Design for Manufacturing integrated with EDA Tools

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ABSTRACT

In this paper a process planning and optimization tool, which can be linked to commercially available EDA tools, is presented. A data model was developed, which can be used for product and process design, simultaneously. The main advantage of the system is that arbitrary technologies can be used to build process flows, as a knowledge based validation system ensures the validity of the produced process plan before manufacturing. Being able to combine new materials and technologies with established process flows makes a specific optimization of the overall process possible. A multi-criteria selection method was adapted for the use within microtechnological process chains. This method helps a designer to choose the right technologies for a given problem and is described in detail.

Keywords: design for manufacturing, technology rating, knowledge database, multi-material MEMS, T-CAD

1 INTRODUCTION

The increasing variety of available fabrication technologies and materials for microtechnological devices make the design process more and more demanding. Engineers are no longer bound to only functional aspects of the design but also have to meet cost targets and optimize the process flow itself. A data model was developed, which can be used for product and process design, simultaneously. This data model is accessed by the designer through a process editor [1]. This editor can also be used in fabrication to document the process results and herby guaranty that all relevant data is preserved for later use in quality management (Figure 1).

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Whenever standard MEMS libraries, which are based on fixed foundry processes, are insufficient for a new design, layout and process design can be performed simultaneously (Figure 2). A layout editor is connected to a building block database [2]. Single building blocks, which contain a layout and a process model are used to design multi material micro systems. The single processes are merged using an interactive algorithm [3].

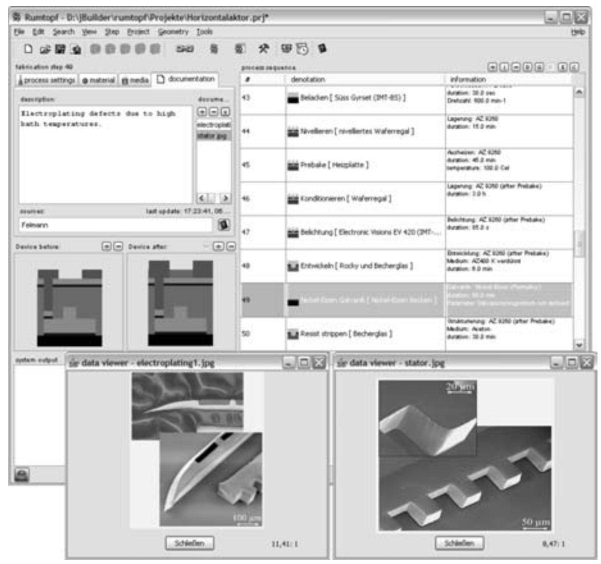

Figure 1: The process flow is edited and monitored in a single tool.

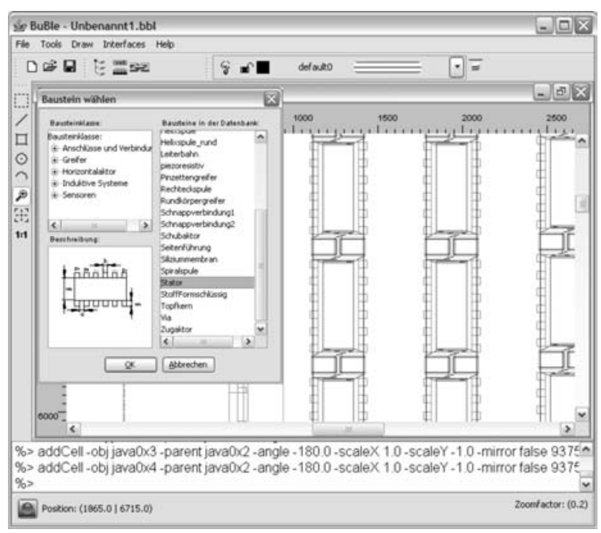

Figure 2: Layout and process are designed simultaneously using a building block editor

Once a satisfying process flow and a design rule compliant layout has been developed, the information can be transferred to SoftMEMS, MEMSPro or Coventor Designer at the push of a button (Fig 3). This enables the designer of microsystems, which are not based on foundry processes, to use the full functionality of specialized MEMS simulation tools for a detailed analysis of the behaviour of the proposed system.

