuite's bottom-up architecture is based upon process elements. Familiar process steps such as photolithography, thin film deposition and selective etching form the basis for understanding the final device geometries.

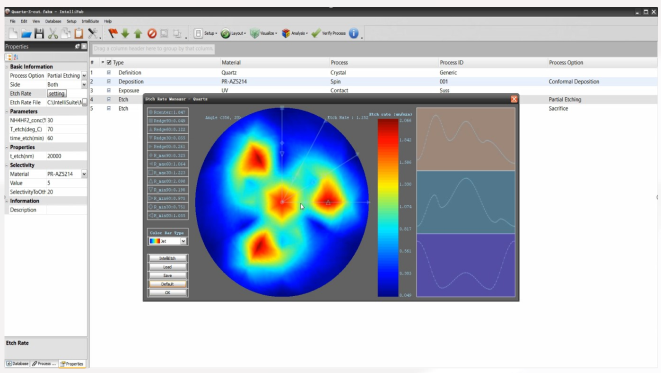
IntelliFAB™ allows you to debug your process flow and your mask set before you even enter the clean room. It enables you to create realistic virtual prototypes, which can prevent costly fabrication mistakes.







Silicon



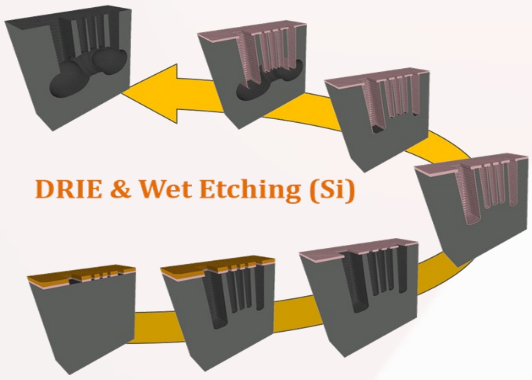
Quartz

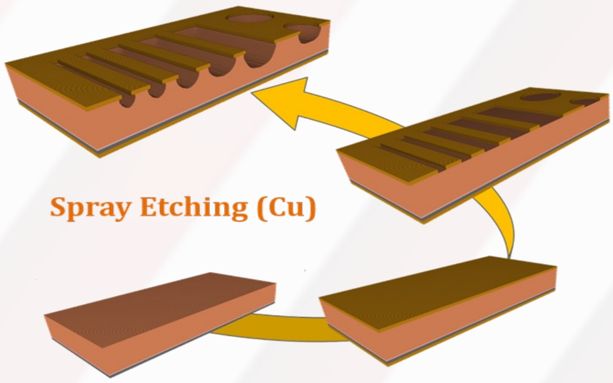
Process flow result renderings can be exported to a variety of formats, including a Microsoft PowerPoint with a slide for each process step (either full 3D view or any desired cross-section).

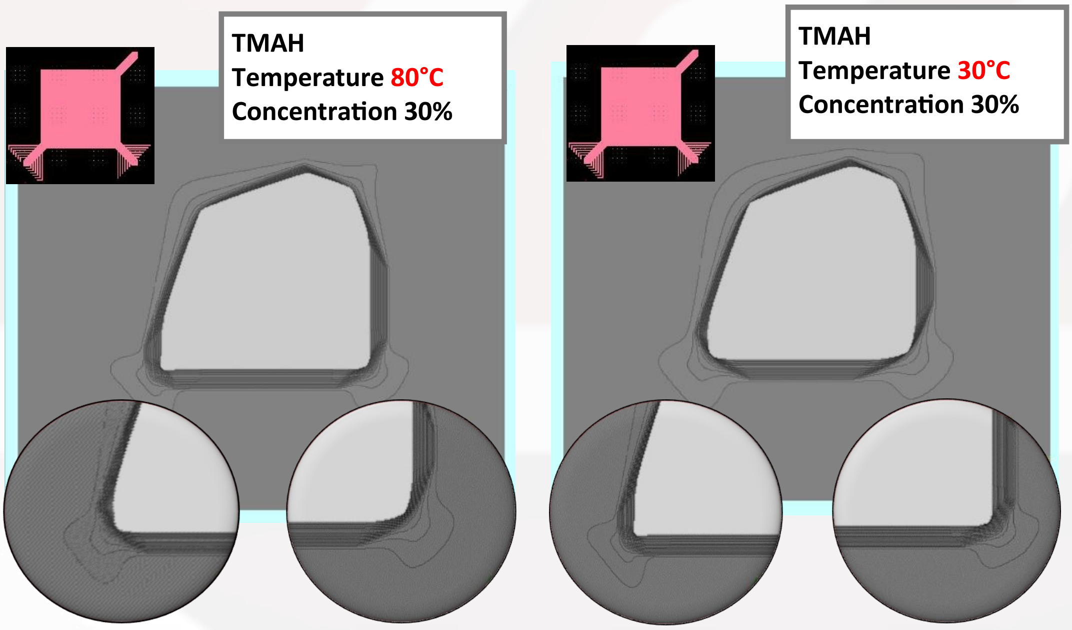
FabSim™ - Quick process simulation

FabSim™ enables users to quickly create realistic process models and cross-sections using full physical simulation, rather than traditional geometrical methods.

By systematically building the prototype in IntelliSuite, you can quickly identify costly process bugs before even entering the fab, which ultimately saves time and money. The process steps, combined with the mask geometries, can be used to build the final virtual device.

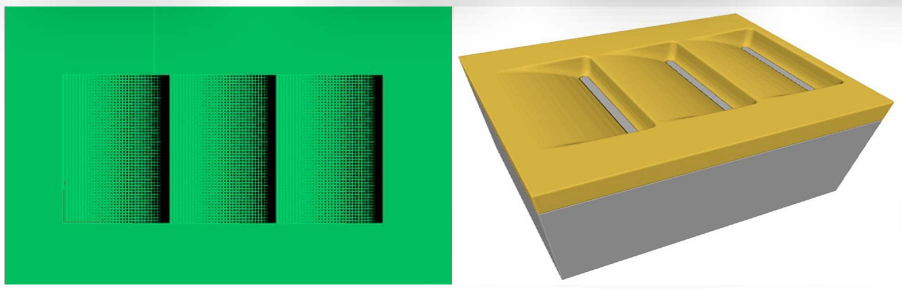






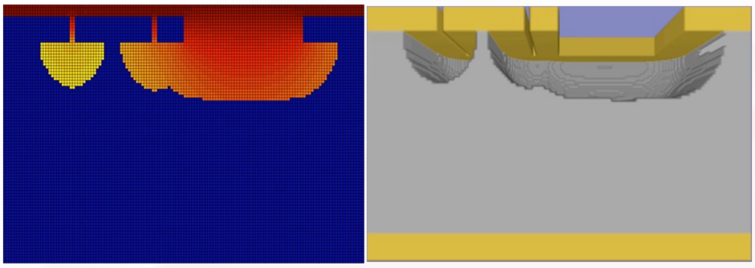
Wet etching is affected by temperature, etchant concentration and other parameters.

Users can specify these parameters right in IntelliFab before running the simulation.

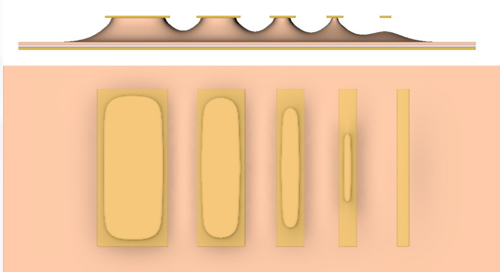


3D lithography physical simulation

Physical simulation of wet etching and DRIE



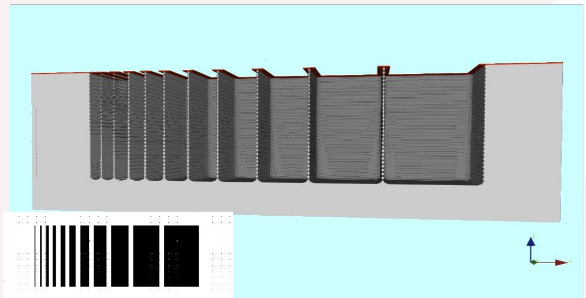
A **silicon isotropic dry etching** simulation based on 3D diffusion theory



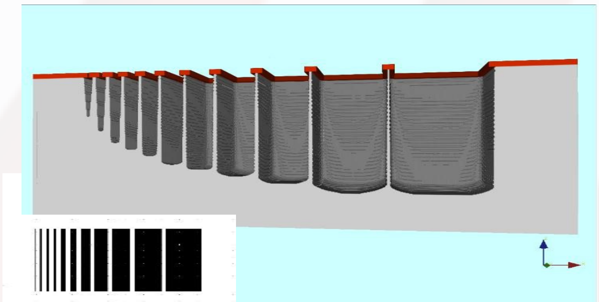
A **metal spray etching** simulation based on 3D diffusion theory

The dry etching engine in FabSim™ has the capability of simulating the lag effect and micro-loading effect for small-sized openings.
The user can set the DRIE parameters directly in IntelliFab or perform their own calibrations using the built in FabSim calibration tool.

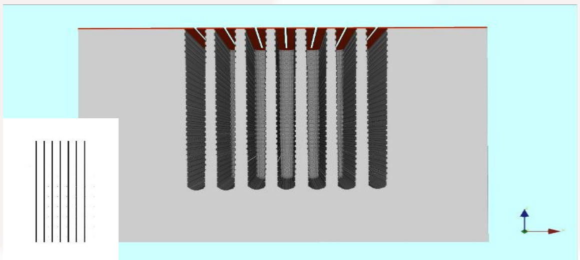
3D Physical Simulation with Calibration



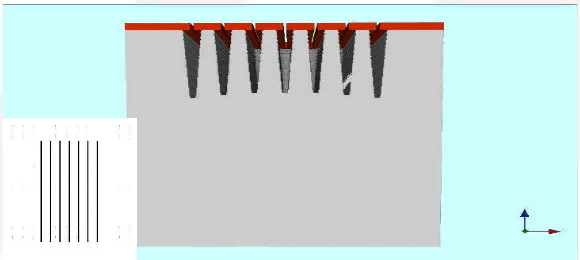
Lag effect ignored



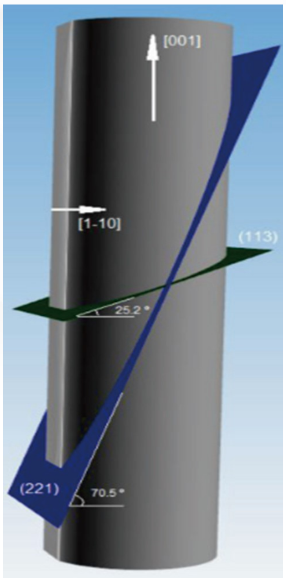
Lag effect considered

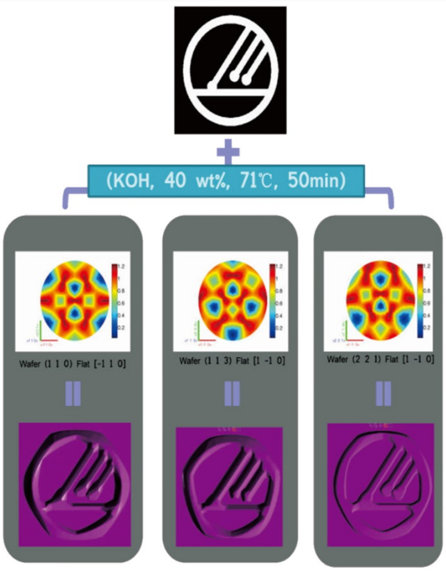


Micro-loading effect ignored



Micro-loading effect considered

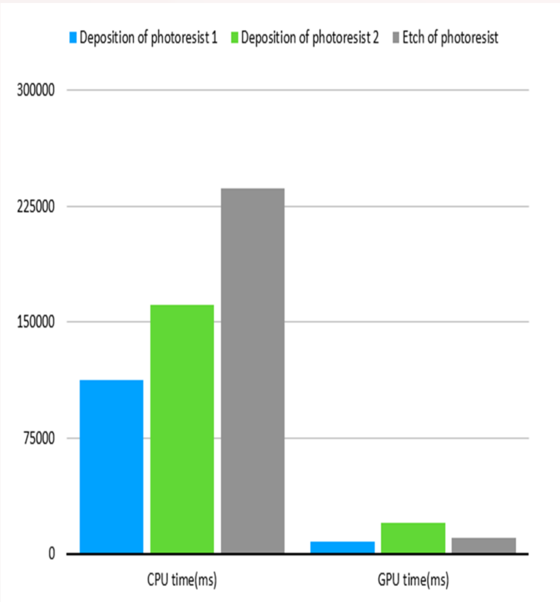


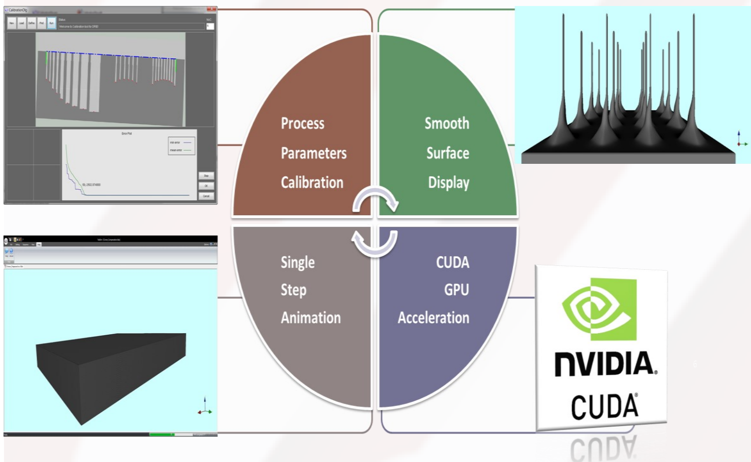


High-index surface etching for crystalline materials is a key feature in FabSim. For materials with orientation-dependent etch rates, FabSim can calculate the etch progress from any high-index surface, giving etch results which are more accurate than ever before. It is expandable, not only for silicon but also for other crystalline materials, such as quartz, and so on.

