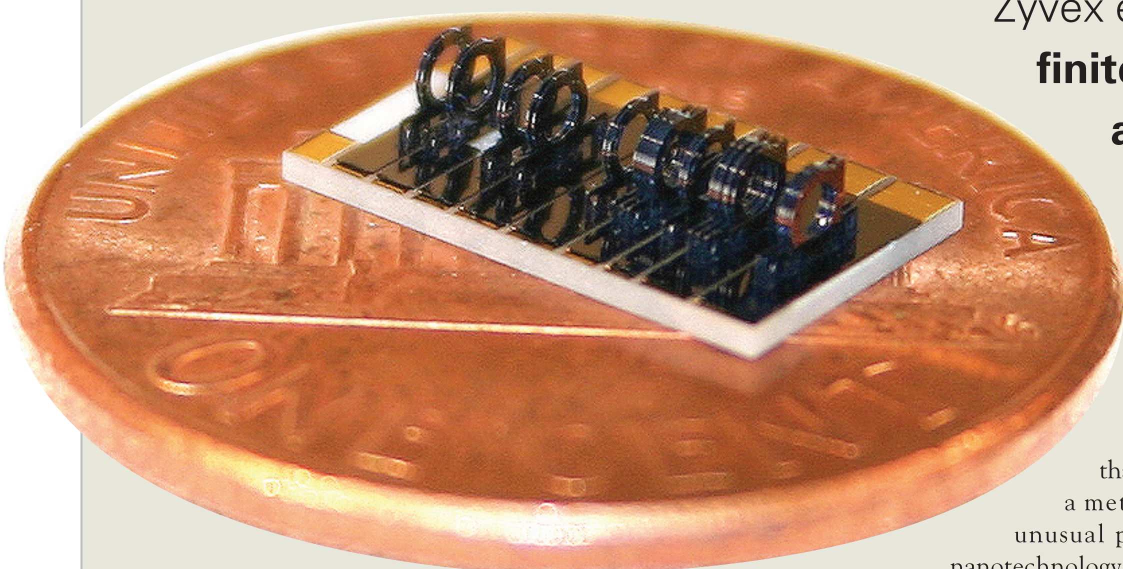
CAE in the Nanotech-Enabling World

Zyvex engineers use **finite-element analysis** to **build** microscopically **small devices.**



by **Aaron A. Geisberger** and **Zoran Jandric**

Line up 10 hydrogen atoms, and you have a row about a nanometer long. Scientists have found that at these dimensions – billionths of a meter – some materials can display unusual properties. Now, we hear about nanotechnology successes in products ranging from golf balls to automobile trim.

Researches also see new opportunities in nanotechnology that will be enabled by micro-electro-mechanical systems (MEMS) – devices and systems that are typically measured in microns and nanometers. This article will focus on research work conducted at Zyvex Corporation, which strives to develop MEMS technology that will ultimately be used to enable new nanotech applications.

Zyvex Corporation of Richardson, TX, is the first molecular nanotechnology development company and an aggressive developer of commercial nanotech applications. The company has three product lines – materials, tools and structures – and is focused on three market segments: aerospace and defense; healthcare and medicine; and electronics and semiconductors. Zyvex customers include industry leaders such as Boeing, Easton Sports, Honeywell International and Texas Instruments.

The company is active in several areas of research, funded by grants from state and federal agencies. Two of these grants – from the National Institute of Standards and Technology (NIST) Advanced Technology Program and the Defense Advanced Research Projects Agency (DARPA) Small Business Innovation Research – focus on the design of microfabricated components for assembly, techniques and tools to conduct microassembly, plus applications of microassembly systems. The use of computational analysis is critical to the design of microstructures, because it may take up to four months for a microfabrication cycle. Finite-element analysis (FEA) tools are indispensable for this work.

