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Micro Device Modeling Method and Design for Manufacturability

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Abstract

The micro device designing flow begins with the mask design currently, which is not intuitive for designer and sometime made them confused. As a result, the manufacturability is hard to prove in advance with the traditional designing way. Especially for surface micro-machined device with multiple structural layers, the 2D mask design cannot ensure the fabrication of complex 3D device with high yields reliably. The rise of structural designing strategies gave a direction to change the traditional habit. On the other hand, the top-down method provides the advanced designing flow, which begins with the system level design. However, there still some key technologies to study further because of the novel design procedure. To improve the manufacturability of micro device, the designing flow based on design for manufacturability methodology is presented, which draw on the advantages and experience of the mechanical design method. The key technologies on the structural design level, the processes planning level and the fabricating level are introduced correspondingly. In addition, we present the framework to implement the method.

Keywords*: design for manufacturability, micro device, optimal design, computer aided design*

1. Introduction

Along with the increasing demands, the most challenge faced in micro device area is the marketization. The traditional designing flow is derived from integrated circuit fabricating processes, which is bottom-up flow and summarized as mask-to-shape-to-verify [1]. Taking the more complex structure into account, it makes the micro device designing process poorly intuitive and unreliable. Especially for surface micromachining, it is too much for the designer to confirm all the processes of multiple layers in advance. Furthermore, the more complex structure and constraint will make this situation worse. Therefore, it is the advanced designing flow to begin with the 3D model from which the fabricating information is derived [2, 3]. Because this designing flow is inverse in contrast with the traditional one, however, how to build the relationship between designing model and the fabricating process becomes an important step to improve manufacturability. It is also the key point of the top-down design methodology [4].

The mechanical designing tools are more mature, which, although belonging to different region, afford lessons meriting attention [5]. Because the fabricating characteristic, the tools evolved from integrated circuit design are still popular [6, 7]. To overcome the shortcoming of those tools, the top-down design method is proposed, which currently faces many challenges [8]. Implementing DFM (design for manufacturability) is conducive to improve manufacturability, which is also the key challenge to realize the top-down method [9]. However, how to comprehensively introduce the design for manufacturability method into the micro device design with the standardized processes is still require study further [10, 11]. With respect to model construction, the feature technology in micro device modeling improves designing efficiency [12]. With the method, in some instances, even the mechanical tools can be used to improve designing efficency [13, 14]. Nevertheless, because the characteristic of the micro fabricating, there is still no method effective enough to combine the feature technology with the processes generation. Current works focus on system level modeling and simulation [15, 16]. Where the overall designing flow of micro device is concerned, there are much more research of solving problem of “function-to-shape” than research in the stage of “shape-to-mask” [17]. In fact, the latter is the key point to improve manufacturability. To introduce the design for manufacturability

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idea into the designing flow of micro device, the framework and according key technologies are presented in this paper.

2. Modeling Methods Evolvement and Tools Development

The deficiency of the traditional designing flow is illustrated in Figure 1.

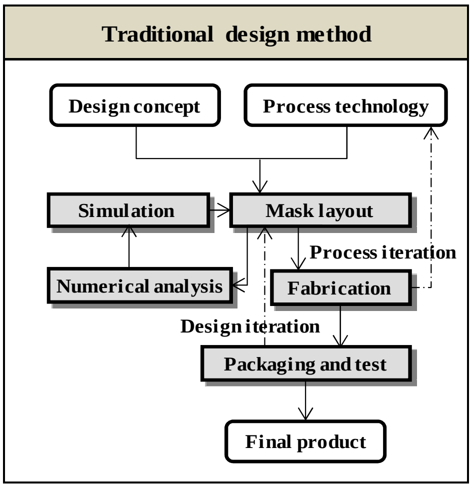

Figure 1. The Traditional Designing Flow

The traditional design method begins with mask layout design. On one hand the process is concerned in the early stage, on the other the consequent two iterations make designing work time-consuming and inaccurate. In constrast, illustrated in Figure 2, the structural design method is more convenient for designer.