All processes support GPU acceleration now in FabSim, significantly improving simulation speed especially at high resolution.

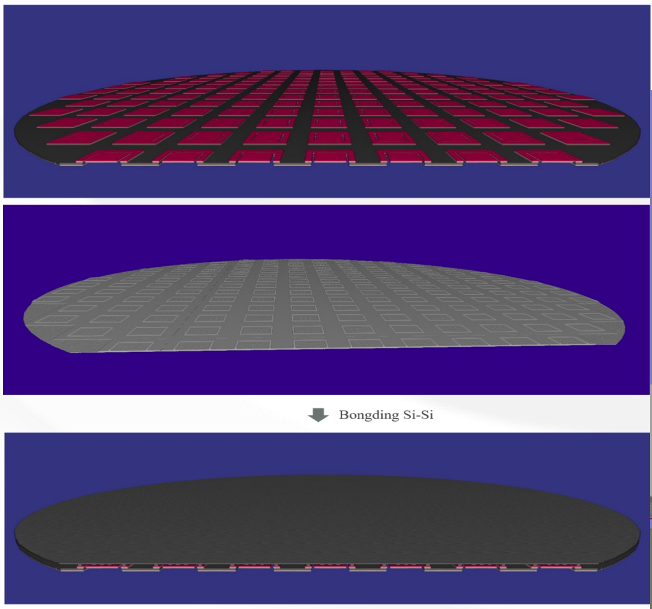
process in high resolution	CPU time (ms)	GPU time (ms)
Deposition of photoresist 1	112606	8183
Deposition of photoresist 2	161544	20138
Etch of photoresist	237099	10497





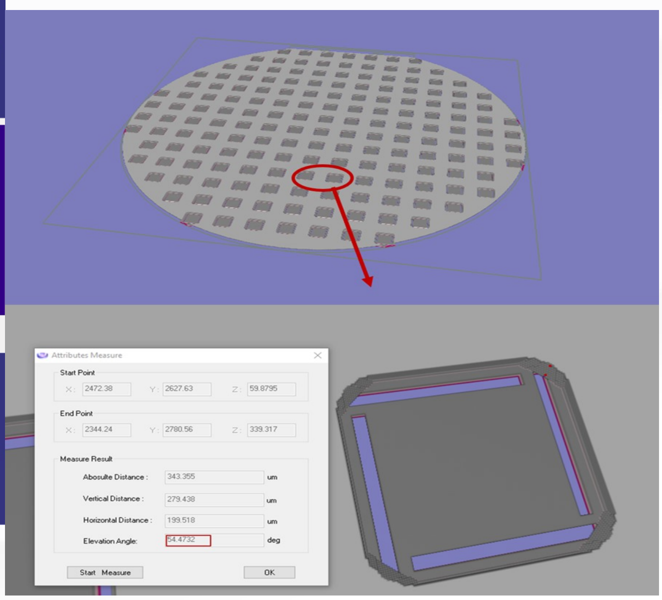
GPU acceleration level set advance algorithm

Process simulation at wafer level

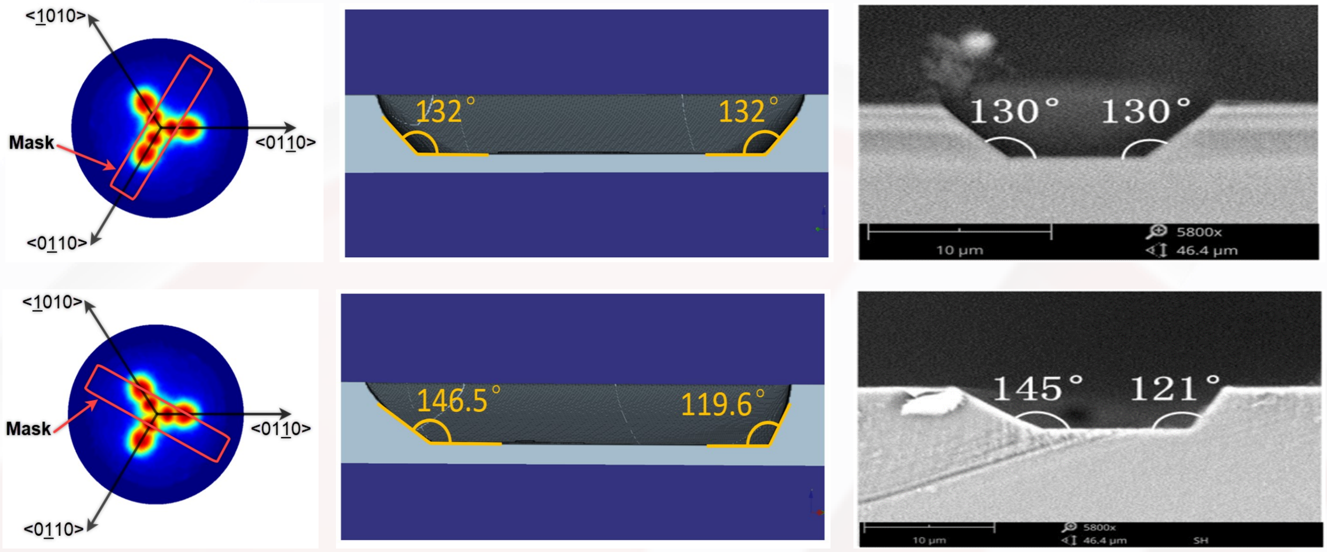


wafer bonding

predict etching profiles (depth, side wall angle) at wafer level

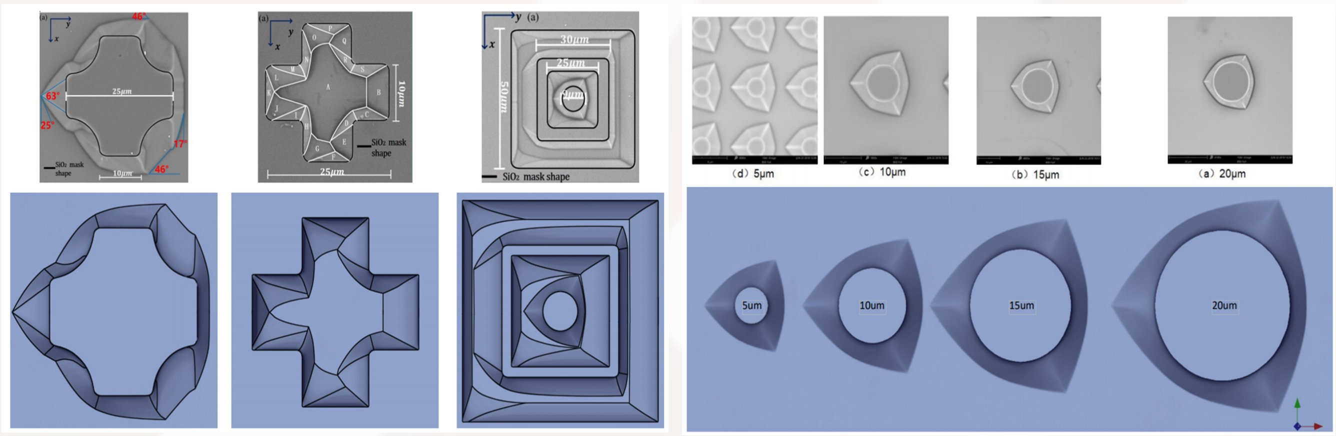


Simulation and experimental results of sapphire (Al_2O_3)

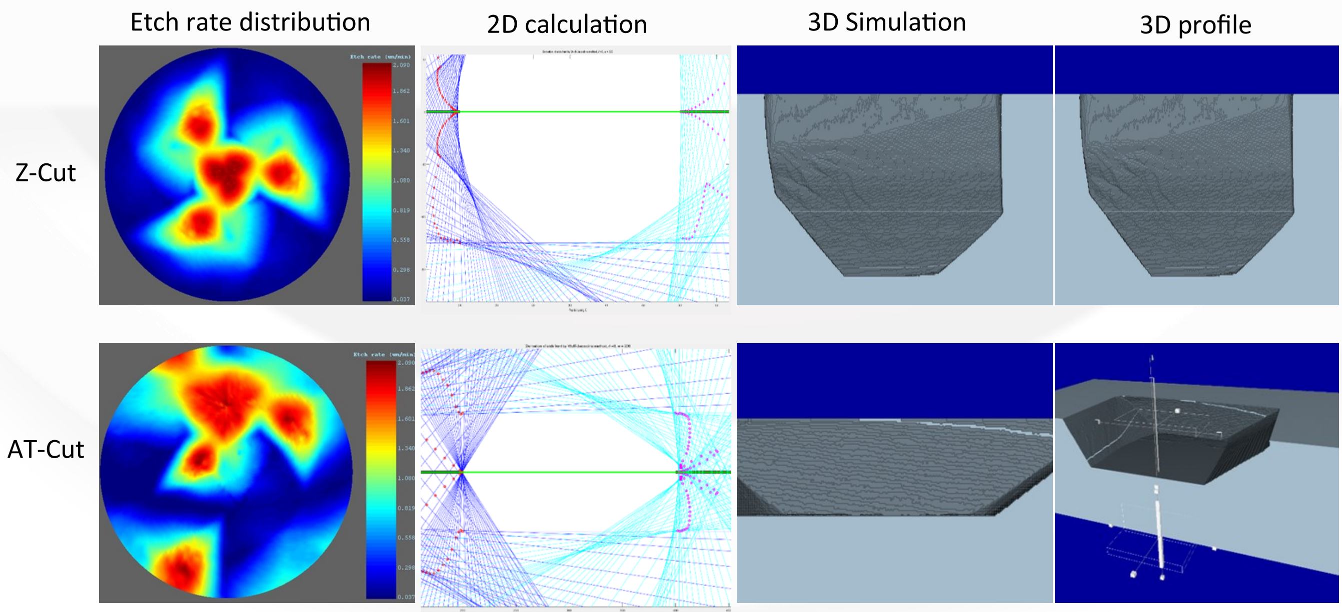


concentrated sulfuric acid98% & Concentrated phosphoric acid 86%(volume proportion 3:1)

orientation<0001>, temperature: 236 C° , time: 180 minutes



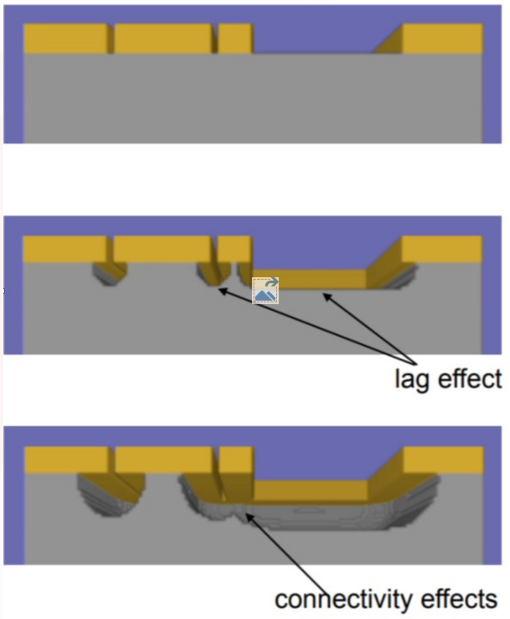
More and complicated material wet etching (eg. quartz)



