

Web-based Design Tools for MEMS-Process Configuration

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ABSTRACT

The micro electromechanical systems (MEMS) industry is characterized by small and medium sized enterprises (SMEs) specialized on products to solve problems in specific domains like medicine, automotive sensor technology, etc. In this field of business the technology driven design approach known from micro electronics is not appropriate. Instead each design problem aims at its own, specific technology to be used for the solution. The variety of technologies at hand, like Si-surface, Si-bulk, LIGA, laser, precision engineering requires a huge set of different design tools to be available. No single SME can afford to hold licenses for all these tools. This calls for a new and flexible way of designing, implementing and distributing design software. The Internet provides a flexible manner of offering software access along with methodologies of flexible licensing e.g. on a pay-per-use basis. INTERLIDO is a tool suite for process specification and layout verification for lithography based MEMS technologies to be accessed via the Internet. The first version provides a Java implementation of LIDO-PEdit, a graphical configuration system for process step sequences. The implementation is based on JavaBeans component technology.

Keywords: MEMS physical design, process configuration, INTERNET tool access, component technology, JAVA.

MODELS OF PHYSICAL MEMS DESIGN

Micro system technology promises to be one of the key technologies for the 21st century. As it is the case for all highly complex technical systems computer based design support is mandatory for this. Concerning the design support for this field we currently face the following situation:

- There is a strong need for design support and an even stronger lack of such tools at this point of time.
- The structure of the industry concerned with design and production of micro system technology products comprises a prototype of the emerging industry for microsystems.
- The design style is problem-oriented - as opposed to the technology oriented design style known from today's classical microelectronic systems design - which turns out to be the appropriate approach for microsystem design.

In the area of physical microsystem design that in lithography-based technologies is concerned with the design of mask layout geometries, the typical design cycle is dominated by the fact that the three-dimensional nature of the products calls for a particular sequence of processing steps and parameters to be specified for each design object. This results in the *circle model* for MEMS physical design. It is characterized by the following circular design flow:

- *Generating activities* creating the mask layout geometries for the design object and the specific process step sequence to be performed in order to generate the appropriate orthogonal extension of the design object during production. The of process step specification part will be in the focus of this paper.
- *Checking activities* deriving a consistent set of design rules from the process sequence and applying it to the mask layout in order to find rule violations. If violations are detected, the design will have to be modified.
- *Changing activities* used to determine what sort of changes will have to be made in order to turn the design into a correct version. This may include mask layout changes, process specification changes or changes in the higher level design.

For more details of the circle model, see [1,2]. Figure 1 gives an alternative view of this model, showing the design flow as two concurrent interwoven circles of layout and process design. The process editing tool to be presented shortly is used to support the process design cycle.

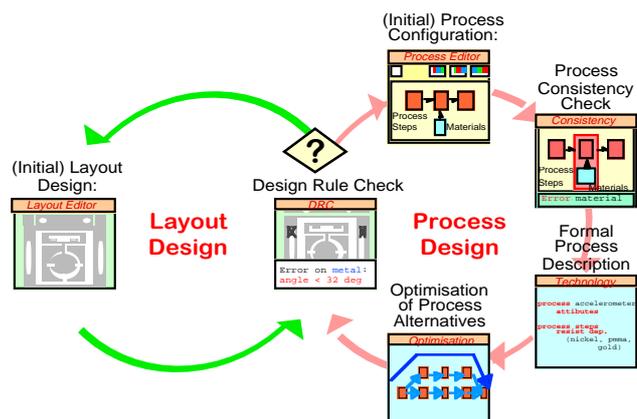


Figure 1: MEMS physical design flow

Each of the steps shown in this figure can be supported by specific design tools. Each of these tools is an independent software module, used to assist the user in a particular subtask of the whole design cycle. The degree of automation provided may differ substantially for each of the tools. The term *assistants* is used to denote this sort of independent software modules. The LIDO-system presented in the following section thus can be regarded as a collection of weakly interacting assistants.

(INTER)-LIDO-MEMS DESIGN SYSTEM

Currently there is hardly any CAD support for the design process as described. A prototype approach for design verification based on the recognition of design properties restricted to LIGA technologies is presented in [3]. Except design capture tools (like AutoCAD) there are no dedicated commercial tools for microstructure design today. The tools used for microelectronics IC design are based on fixed technology data accessed via design rule interfaces. The user has no opportunity to influence the fabrication process. Correctness with regard to process or layout rules as a result of this tool configuration can only guarantee that the following fabrication of microstructures can be performed without running into problems caused by design errors.