From Two Dimensions to Three

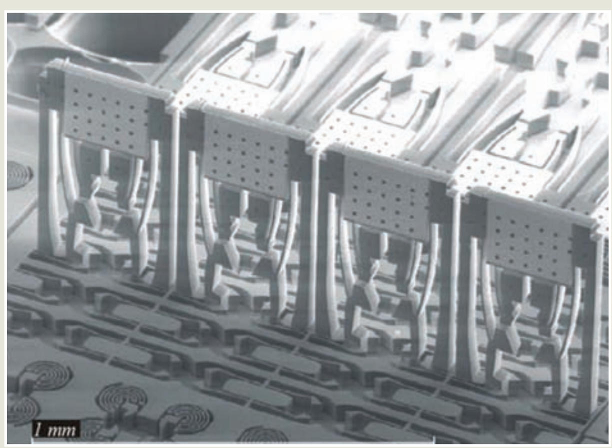
Currently, the majority of commercially available MEMS devices are essentially two-dimensional, since the structural layers are grown onto or etched from a flat substrate. These successful MEMS devices include accelerometers, gyroscopes, pressure sensors, microphones and micromechanical resonators.

The researchers at Zyvex feel that an enabling MEMS technology would be one that provides structures and devices with 3D characteristics. Very few existing devices incorporate true 3D characteristics because of the challenge associated with manufacturing them. To build a 3D MEMS device, some form of assembly is required in order to raise structures from the plane of fabrication and move them into appropriate position.

Conventional assembly methods for MEMS demand ultra-precise machine tools, which are very costly. Several alternative methods have been developed, including hinged structures, plastic deformation and the use of surface tension forces, but in all these methods, the structures remain tethered near the point where they were fabricated. Fluidic self-assembly methods overcome this problem, but they can't orient standing 3D structures with a high degree of control.

Zyvex has taken a different approach. We have designed compliant MEMS components that can be de-tethered, removed from the plane of the wafer, and assembled, all in an automated process.

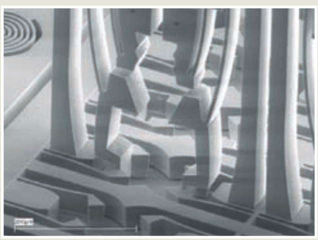
Using this approach, we have developed a directed pick-and-place microassembly process using MEMS end-effectors and high-precision robotics that make it possible to integrate microcomponents that have been fabricated in separate processes. Although work is under way to commercialize devices that utilize this technology, one family of microassembly tool products has been released. Zyvex Microgrippers are currently sold and were developed using an industry-standard FEA solver and a pre- and post-processing software toolset. We designed and performed analysis on this product, which has features as small as five microns.



Zyvex Corporation carries out work to develop micro-electro-mechanical systems (MEMS) technology for use in nanotech applications.

Shrinking Microscopy

A current goal for Zyvex is to find applications for its microassembly technology that will help fund further research and product development in the field of nanotech-enabling. One class of applications in which this technology can make a significant difference is charged particle optics. These applications include electron and ion optical systems for applications in scanning electron microscopy and mass spectrometry, respectively. For example, MEMS technology enables us to create a very small ion trap so that mass spectrometers can be greatly miniaturized.



This is a scanning electron microscopy (SEM) image of a microconnector after assembly.

In addition, by using these microassembly techniques, we are developing a key component for a highly miniaturized scanning electron microscopy (SEM) system. This development effort uses our MEMS connector and socket technology for the manufacture of SEM electrostatic electron-beam micro-columns.

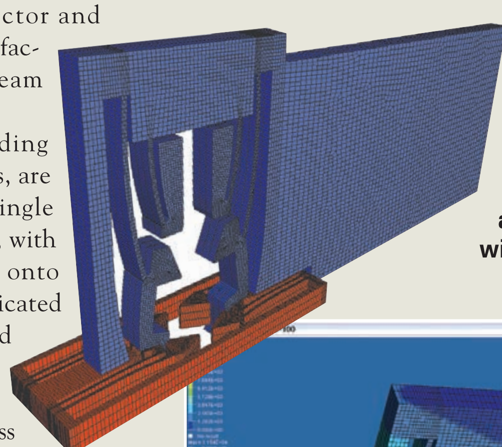
Micro-column components, including deflectors, lens elements and apertures, are fabricated on a silicon wafer using a single silicon device layer. These components, with compliant connectors, are assembled onto compliant MEMS sockets that are fabricated on the same wafer using automated assembly techniques.

The result is a scanning electron microscope column with a footprint of less than a square centimeter, which can focus a beam diameter of 30 nanometers. This device, which we have now prototyped, offers potential advantages for low-cost, portable SEMs that can be used in the fabrication process for inspection, imaging, high-throughput lithography for mask-making, and direct-write applications using micro-column arrays.