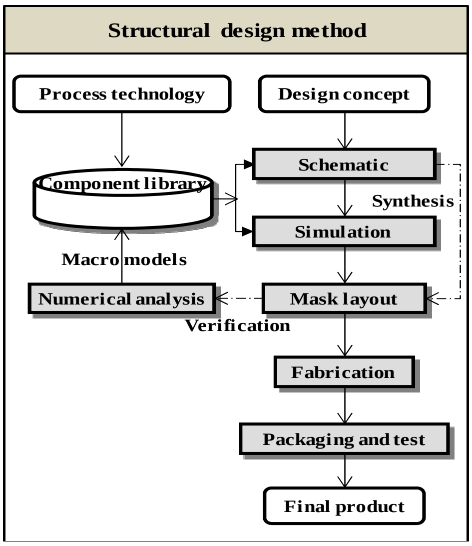

Figure 2. The Structural Design Method

For structural design method, the component library and schematic synthesis improves the designing efficiency. However, the problem to improve manufacturability emerged because of the new flow of simulation-to-mask-to-fabrication. How to improve the manufacturability according with the advance high level modeling method still needs further study. To ensure better manufacturability, the DFM-oriented top-down design method is presented as shown in Figure 3.

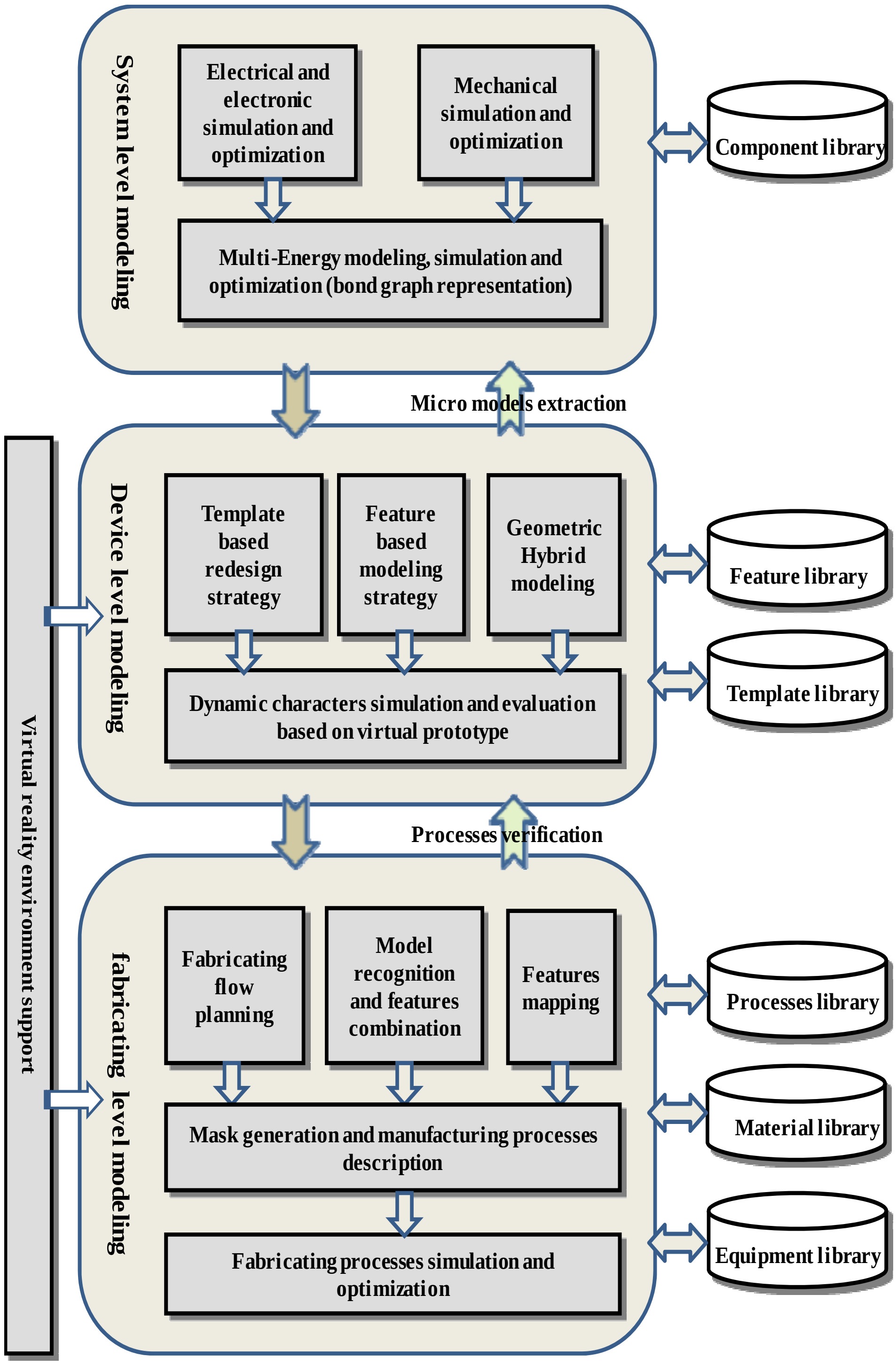

Figure 3. The Three Levels of Top-down Design Method

The first level is system level designing, which deals with simulation and optimization of both electrical and mechanical components. As the effective way of analyzing the troditional mechanical structure, the multi-physics simulating method is introduced into the area of micro device [18]. To perform the task of modeling and simulation of multi-energy domain, bond graph is applied on the support of components library. In the device level modeling, the 3D model of micro device is constructed. Three ways are supplied to build the model. If the structure of the new designing instance is similar to the template, that is, the codes of the new sturcture matches the codes retrieved from the template library on the basis of Neural Networks technology, the parameters of the template are revised to construct the new model. For example, a series of micro spring can be constructed with facility by means of the parametric template. The actual structure of the spring agrees with the desired one and conforms to LIGA technology [19]. While for those not matching any template, the parametric features are provided to build the model. These features are revisable 3D elements satisfying the intuitive modeling habit, which are stored in the flexible and extensible feature library. Taking the complexity of device into account, the hybrid modeling method is also permitted to deal with arbitrary structures. After model construction, the dynamic characters simulation and evaluation is performed based on virtual prototype method. Finally, the fabricating level modeling happens, which is completed in a features mapping way. For surface micro-machining, the procedures of features combination and fabricating flow planning are followed to carry out the layering operation. The information of mask is derived from the 3D model by means of geometric algorithm. With the derived process model, the corresponding simulation and optimization is finished before fabrication. To improve the intuition of modeling processes, the virtual reality environment is constructed to support the latter modeling stages. At the same time, the two feedbacks between different levels provide better manufacturability.