The LIDO system is the first approach to physical design support that takes the requirements of microstructure design into account [4]. On the one hand LIDO provides means to determine the technological process to apply in order to fabricate the designed microstructure in LIGA or silicon techniques. On the other hand the mask layout can be verified with respect to design rules derived from the process configuration.

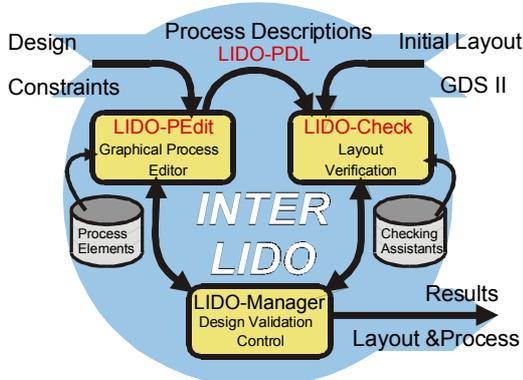


Figure 2: INTERLIDO system overview

The system as a whole is composed of a set of assistants. It consists of a common user interface and a common technology and geometry database, both combined in the *LIDO-Manager*. Fig. 2 shows a system view of the LIDO system. The user interface offers two major applications: *LIDO-Pedit* - the graphical process configuration editor and *LIDO-Check* - the microstructure design rule checker.

Currently the LIDO-system is completely re-implemented as componentware to be accessible via the Internet. The benefits of component based software with

Internet access capabilities especially for MEMS design tools will be presented later in this article.

THE PEDIT PROCESS EDITING TOOL

LIDO-Pedit enables the configuration of a process sequence considering the requirements of the specification and the layout design of the intended microstructure. The process arrangement is performed graphically in an editor window. The user selects and arranges icons on the editor window representing design process elements like process steps, materials etc. from libraries based on the specific design task he/she is performing. Icons can graphically be connected to complete process sequences. Each icon is assigned to process or technology data such as design rules, process parameters or economic properties. This data is provided by process experts using the process description language LIDO-PDL. [5]

LIDO-Pedit additionally provides the option to check the current process configuration for consistency (like compatibility of process steps or materials, sequence rules, assignment rules etc.). This check is normally necessary because the designer need not to know internal properties of all process elements. As alternative process branches are possible to describe (e.g. in case of alternative process sequences for different machines) an optimization is provided to find the optimum flow with respect to predefined objective functions (e.g. cost, time etc.). This reacts to the demands of designers who want to learn about the economic implications of a process layout as early as possible. [6].

LIDO-Pedit consists of

- the graphical user interface that provides the editing windows used for selecting process icons and arranging them into process sequences,
- a process module library containing LIDO-PDL representations of generic process elements that are linked to the editing icons
- consistency checking modules used to assure that only valid process sequences can be used to generate LIDO-PDL process descriptions
- LIDO-PDL generation routines turning a given consistent process sequence into a LIDO-PDL process description, if desired in an optimized fashion.

Figure 3 shows an overview of the LIDO-Pedit system. The modular system structure lends itself to a component-based implementation.

The modular software structure of LIDO-PDL, however, keeps transparent for the user, who will only be provided with the user interface that looks like the example given in Figure 4. It is roughly the same for the original version of LIDO-Pedit and for the new one that makes INTERNET access possible.