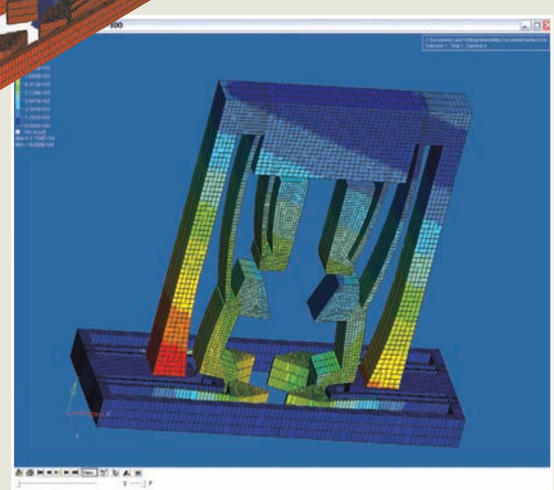
FEA: The Indispensable Tool

In general, our MEMS design process relies heavily on CAE tools. At Zyvex we design, analyze and test MEMS structures, however, microfabrication is completed external to the company. When we complete our MEMS design development, including product design performance analysis, the design is sent to a silicon wafer foundry for production. When we receive the part, we have the characterization equipment and clean room facilities to perform all necessary tests.

Without the benefit of FEA tools, what alternatives would we have to do this kind of work? We would be forced to use an iterative process in which we would make a design, send it out to a foundry, wait for several months to receive the part, study it, make corrections, and send it out again in a repetitive cycle until the design could be considered finalized. So it's clear that FEA tools have greatly accelerated our work.



Zyvex engineers develop finite-element models with Altair HyperMesh (left) and visualize results with Altair HyperView (below).



FEA simulation results give research engineers insight into the performance of micro-assembled systems.

We originally began our mechanical engineering design work with the pre- and post-processing tools of our FEA solver, which we use for a number of multiphysics simulations, such as electrothermal structural and electrostatic structural simulations. Using more advanced FEA tools, like Altair HyperMesh, enables us to have more control over the mesh densities far more quickly.

In the case of the miniaturized SEM design, we could get a fine mesh for accurate results in the compliant parts of sockets and connectors, while a coarse mesh can be used for remaining areas of the lens components. These focused and feature-rich pre- and post-processing tools are definitely easier and faster to work with.

Typically, our design process from initial concept first involves a system model to provide a general design. Next, the parts are designed using a 2D CAD package that resembles an IC layout tool. Once designed, the 2D drawing is converted – usually to DXF format – and brought into HyperMesh to develop our finite-element model.

The modeling process typically involves building a 2D mesh and extruding and offsetting to build a 3D model. About 75 percent of what we do is 3D, because many of the structures we work with are electrothermally activated and require 3D thermal conduction. This requires considerable modeling.

We have found the visualization capabilities of post-processing tools, like Altair HyperView, extremely useful in understanding the performance and function of MEMS devices and in presenting the results of our work to management as well as funding agencies. It enables us not only to show a complete 3D image of the structure but also to animate the simulation results and evaluate the performance. This provides a virtual design review before production. HyperView also allows us to save the visualization in a compact slide-presentation format for later use, embedding the files in PowerPoint, when appropriate.

We also use our visualization tools for model analysis, zooming in and out to view the movement of connectors into sockets and their interlocked positions. Socket interconnects are the smallest parts of the entire assembly and are often hidden under larger parts of the structure. The viewing tools let us visualize the details underneath.

The Future: FEA in MEMS Design

It is clear that our analysis tools, which include Altair products, have played a significant role in our MEMS design. Furthermore, FEA simulation results will continue to give research engineers insight into the performance of our microassembled systems.

Recent advances in the application of Zyvex technology in the area of charged particle optics are driving further development. As we continue to push the envelope to build 3D MEMS structures of increasing complexity, we strive to develop devices that will enable new opportunities in nanotechnology. C2R

Aaron A. Geisberger is Staff Mechanical Engineer and **Zoran Jandric** is Mechanical Engineer, Zyvex Corporation, Richardson, TX.

To receive the Zyvex HyperWorks success story, visit *www.altair.com/c2r* or check 01 on the reply card.