3. Design for Manufacturability in Micro Device Designing

To introduce design for manufacturability methodology into the designing process of micro device, the stages involved are taken into account to provide the overall constraint. Besides the conceptual designing stage, there are three stages in designing cycle, in which the DFM elements work to cooperate with the top-down designing flow. The main factors to apply the design for manufacturability strategy are as follows:

1) Structural design stage

Above all, the models are constructed with feature technology. The functional and structural models consist of functional components and structural features correspondingly. These features themselves possess good manufacturability in a sense. When combined together, however, more constraint should be taken into account. The designing rules are based on MUMPs standard, which is a commercial program that provides cost-effective, proof-of-concept MEMS fabrication. For the devices that are common to use, the templates are built up to make the models of these devices parametric. When new designing task comes, it is compared with the templates firstly. The similar instance is retrieved from the library, which is parameterized to accommodate to the new task. As for the templates, each of them has good manufacturability by means of the constraint on the adjusting limit of the parameters.

2) Processes design stage

In the processes design stage, the mapping relationship between designing model and process model is constructed. The designing model is based on hybrid modeling representation technology. However, the overall consideration of fabrication is insufficient with the original designing model. When mapped into process model, which is organized with process features, the constraint features based on standardized processes take essential effect to improve manufacturability.

3) Test and fabricating stage

Before fabricating, the geometric and physical simulation is carried out to verify the manufacturability of the previous models. The consequent feedback directs the revision process. Together with the feedback occurring in processes designing stage, they constitute the feedback flow of the designing circle.

The design for manufacturability strategy in different stages is illustrated in in Figure 4.