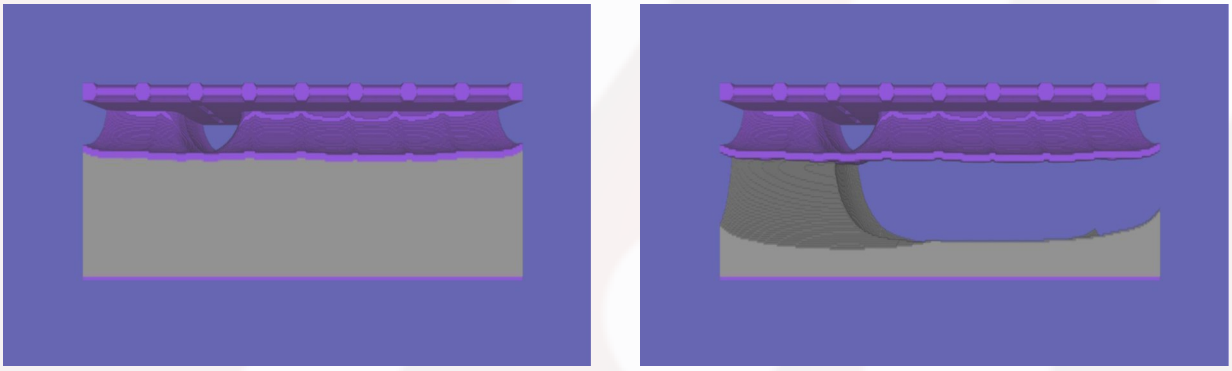
Added various etch rate database for Quartz

Isotropic etching

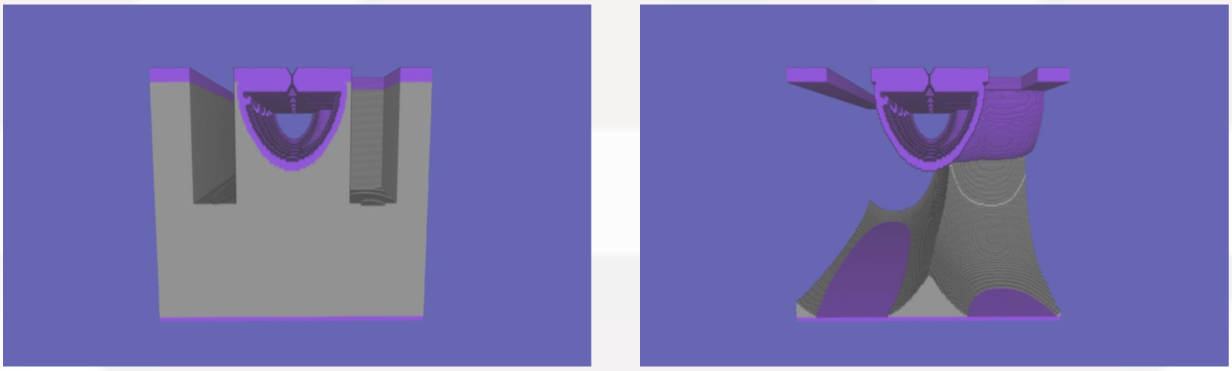
The etched shape varies with the opening size.
Quickly simulate the etched shape for any arbitrarily-shaped mask pattern.



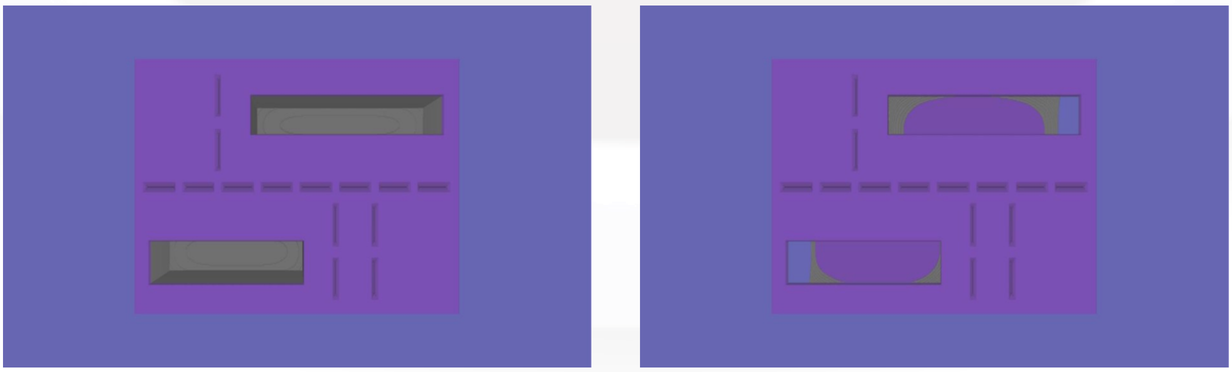
Process simulation of microchannels



Front cut view of the microchannels



Left cut view of the microchannels



Top cut view of the microchannels

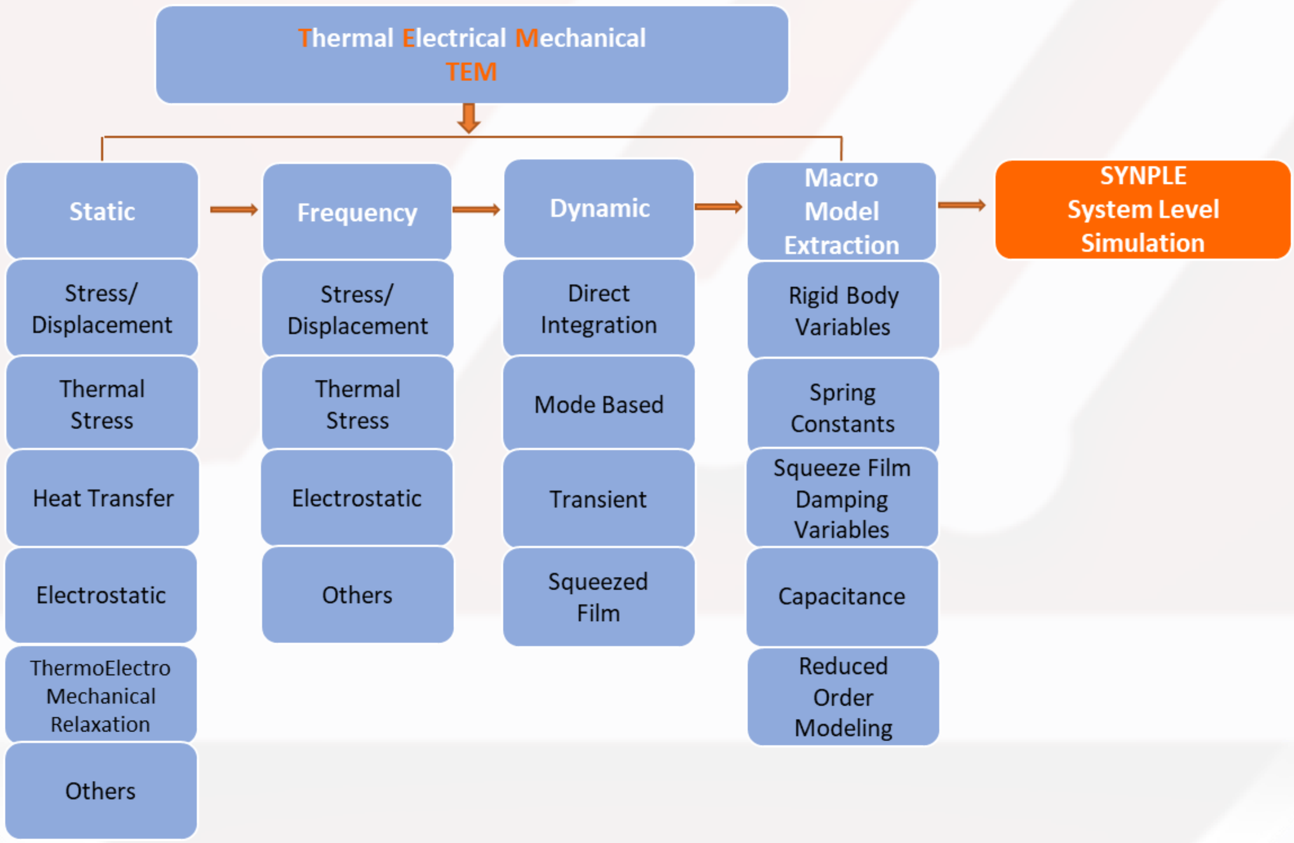
IntelliSuite

Fast field

ThermoElectroMechanical (TEM) is a fully coupled Multiphysics tool for electrostatic, mechanical and thermal analysis. It is now also capable of simulating magnetostrictive materials. Additional modules are available for electromagnetic and microfluidic simulation.

Fast field™ - Incredibly fast Multiphysics

In 1995, we released the first fully coupled thermal, electrostatic and mechanical (TEM) analysis tool for MEMS. Since then, our multiphysics capabilities have grown by leaps and bounds, encompassing all domains of physical phenomena including fludics, magnetostatics,and high frequency electromagnetics. At the same time, we've added support for orthotropic, anisotropic, piezoresistive, piezoelectric and anisoelastic materials. While the breadth of analyses have grown to include, linear and non-linear, static, steady state, transient, frequency domain and harmonic simulations. A plethora of enhancements allow you to perform parametric loading, take into account processing conditions, or greatly reduce problem size by sub-modeling. You can also use the tool to create macromodels for integration with system modeling tools.



ThermoElectroMechanical Analysis Module™

Users can perform a wide range of coupled simulations ranging from:

Electrothermal\ Electromechanical\ Thermomechanical \ Magnetomechanical

Thermal-Electrostatic-Mechanical \ Electro-Magneto-Mechanical

Thermal-Electrostatic-Mechanical with contact physics

Thermo-Electrostatic-Mechanical with Rayleigh damping

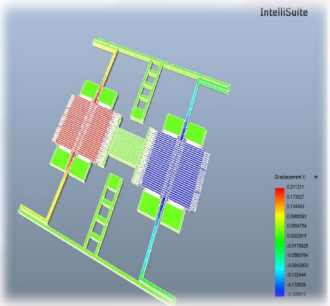
Thermo-Electro-Mechanical with full Fluid-structure Interaction (Navier-Stokes)

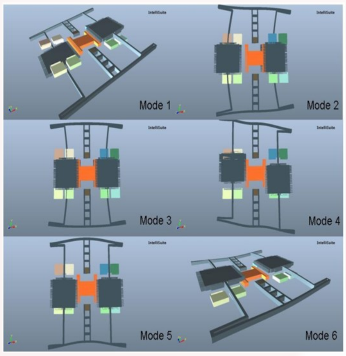
Piezoacoustic\ Piezoresistive-Mechanical\ Piezoresistive-Electrothermal

