OVERVIEW OF ADVANCED MEMS DESIGN SYSTEMS

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Abstract: This paper presents state-of-the-art design processes for microelectromechanical systems (MEMS) devices in concurrent collaborative design environment. The design of MEMS integrated system will occur at the system level, driven primarily by the application. Methodologies that ease the integration of the digital domain to the real world using mixed domain technologies are therefore crucial. A hierarchical structured design approach is compatible with standard IC design. It starts with schematic capture of a design topology, followed by behavioral simulation, layout generation, parasitic extraction, and final verification. This flow is based on a process-independent design representation of commonly used MEMS building blocks, and process-dependent materials properties, design rules, and parasitic parameters.

Keywords: Design Kit, Design Suite, MEMS design, VLSI, Xplorer

I. INTRODUCTION

There are many factors which need to be considered at the design stage, for example, the size of component, the material to be processed and tolerance on dimensions [1]. While all processes have slightly different capabilities, there is also a large overlap; for many components there are a large number of processes which can be used. Methods and software tools for process selection stem from the more widespread use of computer tools to assist with material selection.

For a micro level product (i.e. MEMS) manufacturing process and material selection, no such system is yet available although there are several commercial MEMS design systems such as MEMCAD (now COVENTORWARE), IntelliSuite, MEMSCAP, etc, which support integrated modeling and process [1]. These systems have some functionality for MEMS designing process or contain some embedded modules for this purpose. In what follows is given an overview of the functionality of the above MEMS design systems in manufacturing process and material selection for MEMS devices.

Characteristics of an integrated MEMS design methodology can enable rapid design of low-volume custom MEMS include: supporting a wide class of MEMS design; being extensible to handle new MEMS concepts; supporting a wide variety of MEMS fabrication techniques; fitting into the existing VLSI design flows; and, having the capability to evaluate integrated system design [2]. A modular approach to MEMS design which addresses these requirements is being developed at Carnegie Mellon. The approach is underpinned by a library of elements that enables modular design composition. The library of elements has been created from the observation that today's full-custom MEMS designs tend to be decomposable to a set of common elements, parameterized by the design (layout) geometry.

II. MEMS DESIGN SYSTEMS

1. DESIGNER design tool

DESIGNER is Coventor's powerful front-end design tool for creating layouts and three-dimensional (3D) models of manufacturable MEMS devices [1]. From DESIGNER users/designers can create models for further analysis or export files for mask making and fabrication. Manufacturing processes and material properties can be added to create 3D models. The process emulator in it can emulate fabrication steps for MEMS devices and use standard processes of deposition and etching with control of bulk and thin-film geometries and materials [3]. The material properties database is used for proper identification of each process layer in the MEMS device. The layout geometry and fabrication process information are furnished for automatic 3D model generation and visualization [1].

2. IntelliSuite design tool

IntelliSuite takes a process-oriented approach to MEMS design and analysis, which starts the design process not from device geometry but from fabrication machine settings [1]. Incorporating process templates, material data, mask layout, and device analysis, it provides a platform for the entire design team to develop manufacturable devices. It is the only CAD for MEMS tool to address process parameters linked with thin film material properties [3]. Processes can be custom-designed one step at a time, or designers/engineers can draw from a wide range of foundry-ready process templates. Users can also create their own process flows from a database of over 70 process steps or by including custom process steps. IntelliSuite's process and materials databases have become a major MEMS resource [1].

3. Advanced Design System (ADS)

Advanced Design System (ADS) from Agilent Technologies is a tool used by engineers for a variety of design applications, such as RFIC, System, MMIC, Hybrid or Board level design [4]. In order to effectively use the design environment and to take advantage of its powerful simulation capabilities, designers must have a library of components that are linked to model files or simulation data.

For IC designers, the components and models are typically distributed by a foundry in the form of a design kit. A unique design kit is created for each process and each CAD tool. This kit is given to the foundry customer to use when designing their circuit.

Design kits in ADS are not only beneficial to IC designers. This library structure can be used for any technology or process to package and distribute a reusable set of components [4].

A design kit combines functionality and features of many parts of ADS.

An ADS Design Kit is a logical grouping of files related to a set of ADS components. The design kit structure is self-contained to provide easy transfer between different users or computer platforms. All component information needed by Advanced Design System is stored within the design kit [4].

At a minimum, a design kit must include a component definition file, schematic symbol files (unless built-in generic symbols are used), bitmap files for the component palette or a records file for the library browser, and information for the circuit simulator in the form of a model file, data file, or a schematic or netlisted subcircuit. Additionally, other optional files can be provided to extend the functionality of the design kit [4].

A design kit is a complex form of a library. A design kit built for external distribution needs to support multiple versions of Advanced Design System.

A design kit has a directory structure that is recognized by ADS and is similar to the directory structure for the ADS installation. All files are stored in specific directories depending on the type of file [4].

Figure 1 shows the directory structure of a design kit that provides a component palette and model data in the form of model cards or subcircuit models.