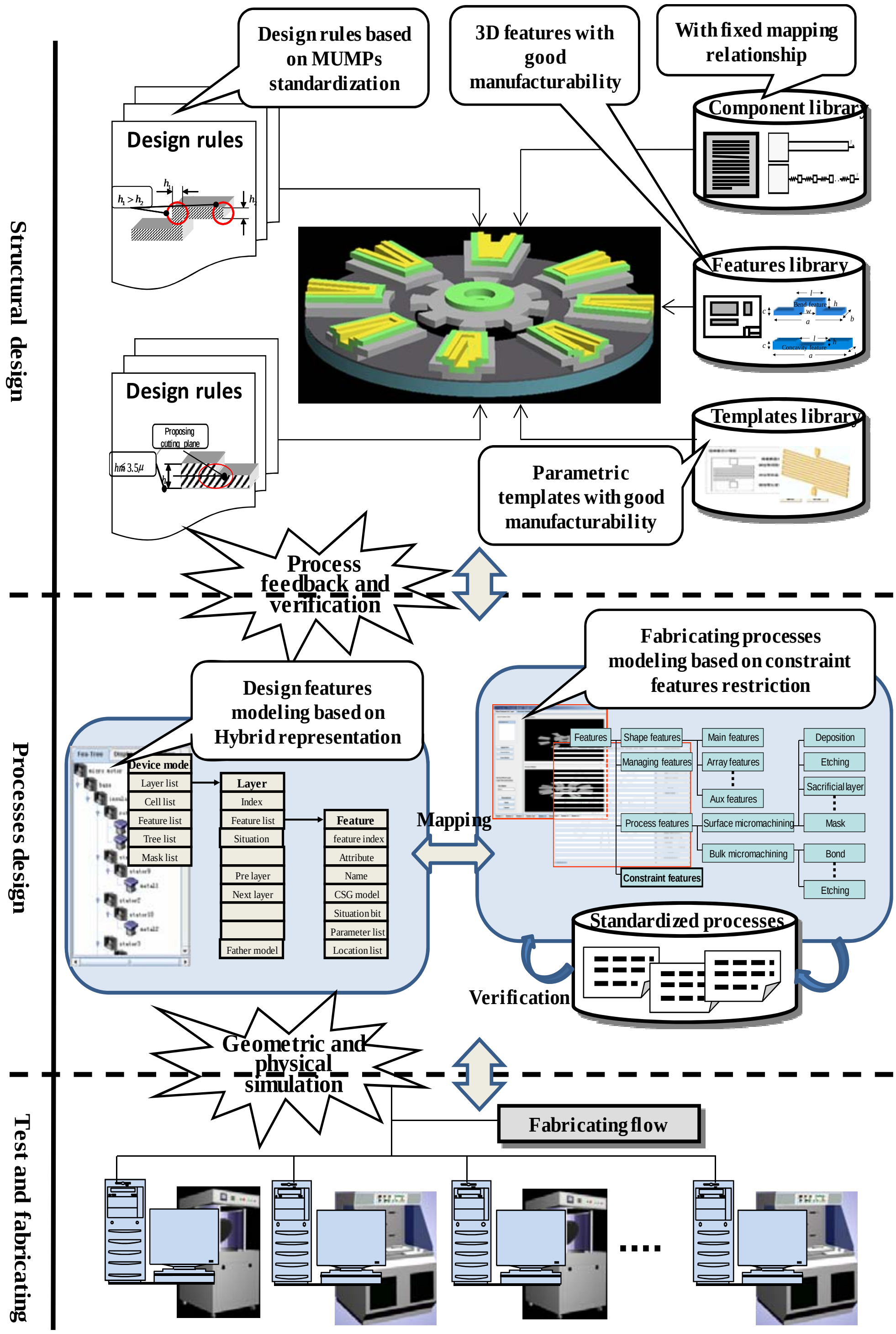

Figure 4. The Design for Manufacturability Strategies

4. The System Framework

To implement the DFM-based designing method, the framework is illustrated in Figure 5. The modules are arranged in the cooperative designing environment with distributed database.