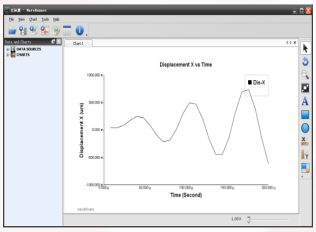
… and much, much more

Inertial MEMS

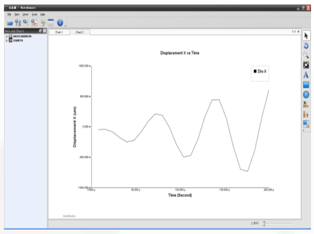
Gyroscopes



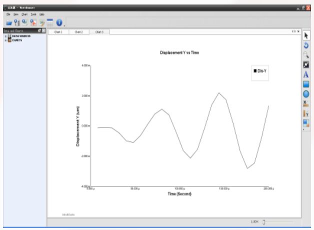




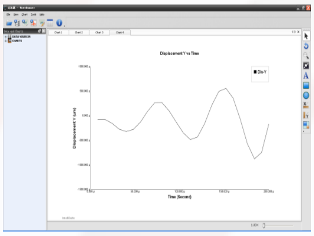
X-Displacement on Mass 1



X-Displacement on Mass 2

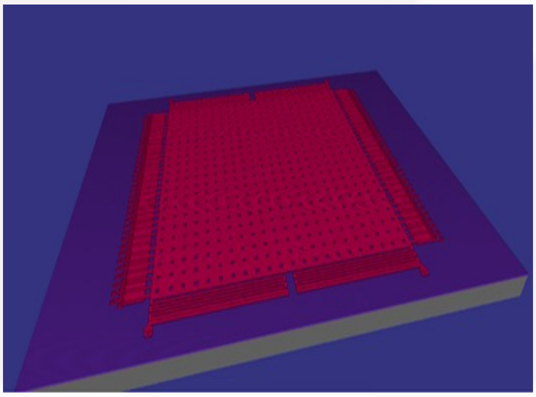


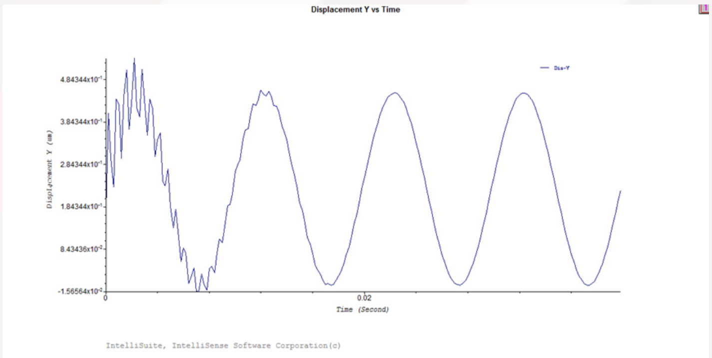
Y-Displacement on Mass 1



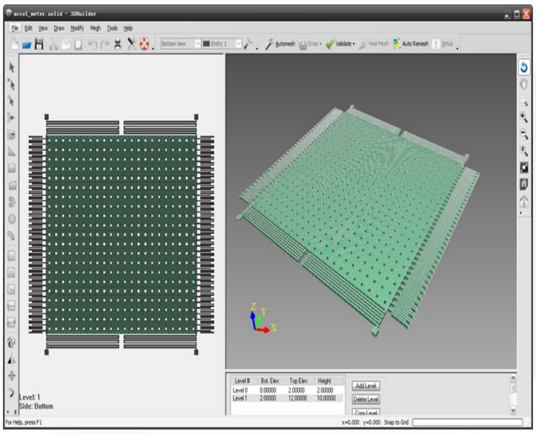
Y-Displacement on Mass 2

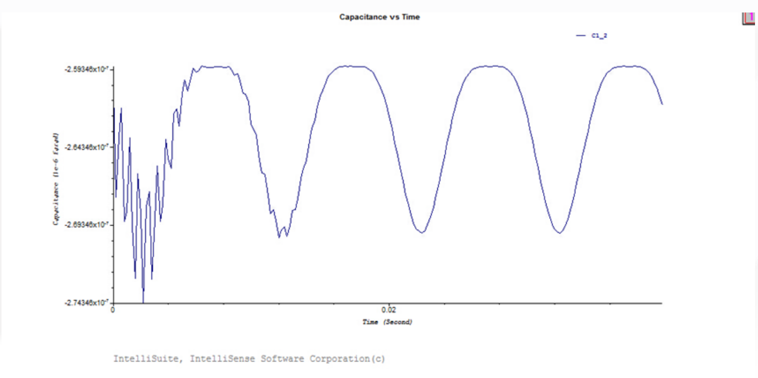
Accelerometers





Y-Displacement Results



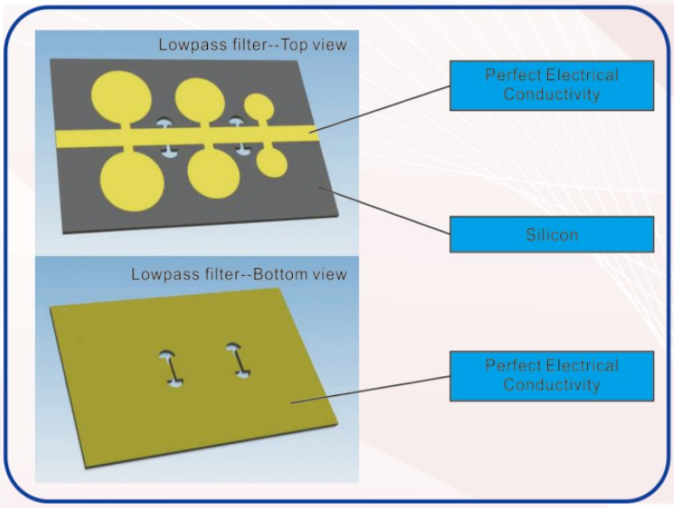


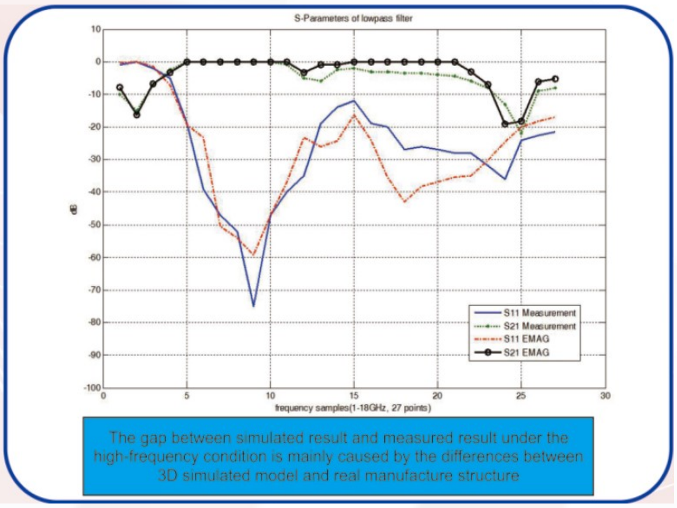
Meshed structure

Capacitance vs. Time Curve

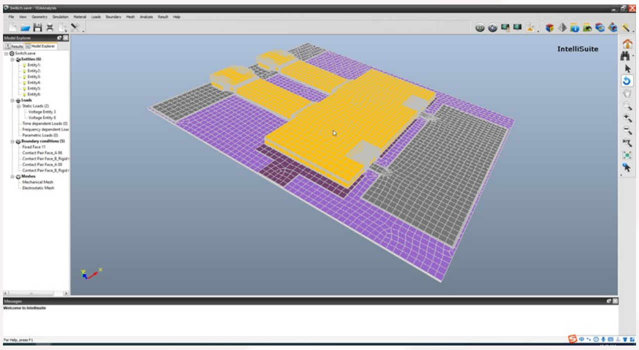
RF MEMS

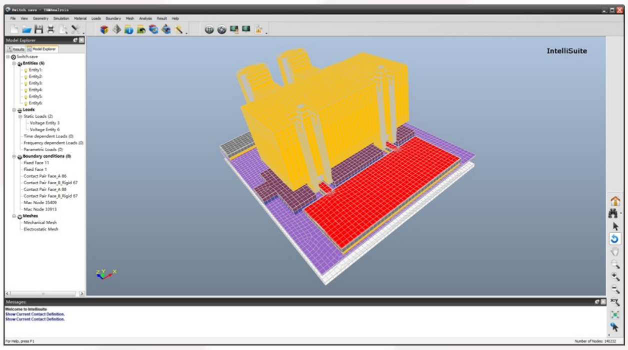
Lowpass filter



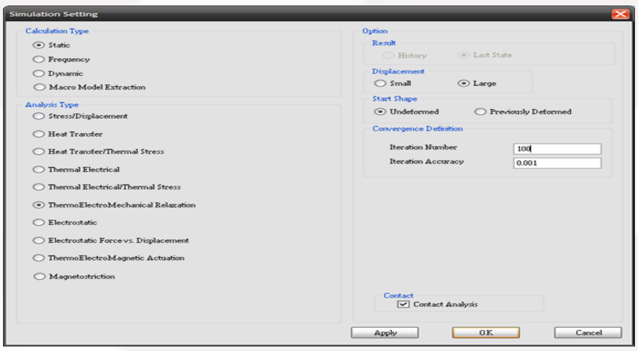


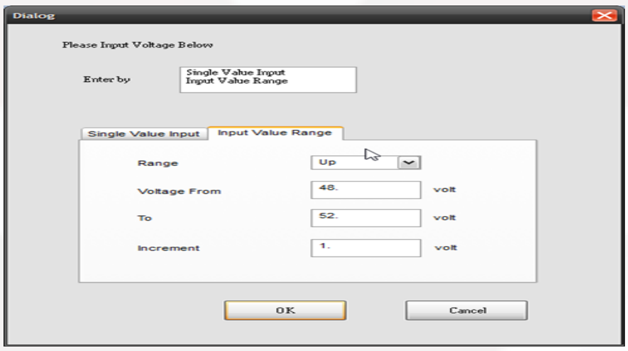
Simulation in TEM module



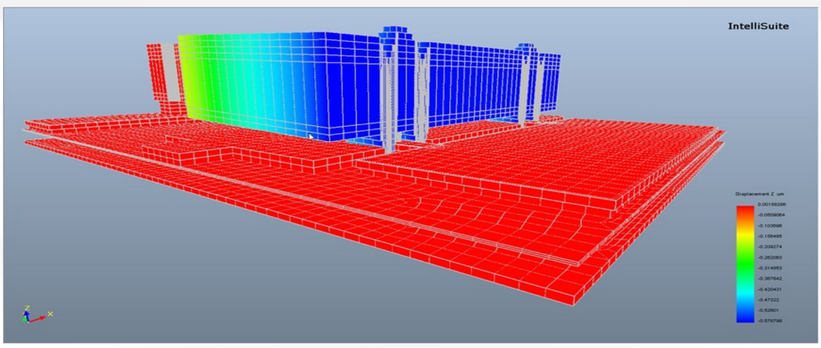


Model in TEM





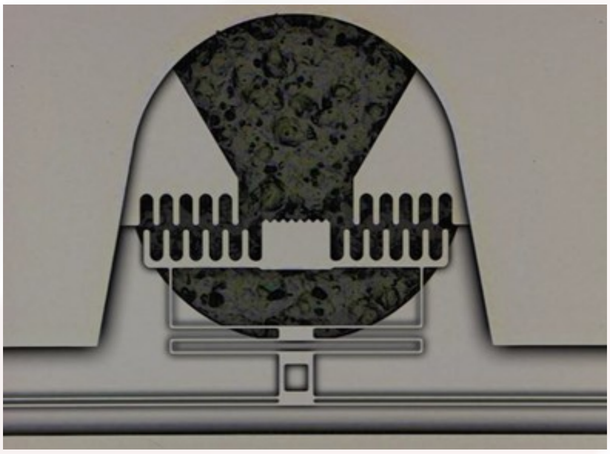
Set the pressure parameters and run the simulation

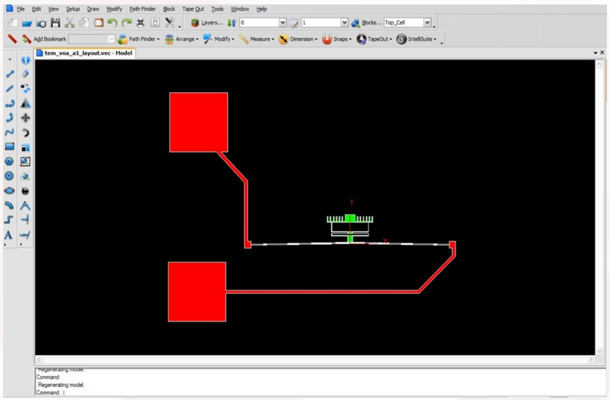


Deformed simulation result

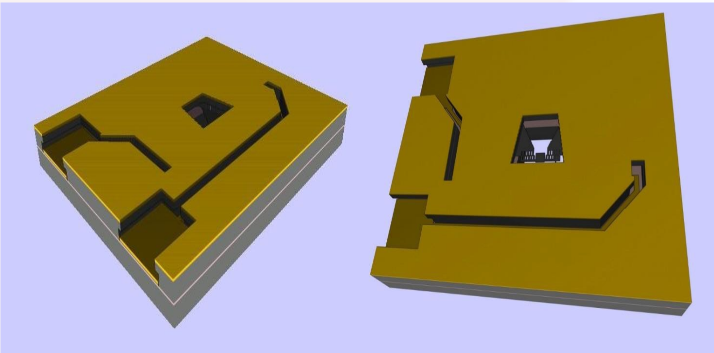
Sensors & Actuators

Variable optical attenuator (VOA)