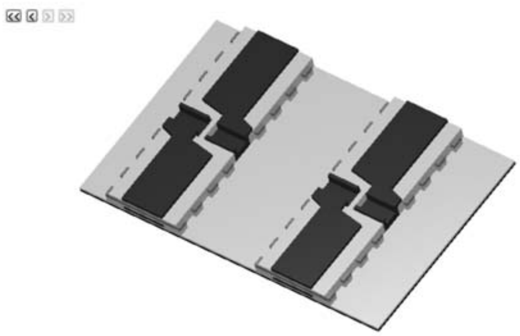

Figure 3: At the push of a button the data is transferred to Softmems MemsPro 3-D Modeller.

Another important feature of the presented system is the connection to specialized process simulators for the wet-chemical or dry-etching of silicon or UV-lithography. Whenever it is crucial to get a more detailed view of the process result such specialized modules are used.

Being able to combine new materials and technologies with established process flows makes a specific optimization of the overall process possible. A multi-criteria selection method was adapted for the use within microtechnological process chains. This method helps a designer to choose the right technologies for a given problem. For example might such factors as the lot size or overall budget influence the choice of technologies and the system assists a designer make the right decision.

The next section of the paper will focus on the description of the rating method.

2 TECHNOLOGY RATING

There are several methods for the rating of single technologies known from literature. All methods can be divided into methods on the operational or the strategic level of technology rating. The strategic level is used for predicting technological impact and market placement for innovative technologies. Such methods are portfolio technologies, s-curves or life cycle models [4].

However, all the strategic methods do not take detailed technological boundary conditions into account. For selecting technologies in existing production scenarios a more detailed view on technologies is needed. Typically methods on the operational level deliver the means to perform a detailed rating for a given problem. One suitable method for the use in microsystem technology is a fuzzy based, analytical hierarchy process as it was introduced by Eversheim [5] for process chains in classical mechanical production environments. He used linguistic fuzzy sets to describe the compliance of technologies with a predefined set of criteria. The use of fuzzy sets makes the mathematical analysis of diffuse information possible. The mapping between a linguistic term and a fuzzy number makes the input for the user easy and comprehensive. Figure 4 shows the use of such linguistic variables for the states exactly 5, approximately 5, between 2 and 8 and approximately between 2 and 8, respectively.

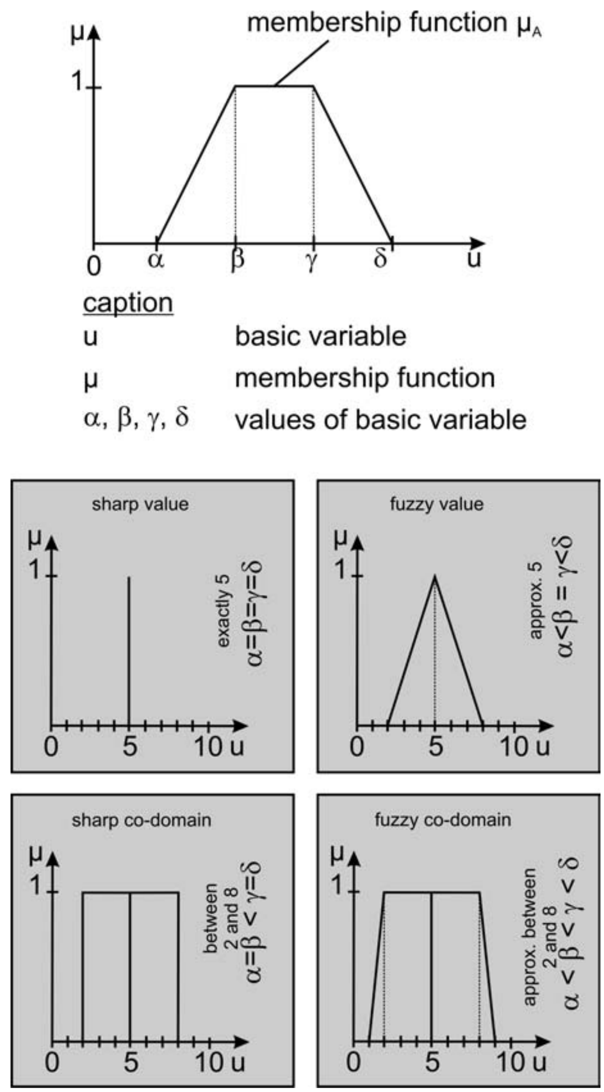

Figure 4: Fuzzy sets can be used for the input of diffuse information and later can be mathematically analyzed to calculate a score for a certain technology.