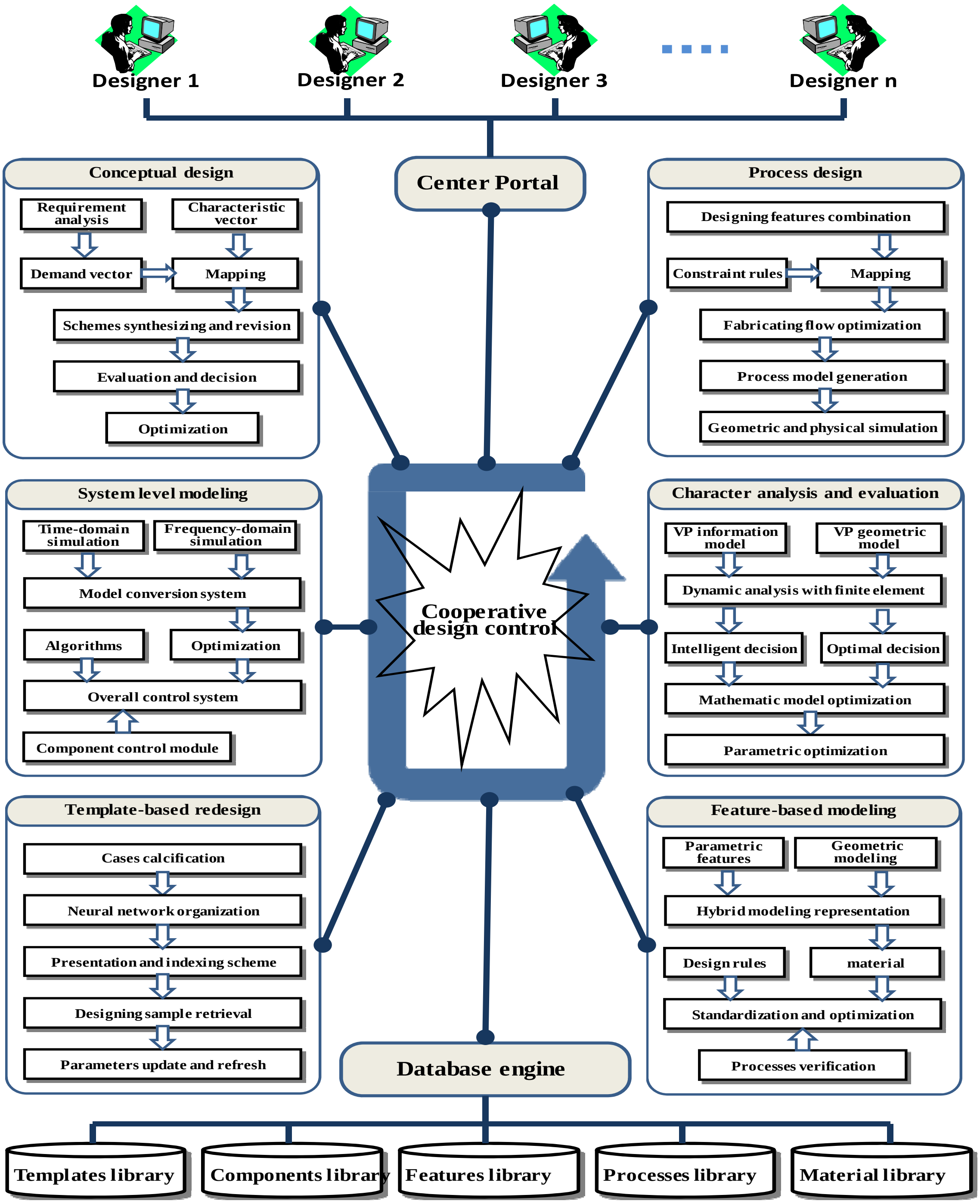

Figure 5. The Framework and Modules of the System

1) System level design

The functional model is constructed with bond graph method. After the simulation in time domain and frequency domain, the model is optimized by control system. Based on mapping algorithm, the functional model corresponds to structural model.

2) Template-based redesign

The previous instances are parameterized and coded storing in template library. After classifying the cases, the template system is organized by neural networks. When new designing work coming, it is retrieved from the library to find the matching template. After parameters revising, the model is update. The system does not need to match the instance absolutely. The mismatched parts can be built with other ways.

3) Feature-based modeling

The parametric features are used as the fundamental components to build up the 3D structural model. For those parts that are too irregular to match features in library, the geometric modeling way is provided to construct the appearance, which relies on the geometric elements and modeling commands. The structural model is the feature-based hybrid representing model.

4) Processes design

The designing features combination procedure deals with the construction of layer information for surface micromachining, in other words, how the features are combined together as one layer. The process features is fabricating-oriented, such as etching feature, depositing feature and sacrificial layer feature. The mapping relationship is built between the different kinds of features. Meanwhile, the unreasonable structures are revised in accordance with the constraint features to improve the manufacturability.

5. Conclusion

The design for manufacturability method for micro device is explored and proposed. Above all, this paper gives an overview of the modeling methods that are considered to be the critical components of designing theory of micro device. With the indication of how designing method evolves, the key technologies to implement the micro device design for manufacturability are presented. This enables designers to model the device more efficiently and intuitively, especially for complex surface micro-machined device that has multiple layers. As a result, the geometric model fulfilling the fabricating requirements is efficiently generated and mapped to fabricating model. Besides improving manufacturability of designing model, the method helps reduce produce development circle beyond the traditional design flow.

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