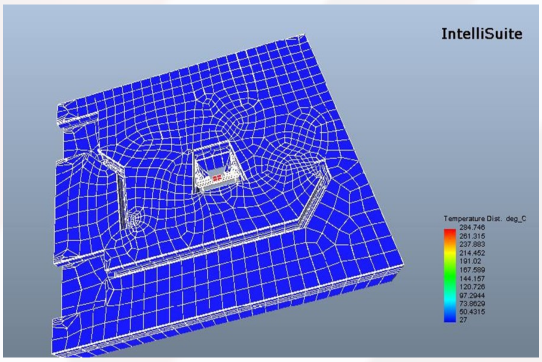




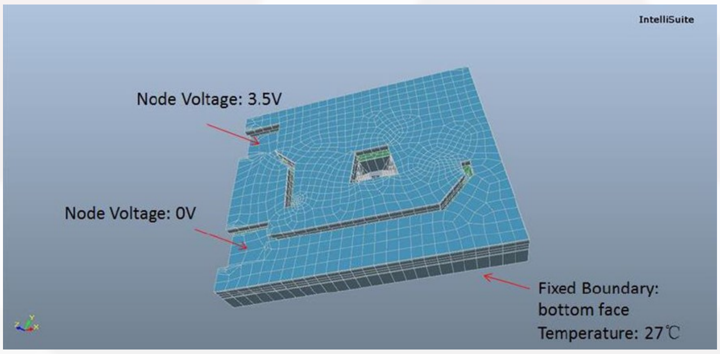
VOA core structure layout

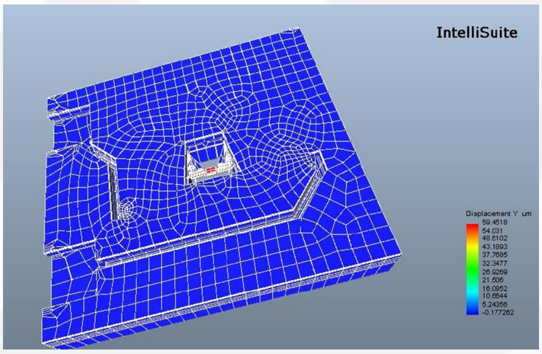


VOA process simulation

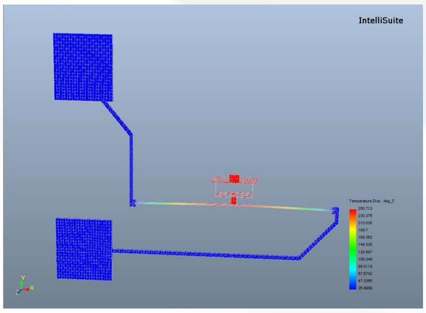


VOA device simulation results

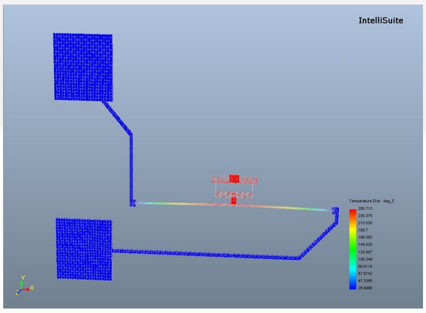




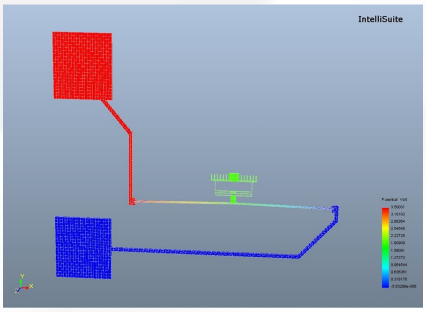
VOA core structure simulation results



Y– displacement



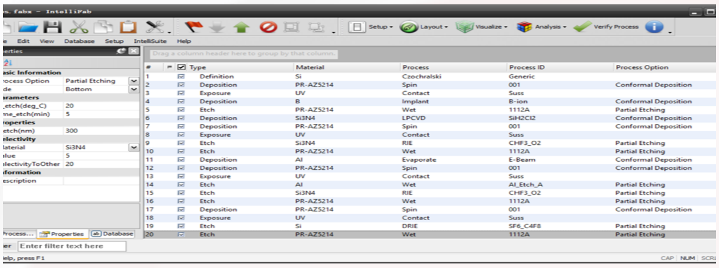
Temperature



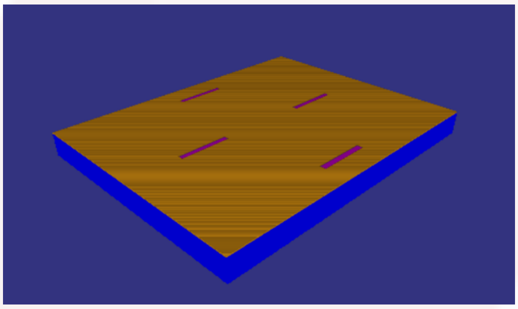
Potential

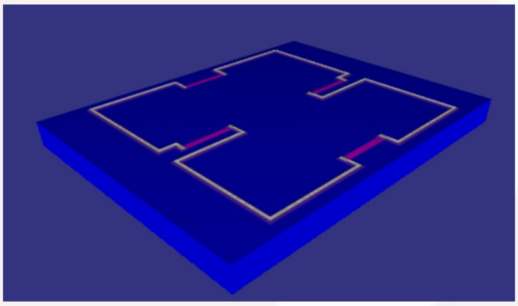
Sensors & Actuators

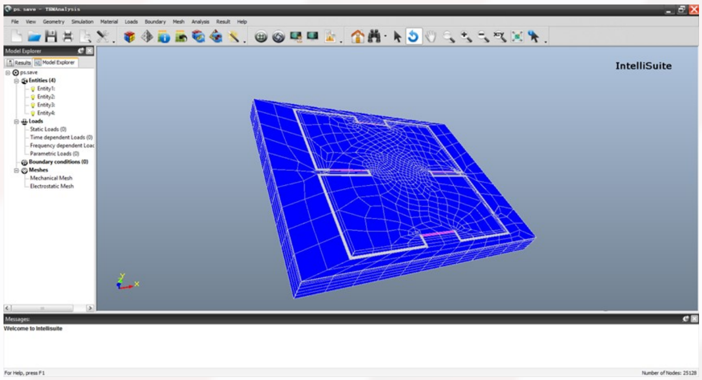
Piezoresistive pressure sensor



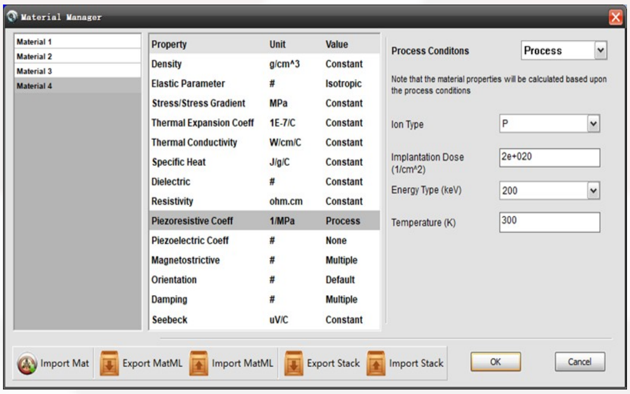
Material parameter setting with orientation preset



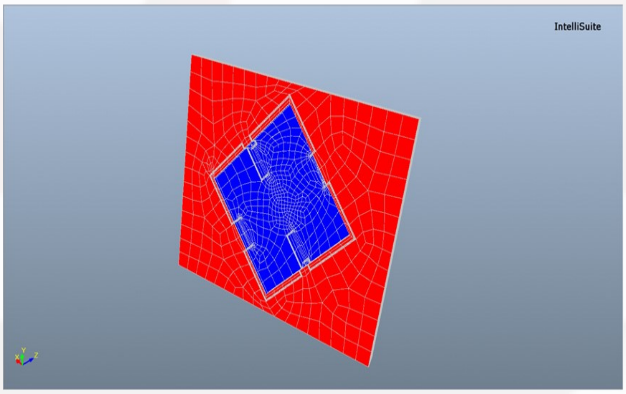




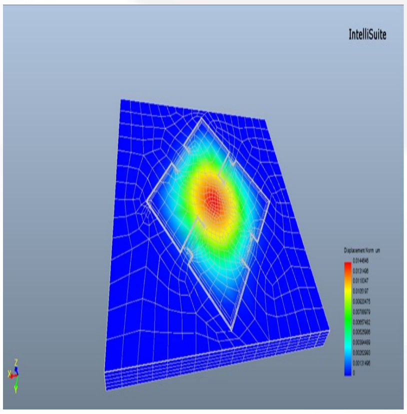
MeshManip module can simplify the voxel model generated by Fabsim into a geometric model, and mesh the geometric model to build the analysis model needed for device level simulation.

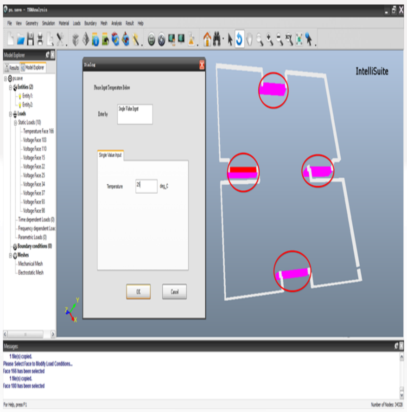


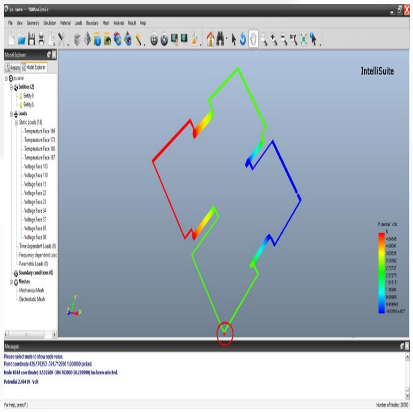
Piezoresistive coeff setting



Boundary setting



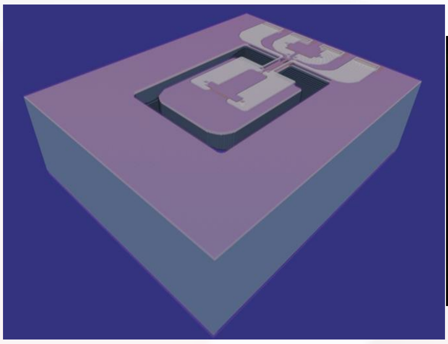


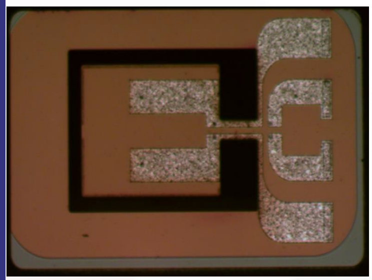


Simulation results

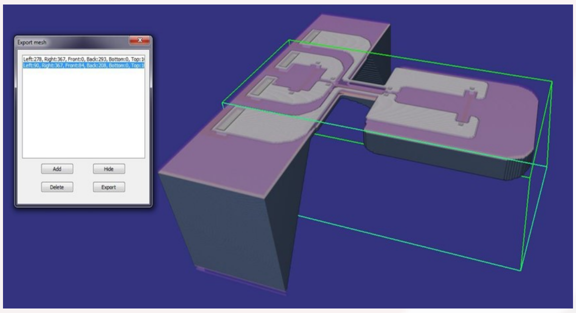
Realistic Virtual Prototypes from Physical Process Models

Accelerometer Multiphysics analysis model can be derived directly from the physical process model before fabrication

