## IntelliCAD'98 industrial modeling applications

IntelliCAD'98 simulates the fabrication process as well as the performance of MEMS device. IntelliSense's CAD tool for MEMS has been utilized to efficiently design the process specifications and performance of devices such as:

- Gyros and accelerometers
- Microphones
- Optical sensing devices
- Fluidic devices
- Pressure sensors
- Deformable mirrors
- Mechanical switches

Three case examples will be summarized in which IntelliCAD'98 has contributed significantly in the device design, reducing the subsequent fabrication costs.

*Micromirror binary switch*

Lockheed Martin Corporation and Texas Christian University are collaborating to develop advanced avionics technology using MEMS micromirrors. These electrostatically-actuated devices were fabricated using the MCNC-MUMPS three-level polysilicon process.

IntelliCAD was used to (I) verify the design resulting from the MUMPS fabrication process, (II) analyze the resonance modes of the device, and (III) determine the voltage-deflection characteristics of the device.

For devices fabricated with the MUMPS technology, IntelliCAD provides a visual step-by-step fabrication process sequence template. This operation renders a 3D visualization of the device to verify that it can be successfully fabricated via the MUMPS process.

After verifying the design, the MEMS structure can be analyzed with any of the IntelliCAD analysis engines. For the deformable mirror being considered, mechanical and coupled electromechanical analyses were performed.

Upon entering the analysis engine after visualization, IntelliCAD automatically discretizes the 3D model into a finite element format. The user has the option of locally refining the mesh in areas of mechanical interest.

For the resonant frequency calculations, the IntelliCAD Mechanical Analysis module was accessed. Fixed boundary conditions were applied to the ground plane of the structure. After analysis, the software automatically provides a resonant frequency value report and generates a dynamic animation of the frequency modes, as shown in the figures below.

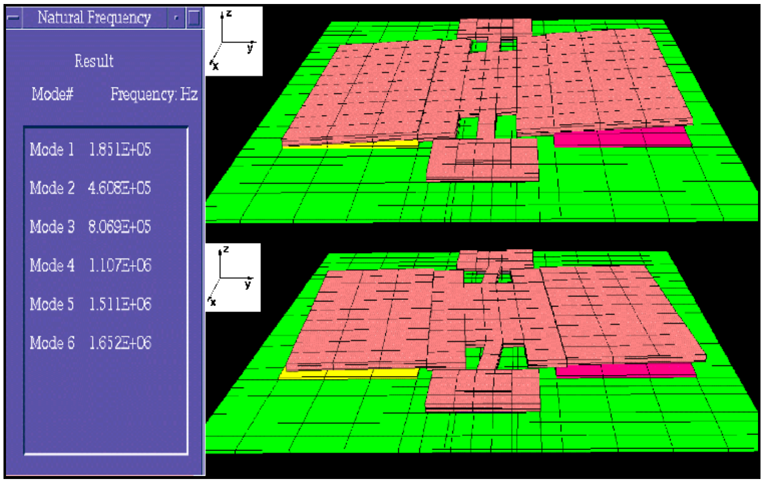


**FIGURE 1: IntelliCAD frequency report and mode shapes (mode 1, top; mode 6, bottom)**

IntelliCAD predicted the device resonance frequency to within 10% and further, it predicted the mode shapes exactly.

For the voltage-deflection characterization, the IntelliCAD ElectroMechanical Analysis module was utilized. Fixed boundary conditions were applied to the ground plane of the structure, and the voltage differential was applied between the mirror and one of the lower electrodes.

After analysis, the software automatically shows the device's deflection, stresses, charge density, and electrostatic pressure distributions. The device's natural frequency shift due to applied voltage loads can also be studied. Compared to actual device results, IntelliCAD predicted the pull-in voltage of the device to within 8%. Sample results are shown in the following figures.

