Integrated MEMS Development

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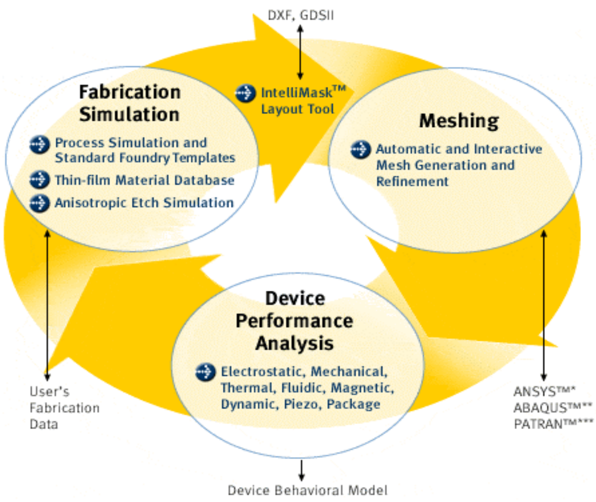
Abstract

MEMS design requires coordination between engineers with a wide variety of backgrounds. These include mechanical, electrical, material, and process engineers as well as experts in industry-specific applications. By integrating process simulation, thin-film materials engineering, mask layout, device analysis, and package analysis within a single design tool, IntelliSuite® enables communication between these designers and accelerates successful MEMS design.

Introduction

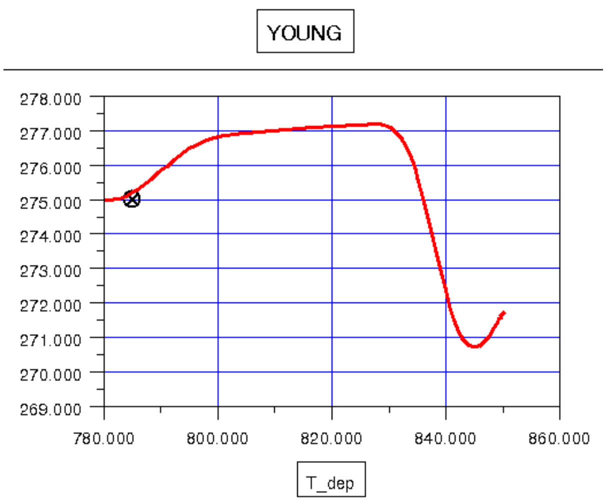
Figure 1 shows a graphical representation of the IntelliSuite design methodology. The design process typically begins in the upper left with the design of a preliminary mask set and process flow; both are requirements for fabrication of an actual MEMS device. Alternatively, IntelliSuite enables users to begin with a meshed solid model and to run analysis. In this case, an optimized mask set can be exported once the device behavior has been perfected so that a suitable fabrication process can then be developed for the device. By integrating all aspects of the design process, IntelliSuite provides the entire product development team with a single communications platform. Also shown in Figure 1 are arrows where data can be imported from or exported to other common design tools, including those for optical modeling and system level design.



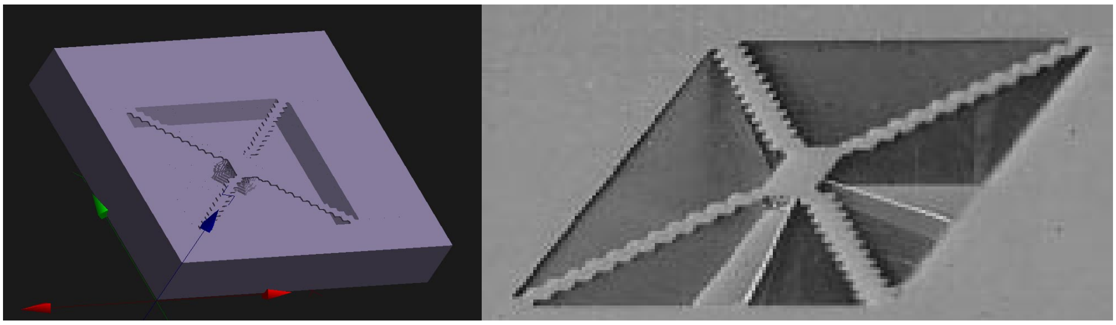
Corning IntelliSense believes that a fundamental aspect of a CAD tool is ease of use. For this reason, all modules of the software are built keeping in mind the requirements of users from varied technical backgrounds. This means that not only can users translate files to and from other common file formats, but they can also transfer models seamlessly between different IntelliSuite analysis modules.