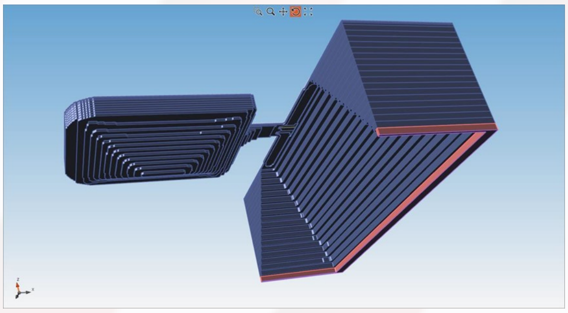




Core part of physical model from process simulation

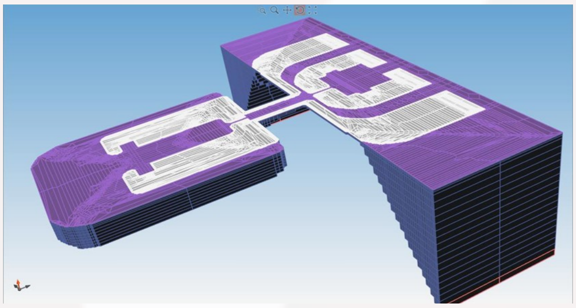


Top view

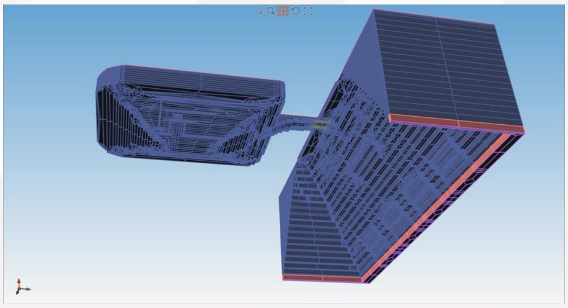


Bottom view

Meshed FEA physical model

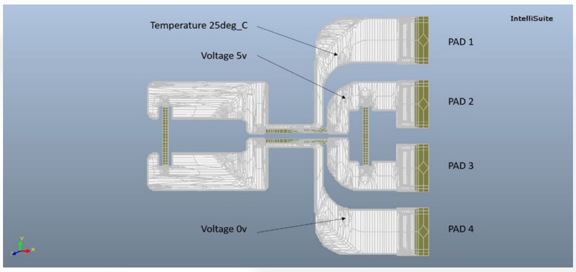


Top view

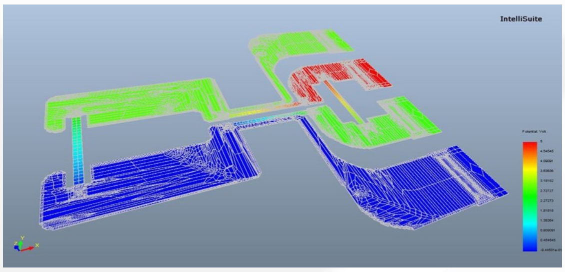


Bottom view

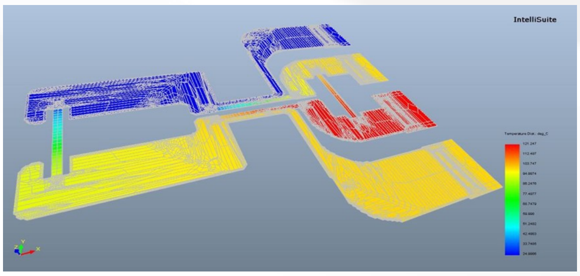
Analysis results



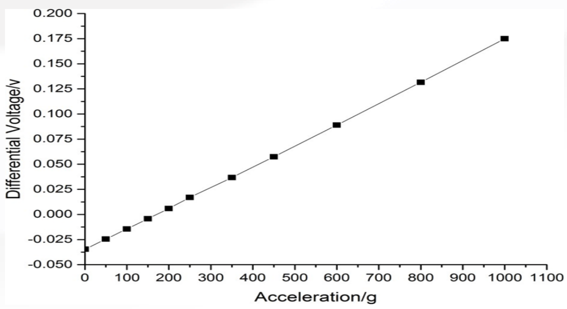
Loads and boundary conditions



Potential distribution



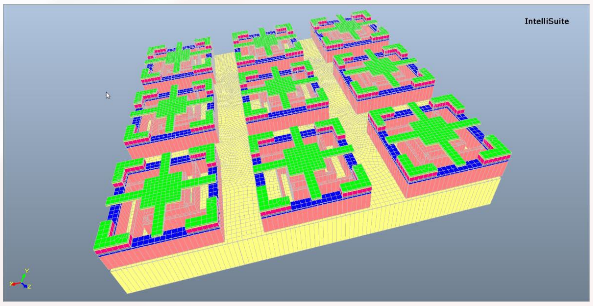
Temperature distribution



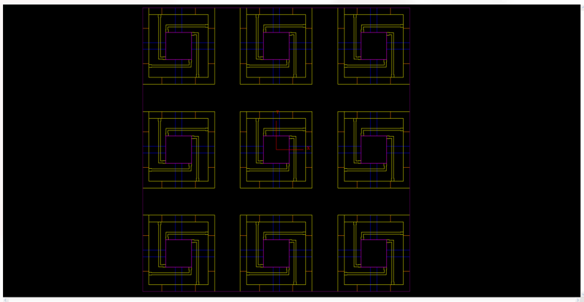
Realistic Virtual Prototypes from Physical Process Models

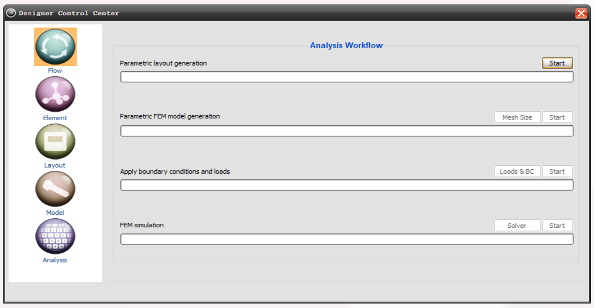
Micromirror arrays process model

Using IntelliSuite, one can optimize a design without having to go through the costly procedure of prototype development and testing.

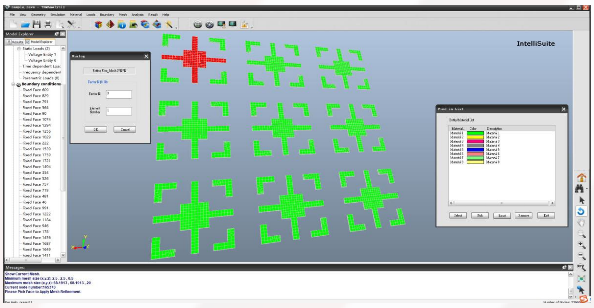


The structure of Micromirror

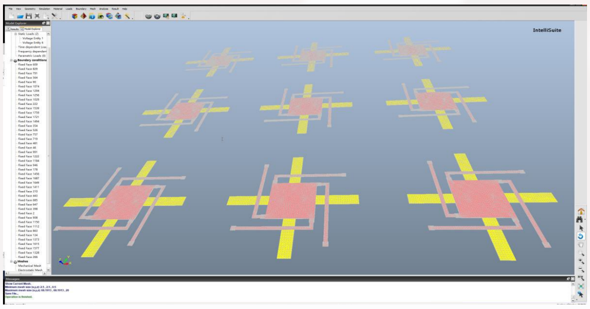

Layout from Blueprint



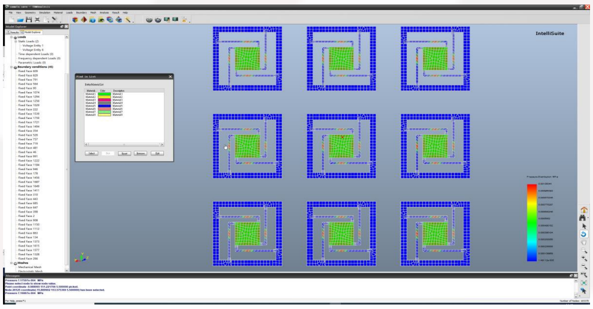
Analysis Workflow



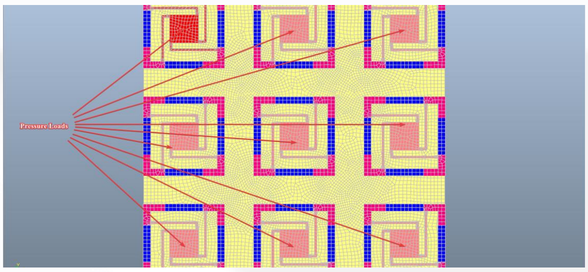
Electrical Mesh Setting



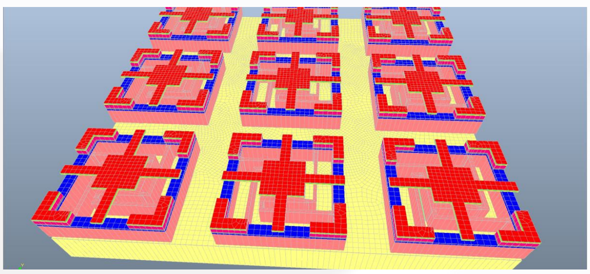
Electrical Mesh

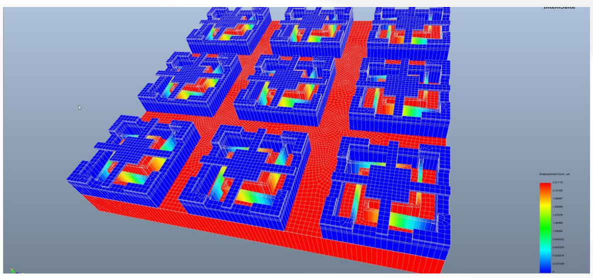


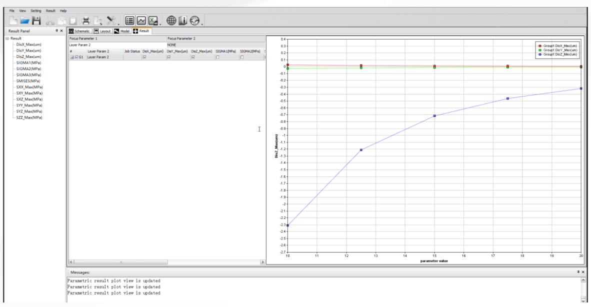
Equivalent pressure



Pressure loads


Boundary Conditions

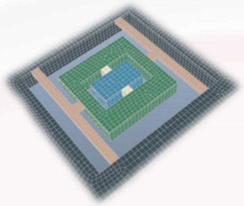

Displacement contour picture



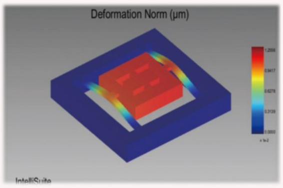
Design and Analysis of Nonlinear MEMS Systems

Applications:

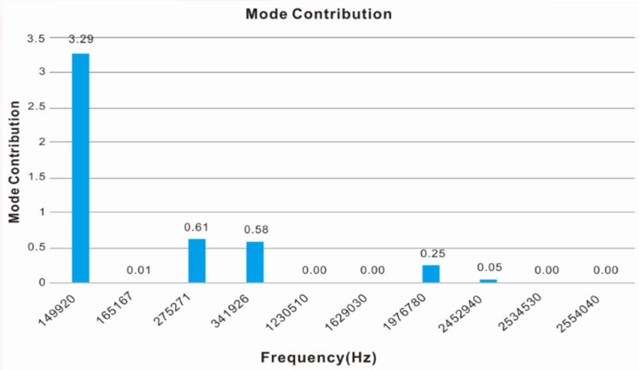
- Energy harvester
- Resonator
- Filter
- Gyro
- Micro mirror
- Etc.