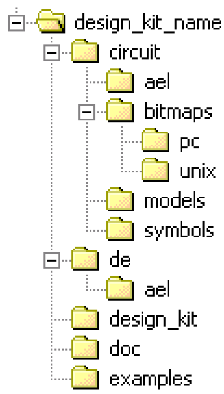

Figure 1. Directory structure of a design kit

As mentioned an ADS design kit is a group of files that is related to a set of ADS components, and which is self-contained for ease of transfer. The files in a design kit reside in specific subdirectories, collected under a directory that bears the name of the design kit itself. For distribution, the files are easily packaged into an archive file, in the .zip file format.

The directories and files that are required for all design kits are shown in Table 1.

Table 1. Directories and files required for all design kits

Directory	Description
circuit/ael	Component definition
circuit/symbols	Schematic symbols
design_kit	Template ads.lib file
doc	'about.txt' information file
examples	Schematic design file

4. *MEMSCAP (MEMS Xplorer and MEMS Pro)*

MEMSCAP offers two primary software MEMS design tool suites: MEMS Xplorer figure 2 for UNIX workstations and MEMS Pro figure 3 for PC operating systems.

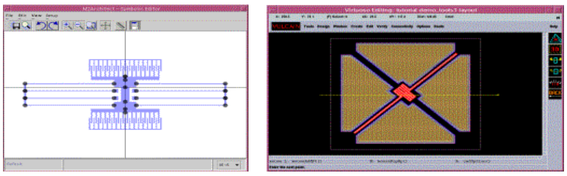

Figure 2. MEMS Xplorer

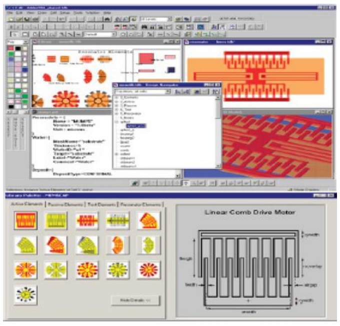

Figure 3. MEMS Pro

The two CAD software tools provide a system-level approach, enabling designers to develop new MEMS designs, integrate existing designs (intellectual property or IP), and couple them with the system electronics that will drive them [1]. The tool suites offer a comprehensive and customizable design environment for the development and testing of MEMS-based products. MEMSCAP CAD tools are open-platform products that support leading electronic design automation environments used for integrated circuit (IC) development. These tools allow data sharing between system designers, IC designers, process engineers and MEMS experts, permitting earlier and consistent design checks between multidisciplinary teams. MEMSCAP also provides modular subsets of these tools for those customers not requiring full capability. Each of the tool suites has easy-to-use graphical interfaces for rapid design. MUMPStart is an all-in-one MEMS design kit. MEMS Pro's built-in Technology Manager permits targeting of specific process technologies [1].

The technology setup for the MEMS Xplorer Design Suite includes:

CAD layer definitions and colors
GDSII / CIF output configuration
extraction rules
process definitions (layer thicknesses, etch times, ...)
material properties

This information is gathered in a single eXtensible Markup Language - Microsystems Technology Database ASCII file in order to simplify not only the data exchange but also the technology versioning [5].

a) Physical Design

A custom environment for MEMS physical design has also been created within the Cadence tool. The output of the physical design is foundry ready and can be sent to any foundry in CIF or GDS II format. The Easy MEMS tools allow the automation of time-consuming tasks (such as the automated generation of curvilinear lines) for the creation of MEMS mask layout. The Layer Release feature automatically calculates the positions of holes or dimples necessary to ensure the proper releasing of plate structures, for Manhattan shapes as well as shapes based on circular geometry [5]. The Easy MEMS tools also include specialized functions for the creation, and the textual and graphical edition of torus, comb fingers and polar arrays. These tools use a polar editing environment with a polar ruler.

MEMS Xplorer eases the generation of complex mask geometry including curved shapes through its automatic device generator libraries. Parameterized cell generators are provided for complete devices such as resonators and comb drives, as well as primitive building blocks and simple but often used geometry that may be combined to build up larger designs. These generators are graphically accessed via the MEMS Xplorer library palette [5].

5. WebMEMS-MASS

WebMEMS-MASS is a Web-based engineering reference tool for concept level MEMS designing process selection. Based on various input parameters provided by the remote designer, WebMEMS-MASS determines which manufacturing processes are most relevant to the input part [1].

A Web-based prototype advisory system for the MEMS designing process WebMEMS-MASS, is developed based on the client–knowledge server architecture and framework to help the designer find good processes for MEMS devices. The system, as one of the important parts of an advanced simulation and modeling tool for MEMS design, is a concept level process and material selection tool, which can be used as a standalone application or a Java applet via the Web [1].

III. CONCLUSION

One of the challenges of MEMS technology is that MEMS devices or systems design must be separated from the complexities of the fabrication sequence and packaging processes with consideration of different materials and processes.

The MEMS Xplorer modules are completely integrated in the Cadence environment making it very easy to learn and to use.

MEMS devices could be represented with multi-physics signals in mechanical, thermal, magnetic, fluidic, optical, and electro-static domains in Verilog-A.

The library of elements could be created from the observation that today's full-custom MEMS designs tend to be decomposable to a set of common elements, parameterized by the design (layout) geometry.

The characteristics of an integrated MEMS design methodology can enable rapid design of low-volume custom MEMS supporting a wide class of MEMS design.

IV. ACKNOWLEDGEMENT

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