Process Simulation

As mentioned earlier, IntelliSuite modeling begins either with a process flow and mask set, from which a 3D model is automatically created, or with direct creation of a 3D model. A process flow can be selected from a database of standard foundry templates that is provided to the user, or a custom process flow can be constructed from the database of individual process steps, also included with the software. Users can also add process templates or steps to these databases for repeat use. Mask sets can be created in the IntelliMask™ module of IntelliSuite or imported in DXF, GDSII, or bitmap file formats. The mask set is linked into the fabrication process flow, and then the automatic mesh generation engines create a course mesh for analysis. Alternatively, the user can directly create a 3D model within IntelliSuite or import ANSYS, ABAQUS, PATRAN, or IDEAS 3D file formats. This initial mesh can later be refined globally or independently in areas of significant change (mechanical stress, electrostatic pressure, fluidic differential, etc.) [1].



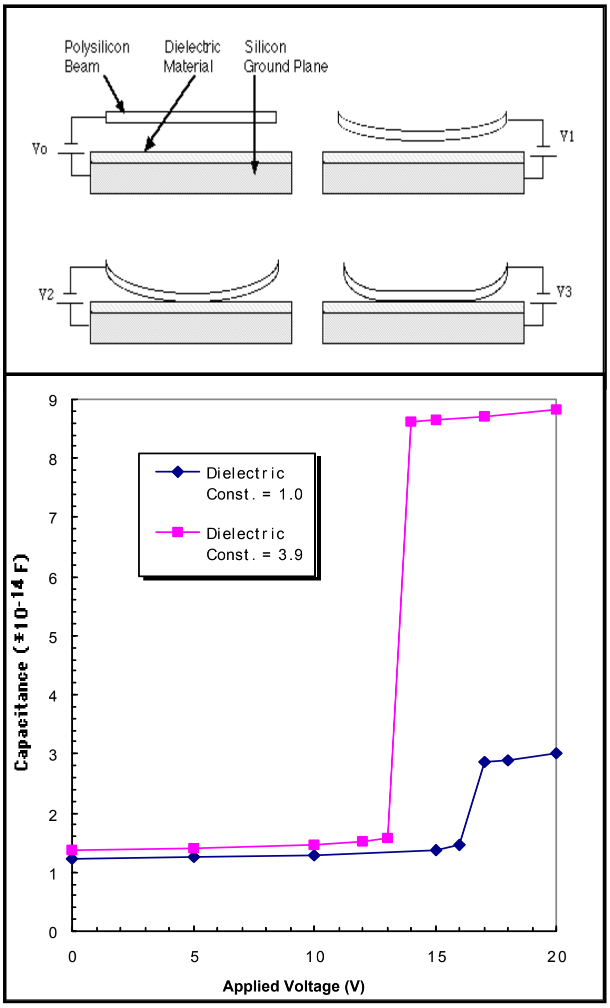
A second aspect of IntelliSuite is process analysis. Once the process flow and mask set has been created, IntelliSuite allows for virtual prototyping. Rather than entering a fabrication facility, engineers can use IntelliSuite to view the device at each step of the fabrication process. IntelliSuite also links the material properties to the individual process steps so that MEMaterial®, an included database, can generate accurate material property data from the fabrication parameters. As with the other databases, MEMaterial one can be updated by the user. Figure 2 shows a sample MEMaterial graph.



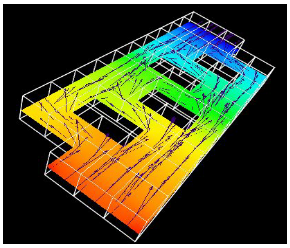
In-line with its focus on fabrication, IntelliSuite is also the only MEMS CAD tool that includes an anisotropic etch simulator, AnisE®. First released in 1997, this module will generate a 3D model of an anisotropically etched silicon wafer based on a mask (or masks) and input parameters such as etchant type, temperature, concentration, etch stops, and etch time [2]. An included database determines the etch rates for the simulation based on these input parameters. Figure 3 shows an example AnisE result with the corresponding SEM image.