3D MEMS Structure

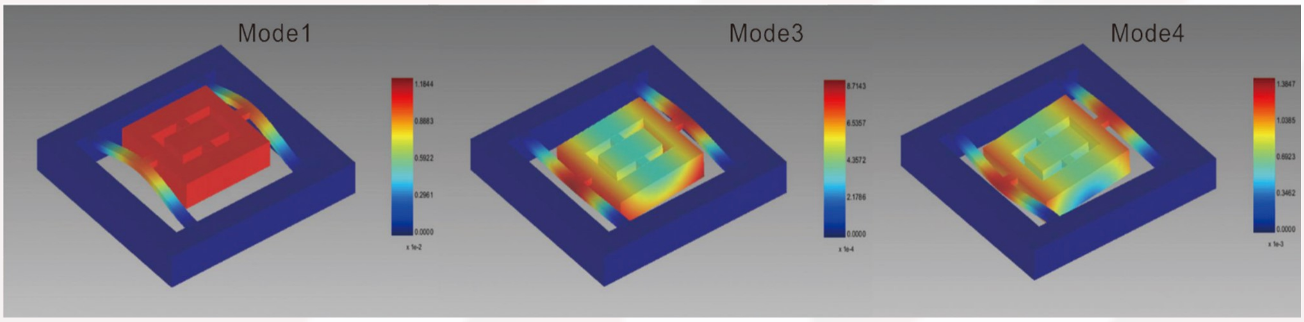


Structure Deformation

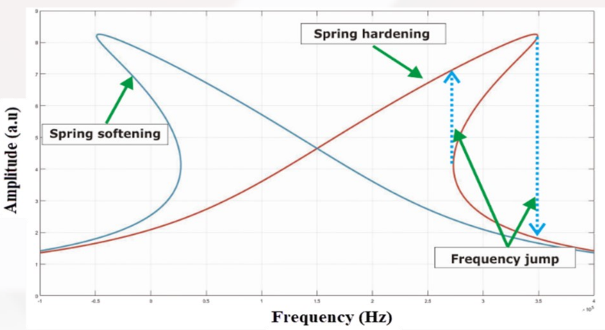


Nonlinear Macro-Model Extraction and Mode Contribution

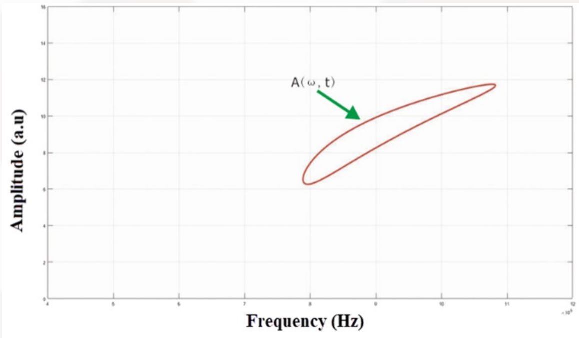
Mode Analysis and Coupling Extraction



Frequency Domain Response of Nonlinear Macro-model

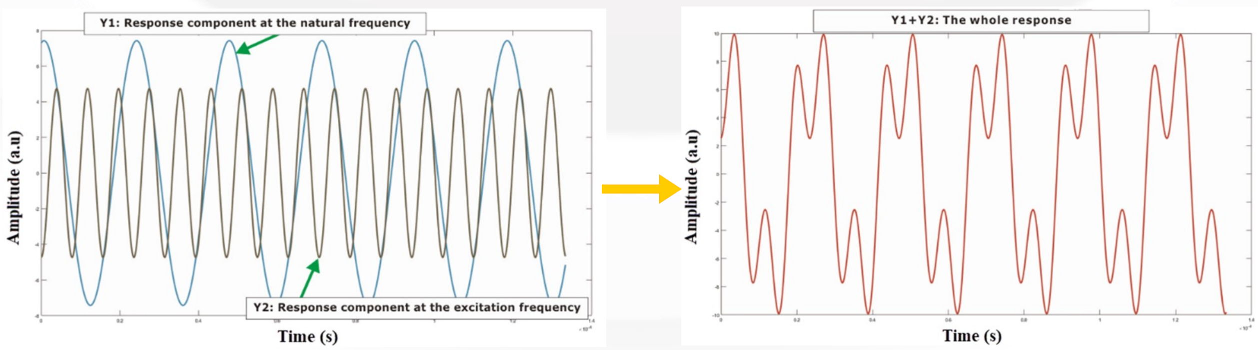


Amplitude vs Frequency Near the Primary Nature Frequency



Subharmonic Response (Amplitude vs Frequency)

Time Domain Response of Nonlinear Macro-model



Subharmonic Response (Transient Analysis)

IntelliSuite

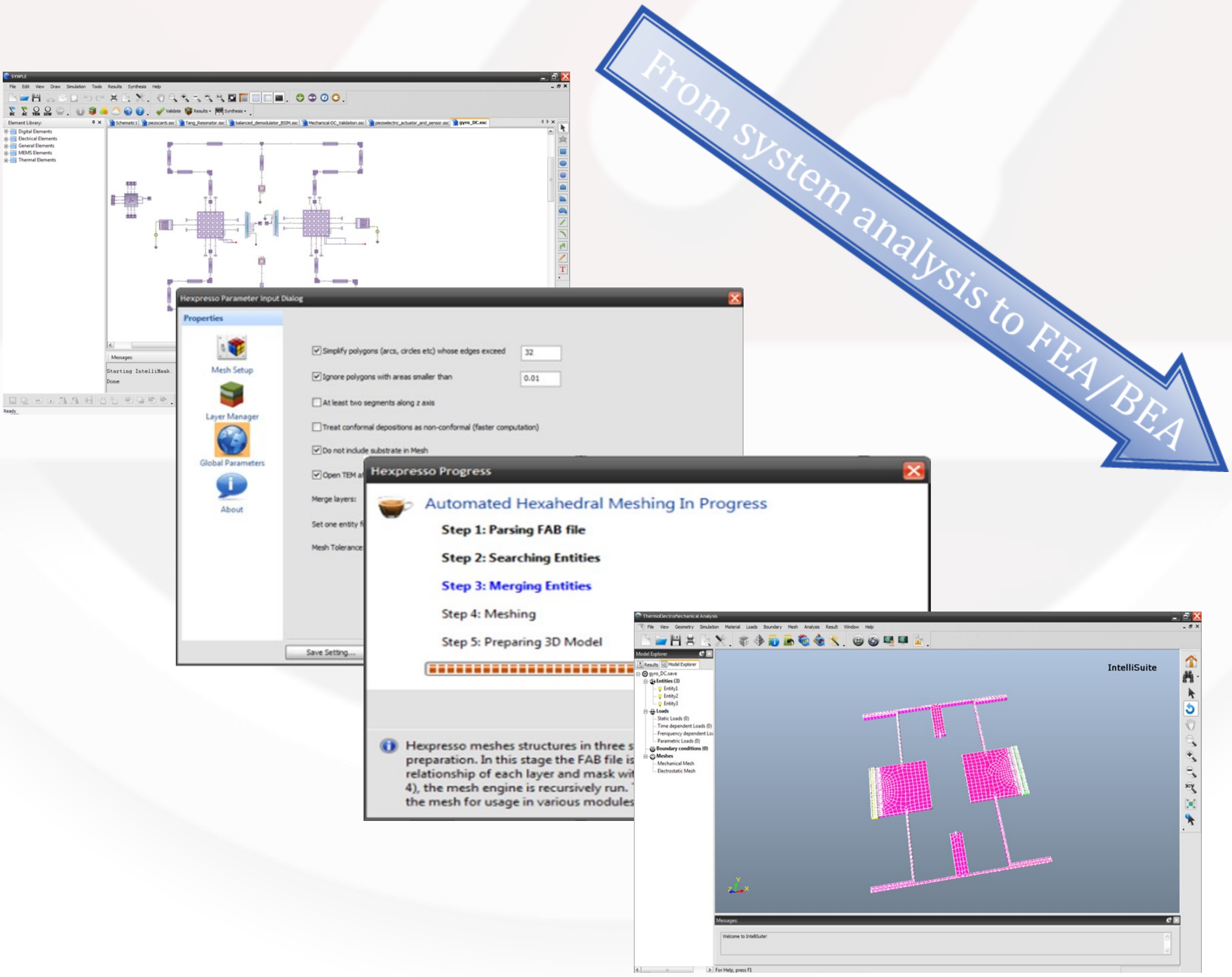
SYNPLE

Capture your MEMS at a schematic level and optimize your design by performing rapid behavioral analysis. Quickly synthesize masks layouts and 3D meshed models directly from your schematic.

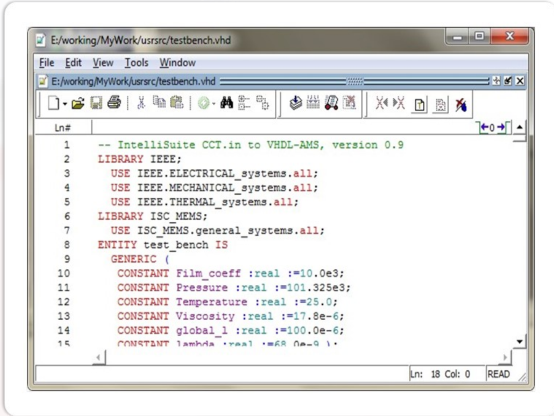
SYNPLE— System Synthesis & Simulation

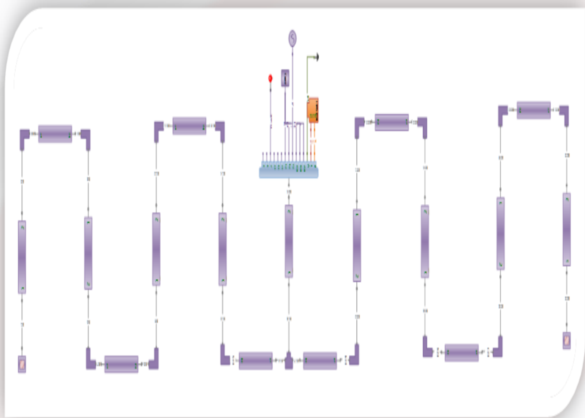
Allows you to capture your MEMS at a schematic level. Your design can then be quickly iterated and optimized at different granularities. Sophisticated synthesis algorithms can automatically convert your schematic into mask layout, 3D or better yet a meshed structure for full multiphysics analysis.

SYNPLE includes cutting edge schematic capture and simulation tools allowing you to take a hierarchical approach to the design space. SYNPLE provides a large multi-domain library of electrical, mechanical, thermal, and MEMS libraries. These elements may be combined in an effortless drag-and-drop fashion and then wired to create schematics of multi-domain systems. As a result, you can quickly survey a large design space before initiating a detailed analysis and verification process.

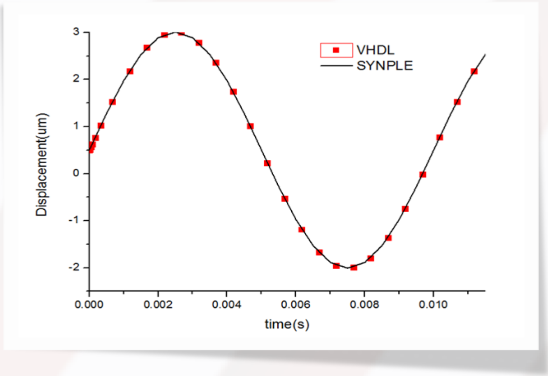


SYNPLE to VHDL





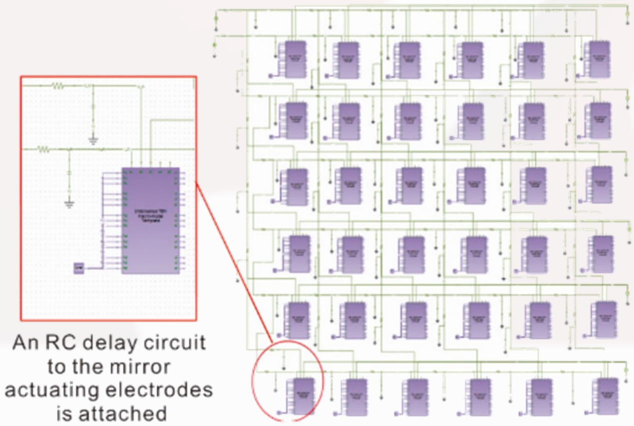
Pressure sensor in SYNPLE



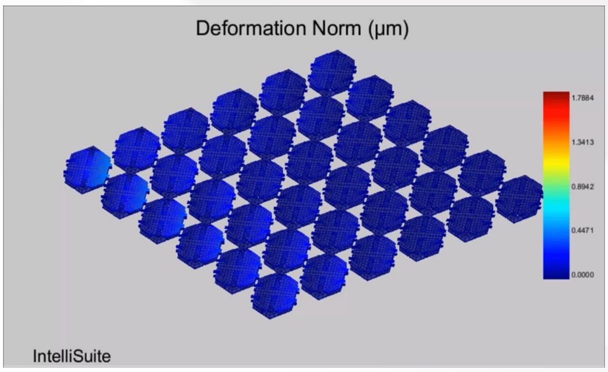
VHDL Code

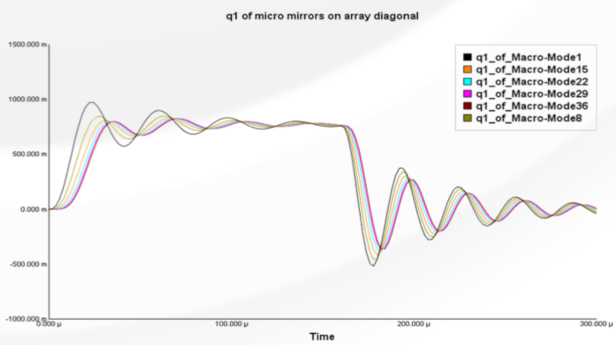
Compact Model Extraction

IntelliSuite uses state-of-the-art model reduction techniques to automatically create compact system models from large finite element models. NDOF (N-degree-of-freedom) system models encompass coupledelectro-mechanical behavior including stress stiffening, electrostatic softening, packaging effects, fluidic and other sources of damping. These accurate compact models can be exported to VHDL, Verilog-A, SPICE,Matlab and other tools for full MEMS-ASIC co-simulation.