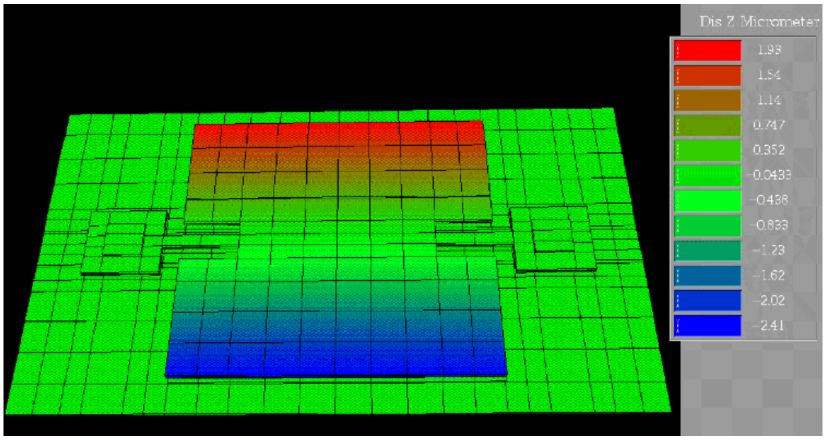


**FIGURE 2: IntelliCAD ElectroMechanical results: Beam deflection in response to an 62V applied DC voltage**

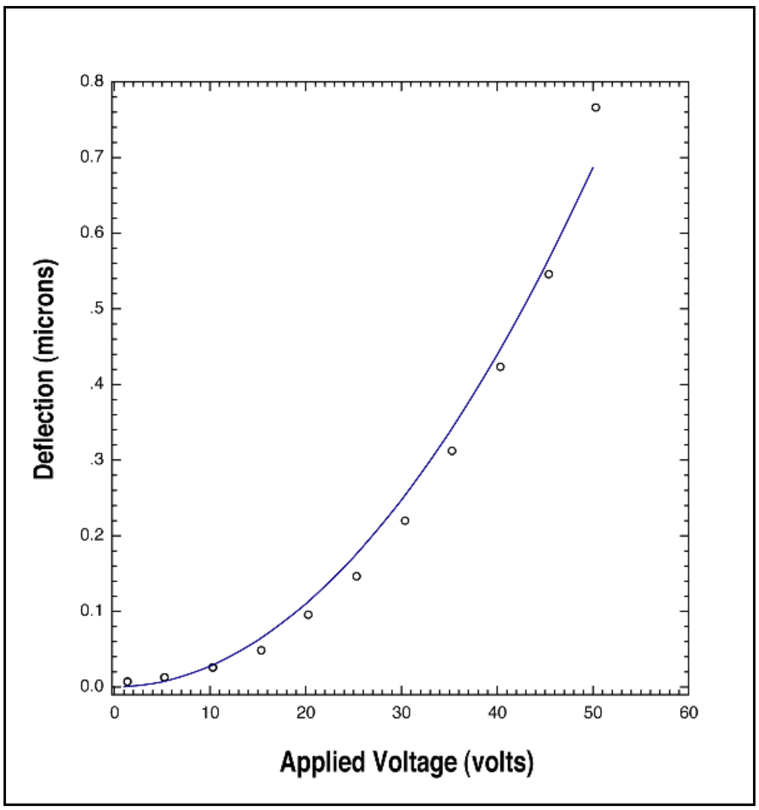


**FIGURE 3: IntelliCAD ElectroMechanical results: Beam deflection vs. DC voltage. Curve represents the non-linear least square fit.**

*Thermal beam structure*

IntelliCAD'98 has assisted the engineers at NASA Goddard Space Flight Center in the design of thermal micro beams. The beam will be used to provide low-thermal conductance electrical connections for cryogenic detector wiring.

Thermal gradients are introduced in the structure during the cycling of the detector from room temperature to cryogenic temperatures, and also during operation due to the fact that the detector operates at a higher temperature than that of the platform on which it is mounted. The temperature distribution in the beam results in its deformation and regions of high stress at the metal-silicon interface.

One of the devices that was analyzed with IntelliCAD is a silicon beam with thickness of 1um. An aluminum layer of 0.34 um is deposited on the silicon. The beam is a repeated set of 16 "S" curves. A close up of the beam is shown in the following figure:

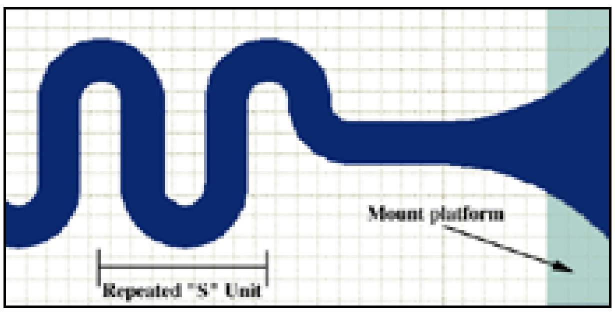


**FIGURE 4: NASA Beam layout**

NASA was interested in determining the stress distribution in the curved beams due to a range of temperature loads and mechanical stresses applied to the silicon beams during temperature cycling of the detector mount. It was desired to design the device (I) to exhibit a thermal stress that was below the failure range of the device and (II) to reduce the thermal conductance of the beam.

The following figure show the stress distribution in the device when beam deforms 10um.