Eversheim defined a set of criteria, which form the portfolio. All single criteria can be assigned to one of the main parameters 'technological attractiveness' and 'economic benefit'. The criteria for these main parameters will be discussed in the next subsections.

2.1 Economic benefit

This main parameter can be subdivided into three parameters which are influenced by certain criteria, each. These parameters are: economic potential, qualitative benefit and costs of implementation. In microtechnology one can assume that not all process steps are performed within the company, but some are purchased from third party providers. For example, it is common practice that electronic components of micromechanical sensors are fabricated using foundry processes and only the structuring of the mechanical components as well as the packaging is accomplished in the own company. This results in an adaptation of the criteria structure. The 'economic potential' is largely dependent on costs of logistics and lot sizes. Investments are not necessarily a determining factor for the 'costs of implementation', as processes can be purchased from third party suppliers. On the other hand the training effort plays an important role, because employees have to be trained on design rules and the development tools of the suppliers. Looking at the parameter 'qualitative benefit' the transfer of know how is a crucial criteria as the company has to exchange designs with third party suppliers.

2.2 Technological attractiveness

Due to the technological restrictions in microsystem technology the ability to use a certain process is largely dependent on material properties and geometrical boundary conditions. To avoid the elimination of too many processes in early design stages it proved to be inadequate to constrict processes to a certain material. The ferromagnetic core of a fluxgate sensor could consist of several different foil materials, which can be mechanically structured. On the other hand electroplated or sputter deposited permalloy could be used. For the function of the sensor only the material properties are crucial not the material itself. Which material and process combination should be used is depended on all other criteria of the rating. This means that for the parameter 'technological feasibility' the restriction to geometrical data is sufficient to constrict the number of possible technologies. The 'technological potential' can be described by the same criteria as suggested by Eversheim. Special focus has to be given to the parameter 'environmental compatibility', as many of the microtechnological processes make use of poisonous and environmentally hazardous substances.

2.3 Criteria structure

The criteria structure for microtechnological processes is depicted in figure 5. Criteria, which come to the fore in this context, are highlighted in bold letters. This approach uses the technology database (ProcessDB) of the design environment to access technologies which already contain criteria regarding the 'technological attractiveness'. Other criteria can easily be integrated into the database by extending the parameters, which already describe the technologies. Unlike the technological parameters the company specific benefits cannot be extracted from a central technology database. The benefit will vary for a single technology depending on the company. Therefore, a criteria database should be implemented, which only provides links to the technology data.

The next section will describe how the described criteria structure is used to evaluate technologies and place them into the portfolio.

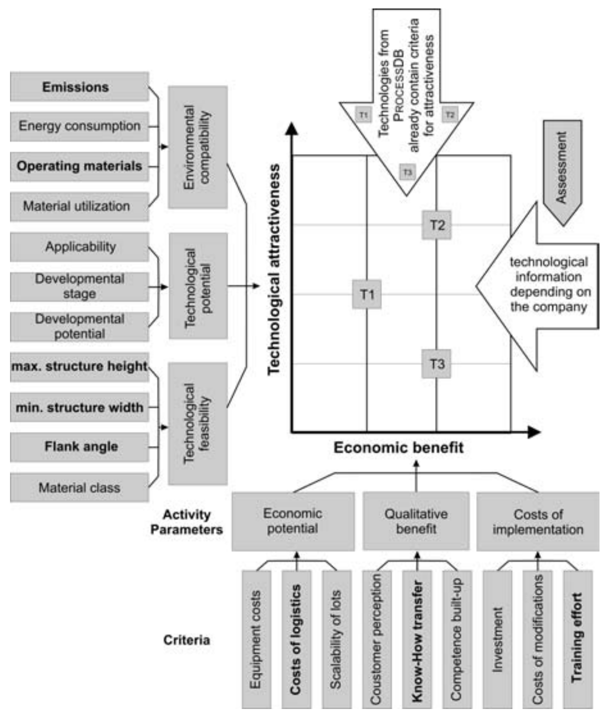

Figure 5: Criteria structure for the rating of microtechnological processes.