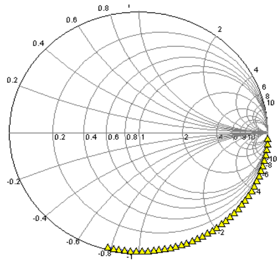
Device Analysis

Once the 3D model is created in IntelliSuite, the user moves to device analysis. IntelliSuite offers complete device analysis including thermo-electro-mechanical, piezo-electric, piezo-resistive, microfluidic, and electromagnetic. All analyses are performed in full 3D, including dynamic analysis, enabling engineers who are creating new MEMS devices to research all aspects of their device and package design in detail.



It is the coupling of multiple physical domains that distinguishes IntelliSuite's analysis engines from non-MEMS mechanical, fluidic, or electromagnetic analysis packages. In 1995, Corning IntelliSense released the first CAD for MEMS tool, defined by the existence of an integrated thermo-electro-mechanical analysis engine [3]. This type of analysis is critical for MEMS design. The need for a MEMS-specific tool becomes evident when modeling a beam coming into contact with a dielectric layer, as shown in Figure 4a. In this example, numerical tolerance errors in existing software packages prevented accurate simulation of contact. This error was due to the mechanical numerical tolerance issues, which resulted in erroneous electrical analysis results. To compensate for this limitation, the packages were required to add an artificial air gap layer to prevent the simulation from failing. In 1997, Corning IntelliSense became the first MEMS CAD company to address this issue and solve the contact analysis problem by developing a proprietary algorithm which located the exact point of contact while maintaining an accurate mechanical stress distribution [4]. Today, pure finite element analysis packages are still limited by the artificial air gap, because all parts of the model must be meshed. Also, other MEMS CAD packages must still include an artificial air gap to model electrostatic forces. Once IntelliSuite had overcome the hurdle of the artificial air gap, multiple dielectric layers had to be addressed. Figure 4b shows the difference between an analysis with an air gap with dielectric constant 1.0 (air) and one with a dielectric constant 3.9 (dielectric material) and illustrates one benefit of an accurately coupled finite element and boundary element approach for thermo-electro-mechanical analysis.





IntelliSuite employs similarly unique engines for microfluidics and electromagnetics to address MEMS-specific phenomena in these areas. Our in-house developed microfluidics engine employs a unified computational framework to address such diverse physical phenomena as pressure gradients, electric fields, surface tension, structural interaction, and electro-chemical interactions. In this way we are able to address most all aspects of fluidic analysis necessary for Lab-on-a-Chip design.

Similarly, IntelliSuite's electromagnetic engine is specifically engineered to address design problems in RF MEMS, microwave, and Optical MEMS devices. Like IntelliSuite's other solvers, this engines employs a full 3D approach, (Method of Moments) to accurately analyze include not only planar, but also out-of-plane effects.

Conclusion

Almost all MEMS engineers perform some level of CAD design prior to entering a fabrication facility. Analysis of both the device and package is widely recommended to decrease costs and to make more efficient use of the fabrication run [5, 6]. Some designers will have direct communication with a foundry during the design process; others can rely more heavily on fabrication expertise built into MEMS CAD tools. In either case, both money and time will be saved with initial efforts by a thorough, virtual evaluation of the design.

Corning IntelliSense also operates a flexible fabrication facility near Boston, Massachusetts, USA, which offers almost all MEMS surface, bulk, and high aspect ratio MEMS processing techniques. The programs and projects are diverse, but primarily focus on BioMEMS / Life Sciences, RF, and Micro-instrumentation. IntelliSuite's process simulation capabilities are supported by this in-house fabrication facility. Also, while only some of the process information in IntelliSuite is from our own facility, in-house processing lends additional importance to the process simulation aspects of IntelliSuite and offers immediate feedback for the results generated by the program. Corning IntelliSense's design engineers understand the importance of accurate modeling, and their knowledge is also translated into the software. Our in-house engineering team makes IntelliSuite the most extensively tested MEMS CAD tool available. Also, enabling our engineers to perform all of their design work within the package keeps Corning IntelliSense on the cutting edge of MEMS software development.

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