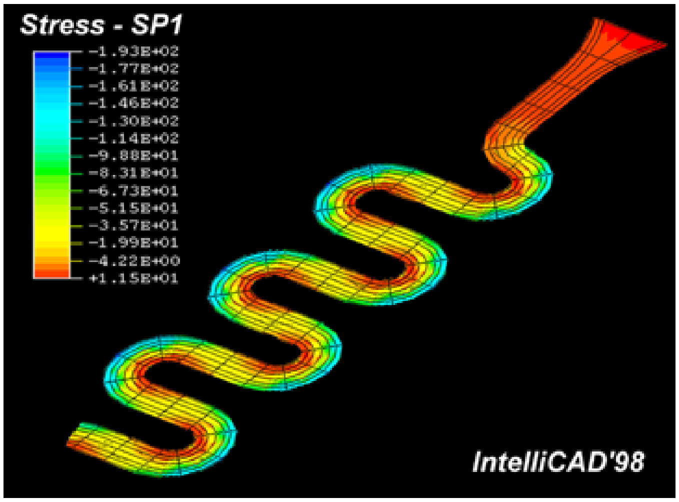


**FIGURE 5: Principal stress 1 due to structure deformation**

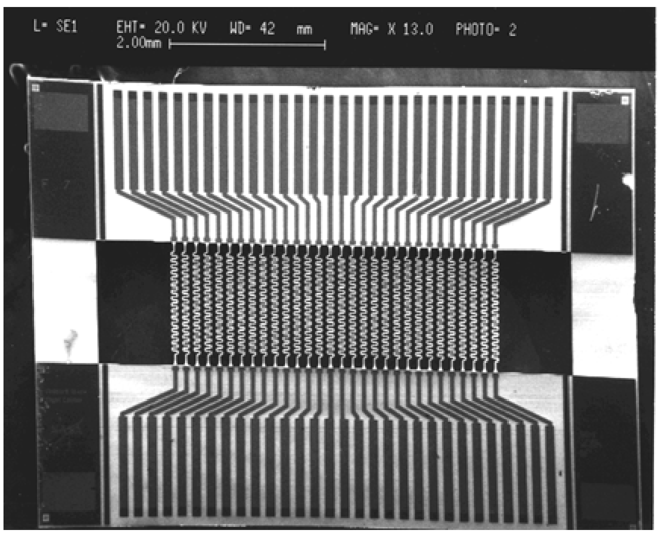


**FIGURE 6: SEM photo of NASA cryogenic detector with “s” beam array**

The IntelliCAD results suggested that the NASA thermal beam could be optimized by increasing the radius of curvature of the S-shaped features.

This detector will be used in an infrared array camera which is being built for the Space Infrared Telescope Facility. The device is scheduled for launch in late 2001. Visit http://ssc.ipac.caltech.edu/sirtf/ for more information.

*Bulk micromachined optical device*

An optical device currently being manufactured was designed using the AnisE module of IntelliCAD'98. The device was built via bulk etching of a <100> silicon wafer with KOH. It was desired that the feature being etched have a square corner in order to maximize the surface area of the reflective top surface. The following sets of figures compare of AnisE simulations to SEMs at different etch times.

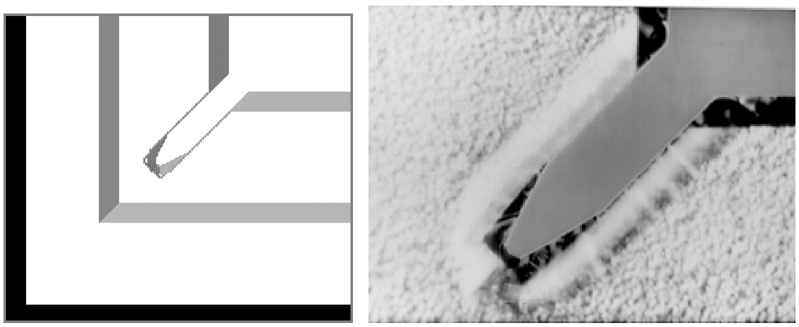

**Figure 7: AnisE simulation (left) and etch results (right) at 40% completion.**

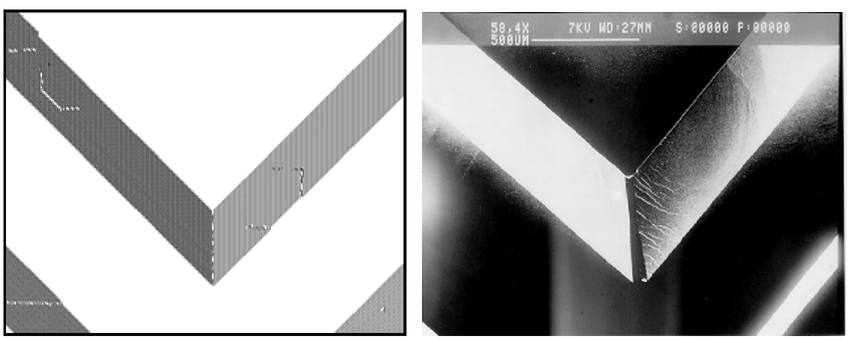


**Figure 8: AnisE simulation (left) and etch results (right) at 100% completion.**

For this example, AnisE was used to successfully predict the etching results in terms of etch depth and corner rounding to within 4%. Other similar corner compensation examples show accuracy to within 7%.

IntelliCAD was first released in 1995, making it the first CAD tool for MEMS commercially available to the MEMS community. Since then, IntelliCAD's reliability has been proven through the analysis of many real MEMS devices from industry, government, and academia. For more information, contact IntelliSense at www.intellis.com.

Word count:

930

Published in:

J. Marchetti, E. Kolesar, C. Allen “IntelliCAD’98 optimizes MEMS design,” *Micromachine Devices*, Vol. 3, pp. 1-3, June, 1998.