2.4 Merging of criteria and rating

All criteria, which describe an activity parameter are weighted and evaluated by the user. For this purpose the user inputs the weight and compliance by linguistic fuzzy sets. The weight of criterion j is given by $w_j = (\alpha_j, \beta_j, \gamma_j, \delta_j)$ and the compliance of an alternative i is specified by the fuzzy number $r_{ij} = (\alpha_{ij}, \beta_{ij}, \gamma_{ij}, \delta_{ij})$. The value of an activity parameter A of an alternative solution i can be calculated by a fuzzy-multi-attributive method according to equation 1:

$$A_i = \frac{\sum_{j=1}^{n} w_j r_{ij}}{\sum_{j=1}^{n} w_j} \quad (1)$$

The resulting activity parameters are then mapped to a rule based rating system as it was introduced by Traeger [6] for fuzzy control systems. This system determines the influence of each single activity parameter on the benefit and the attractiveness of the technology under investigation. Figure 6 shows the rule based rating method for the attractiveness of a technology as an example.

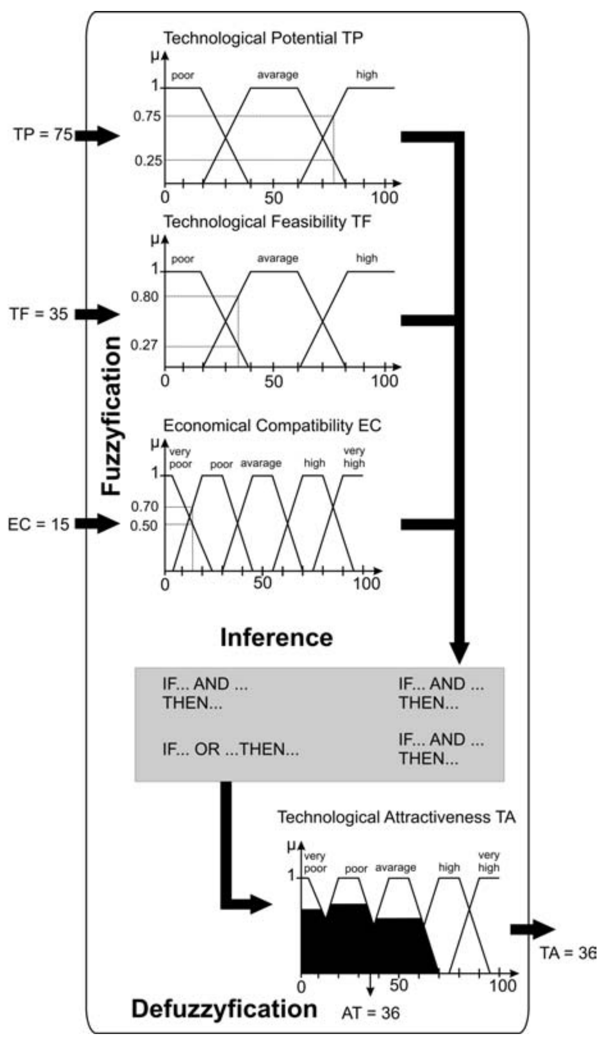

Figure 6: Rule-based rating of individual activity parameters [6].

All rules, which are used by the inference mechanism, are configured using certain fuzzy sets. As the rules are configured only once, the fuzzy numbers that result from equation 1 cannot be used directly. They must be defuzzyficated and then mapped to the predefined sets. The main advantage of this system is that complex rules can be stated without using mathematical expressions. This again is achieved by the use of linguistic fuzzy sets and simple if-then statements. After using the inference mechanism a defuzzification method, e.g. the center of gravity method, leads to a sharp score of an alternative. The sharp values for attractiveness and benefit can then be used to place a technology into the portfolio.

3 SUMMARY AND PERSPECTIVE

A software environment for integrated process and layout design was presented. Due to the capabilities of the system to validate process flows an optimization of process chains by substituting single processes is possible. A method for the rating of the most suitable process for a given design at certain economical boundary conditions was developed. This system uses a fuzzy-based analytical hierarchy process. A special criteria structure for the use in microtechnology was developed and presented.

To make use of the presented method a user interface has to be designed and a data structure for storing company specific criteria will be implemented.

4 ACKNOWLEDGEMENT

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