MTO Composite CAD

Organization(s): Stanford University

Title: Advanced CAD System for Electromagnetic MEMS Interactive Analysis

Duration of Effort: September 1996 - August 2000

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Objective

Develop and demonstrate fully-integrated, FEM-based prototyping capabilities to model behavior of MEMS devices that includes fabrication details--materials dependencies as well as other process induced factors such as geometry effects due to deposition/etching. Demonstration based on analysis and design of canonical test devices (i.e. RF switch) that calibrates accuracy requirements for tools and parametric dependencies of geometry, process and reduced-order models. Develop materials extraction methodology, physical understanding and supporting data to address reliability issues such as plastic yield and fatigue. Develop integrated test vehicles, combining canonical and application-oriented prototypes, to provide critical evaluation of models, physical parameters and overall simulation accuracy of CAD for RF MEMS.

Progress/Results

- Report on characterization of electrostatically actuated micromechanical devices (Chan, PhD); unified set of measurements on RF MEMS canonical test (see above web page).
- Demonstration of integrated process/mask specification and geometry modeling capabilities; prototype Geodesic module compiled on multiple (see above web page).
- Report and comprehensive documentation (Cornella, PhD) of: Al (micro-)beam testing, procedures, equipment and data analysis used in fatigue application.
- Determined plateau stress by cyclic testing of Al beams; two-mechanism model and FEM implementation reproduces observed anelastic relaxation behavior.
- Fatigue/tensile tests and TEM characterization: stress relaxation observed in elastic regime; inhomogeneous deformation in plastic regime; sensitivity of grain size and Ti alloying.
- Low temperature (CMOS compatible) sputtered Si process demonstrated; issues of integration and MOS electrical characteristics documented (Honer, PhD).
- The design of a 4-level RF MEMS switches was completed and masks were made based on the designs from AFRL.

Status

- The work of E. Chan provides quantitative benchmarking of simulations for the RF switch and process/layout variables that impact design issues i.e. control voltage limits. G. Cornella's thesis shows first time Al (micro-)beam testing of fatigue, procedures of measurement, equipment used, data analysis methodology and a parameterized (FEM) fatigue model. K. Honer has explored new materials suitable for MEMS applications and demonstrated that low temperature sputtered Si provides an extremely promising integration path. This has resulted in a Stanford patent application collaborative work with AFRL (Hanscomb AFB) in design of masks suitable for SOS implementation. Finally, the Geodesic software module provides a first-time demonstration of combined MEMS specification and geometric modeling that allows inclusion of process dependent factors.

The ACADEMIA project has developed new prototyping capabilities for MEMS with emphasis on fabrication process dependencies--both materials and geometric. The demonstration vehicles used in this work have involved both test structures to quantify the critical factors and software for computational prototyping. The test structures work included the dual-electrode version of a RF switch shown in Figure 1. The switch was completely characterized and is documented in the Ph.D. thesis of Edward Chan. On the software side the Geodesic framework provides a vehicle for demonstrating interoperability, specific tool capabilities, and internet-based (remote) prototyping for MEMS. Figure 2 shows the framework architecture with Tcl/Tk as a front end along with the standardized input specifications (i.e. CCPDS and CIF). An object-oriented approach for module integration has facilitated the use of heterogeneous (academic and commercial) codes with different data representations. In addition to an efficient and robust method to create geometry using only solid modeling operations, Geodesic uniquely provides the capability to smoothly incorporate physically based 2-D and 3-D level set deposition and etching process simulation results into the geometry. The level set core is a powerful new module for handling processing changes to MEMS structures, for example the material-dependent etching sequence as shown in Figure 3. The generic solid modeler interface is essential for achieving interoperability with different commercial kernels. The two primary demonstrations of Geodesic for MEMS have been in creation of Comb Drive and RF Switch devices. Detailed examples can be found on the world-wide-web at http://www-tcad.stanford.edu/academia/.

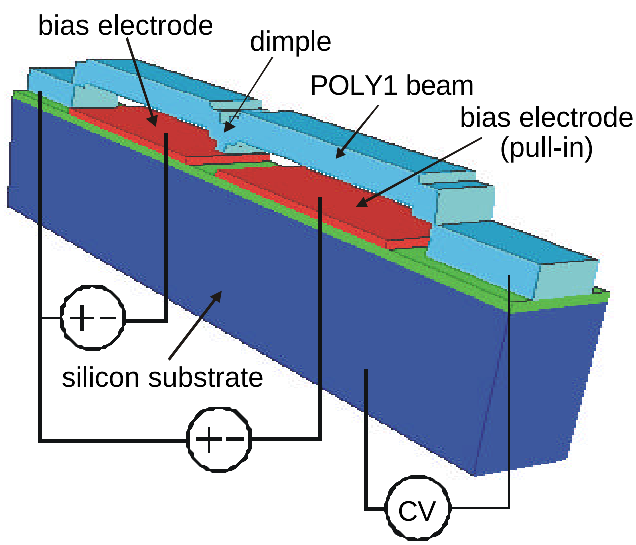

Figure 1: Dual electrode switch.

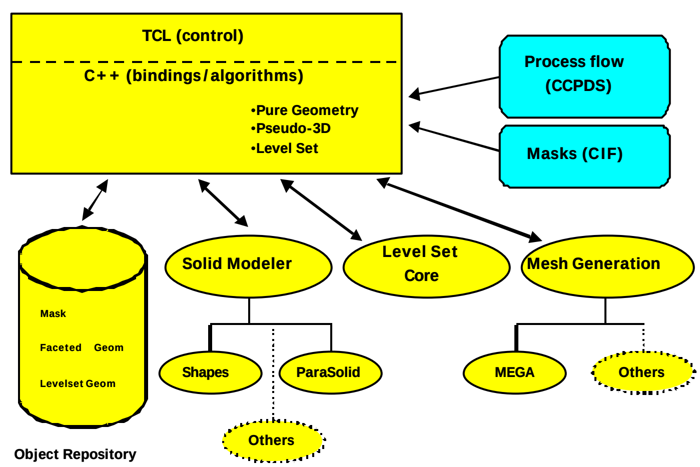

Figure 2: Geodesic Architecture.

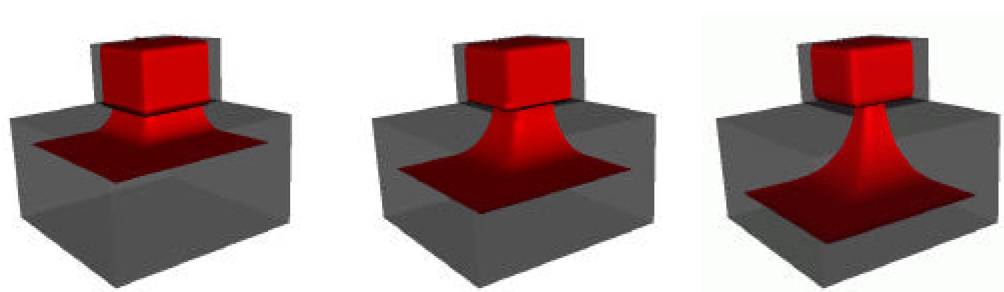

Figure 3: Example of a selective corner etch using the integrated 3-D Levelset kernel in Geodesic. The figure shows three steps in the evolution of the boundary surface, where the red surface indicates the level zero function. As can be seen, the small block on top of the larger block is more resistive to etch.