Array of system schematic design





Displacement time delays of the mirrors array

IntelliSuite

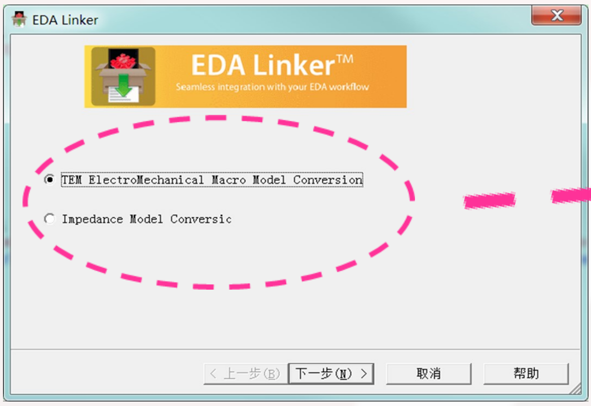
EDA-Linker

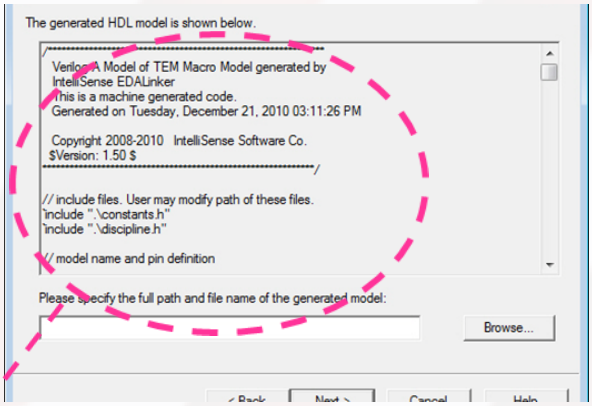
Behavioral model is outputted as a set of HDL (hardware description language) that can be easy to combine with CMOS and IC Design.

EDA Linker— Link to your EDA tools

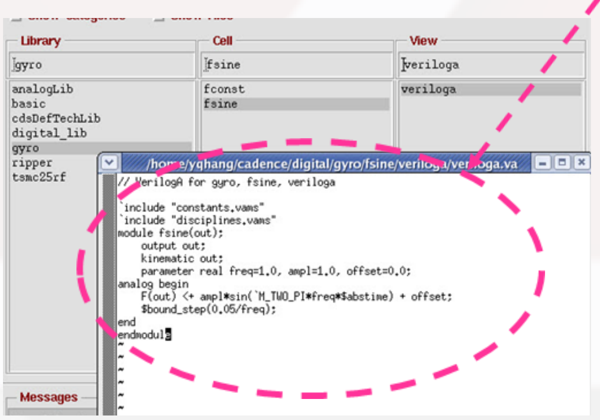
This tool is provided for converting the ElectroMechanical Reduced Order Macromodel extracted from the TEM™ module to the other Hardware Description Languages such as verilogA, VHDL-AMS etc , so that the extracted model can be used in other simulators. Now EDA Linker supports converting PZT and nonlinear macromodel as well as frequency shifted as voltage change in electrostatic case.

Conversion

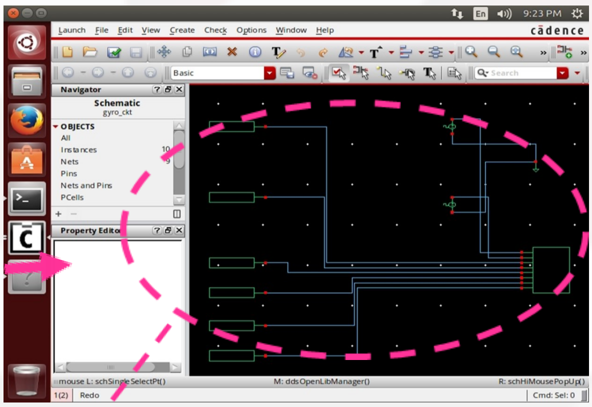




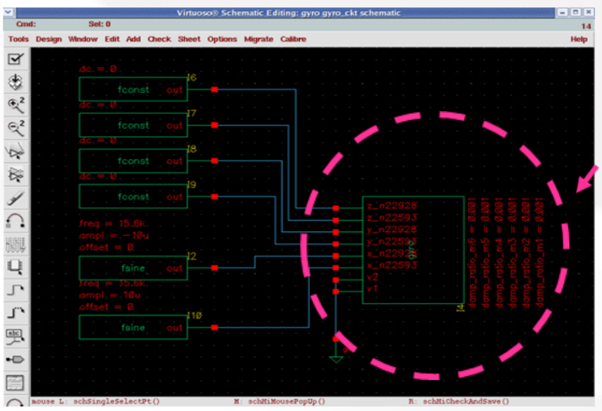
Link to your EDA tools

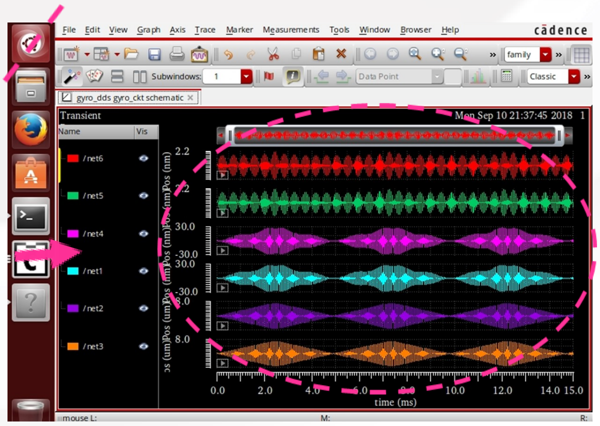


Open in Cadence



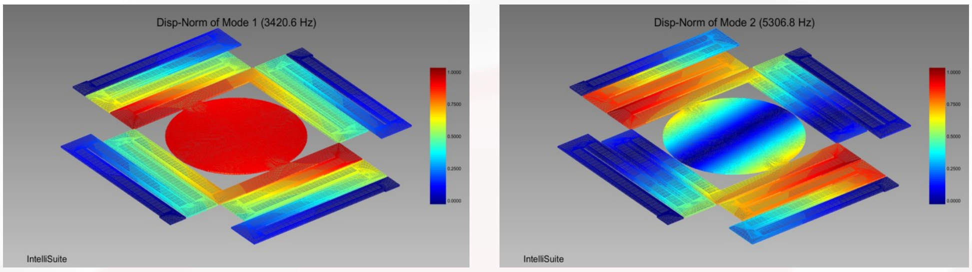
Drawing circuit diagram



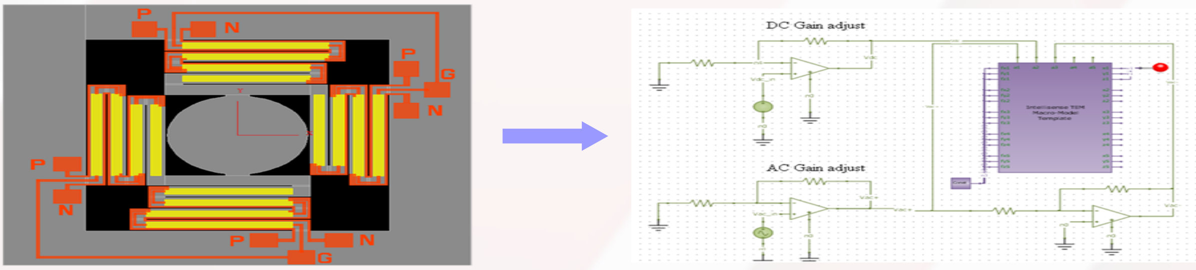


calculation results

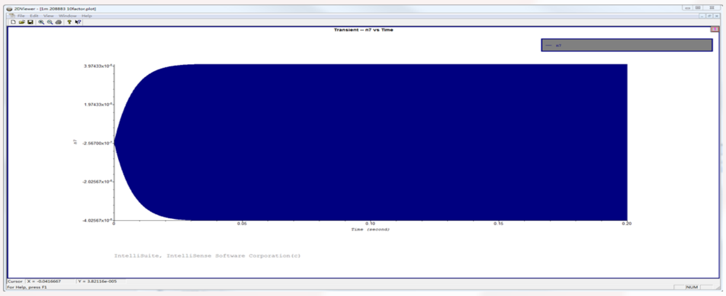
Piezoelectric based MEMS Micro-Mirror



FEM and respective mode shape

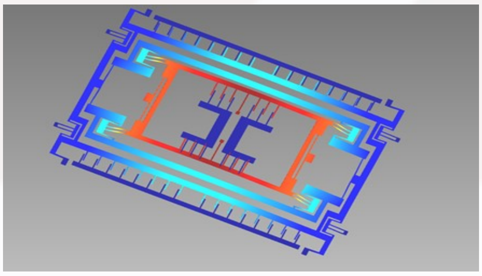


From Masked to Macro-model of piezoelectric based micro-mirror

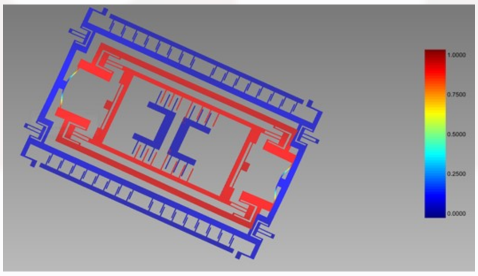


Displacement of micro-mirror in Z-direction

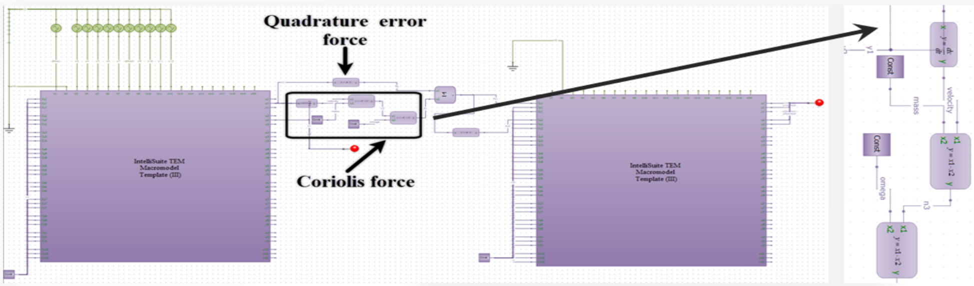
Gyro Design



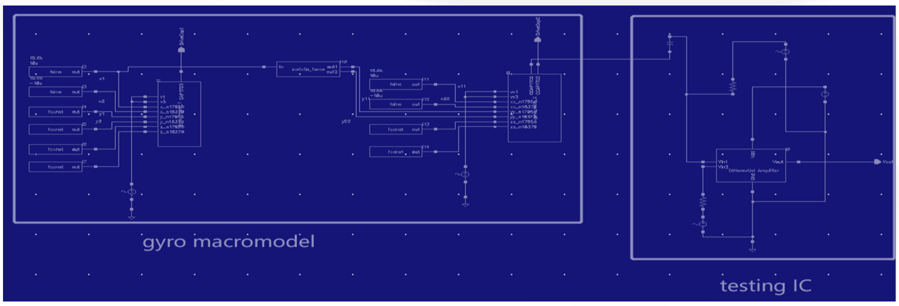
Drive mode



Sense mode



Macro-model for gyro to find the Quadrature error



MEMS-IC
co-simulation
for gyro macromodel