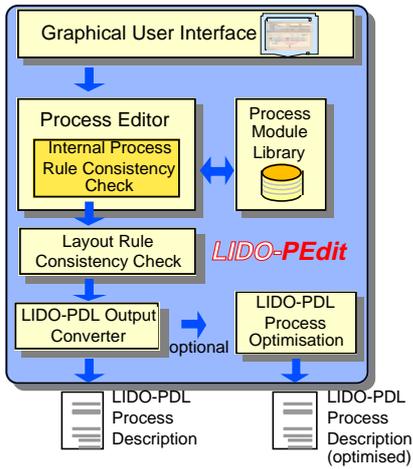


Figure 2: LIDO-PEdit system overview

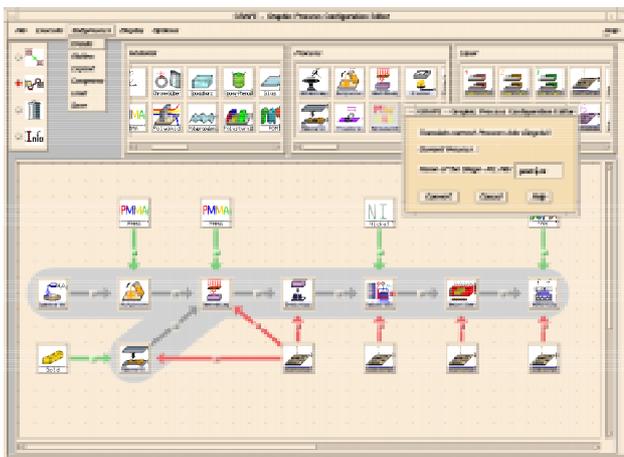


Figure 3: LIDO-PEdit session screen shot

COMPONENT TECHNOLOGY

As has been pointed out in the previous chapters in micro engineering the design process has to be tailored towards every specific design object. As a consequence of this, specific design assistants have to be selected for each design task and especially adapted towards the restrictions to be met in each particular case. To achieve this, component-based software design is currently the method of the choice. It is targeted towards realizing so-called *software components*, executable pieces of software with a clearly defined interface, defined interoperability- and autonomy criteria, as well as the proof of reusability [7].

Componentware is generally understood to be a collection of interacting components. Design assistants in INTERLIDO are realized as componentware based on the component technology *JavaBeans* by SUN Microsystems. JavaBeans is a platform independent component architecture for the Java Application Environment [8]. Fig. 4 shows the general procedure to be followed during component-oriented software development. The *component developer*

implements a set of software components, *the application developer* configures these components in an application dependent manner and connects them to form complete applications. The customer, finally, is able to perform minor configuration modifications. The term “Application Family Engineering” denotes the development of a complete framework of components useful for a specific set of applications, like, e.g. micro engineering physical design. An important precondition for a useful set of components is that they are well-adapted to each others.

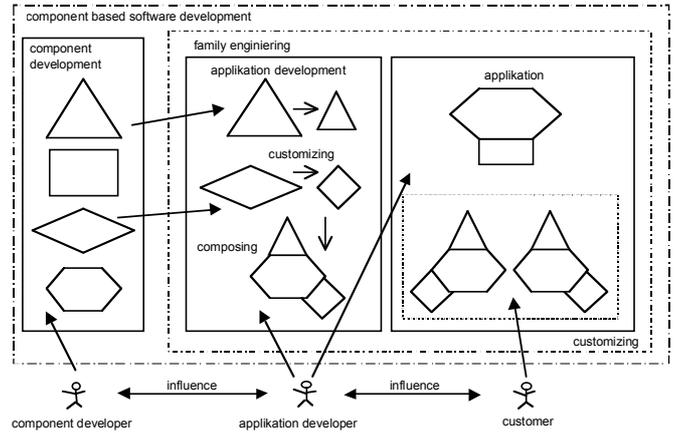


Fig. 4: Steps of component based software development

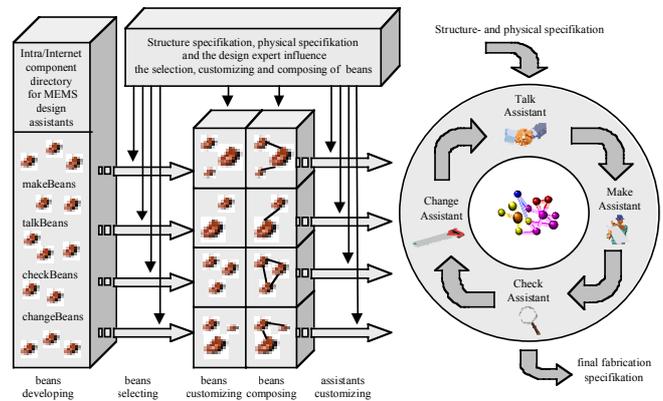


Fig. 5 Component based design assistants

Fig. 5 shows an integrated view of the circle model for MEMS design. The Intranet/Internet component directory for physical MEMS design assistants contains various beans for the basic tasks to be performed during design. They are the building block for the process of dynamically generating design assistants. The selection, configuration, and composition processes are controlled by the given formal specification of the design object and the knowledge of the design expert. At the end of this process there are design assistants that will be selected based on the design re-

restrictions at hand, and that will be used as componentware to support the design process.

For design assistants and their components different licensing scenarios may be applied. Components might be freely accessible to be downloaded via the Internet. After downloading the user might use the component freely, restricted to a certain range of time, or for a fixed number of times. This provides especially SMEs with a possibility to create proprietary MEMS-Beans, hence commercializing their know-how on some kind of pay-per-use regime. At the same time component technology offers an interesting opportunity for various cooperating software development scenarios, either between industry companies, or companies and research institutes.

The INTERLIDO is a first prototype of a component-based MEMS physical design tool. At this point of time the dynamic creation of problem-oriented beans has not yet been realized. INTERLIDO is currently used to demonstrate the robustness of a component approach and to show that it can really be useful and not prohibitively limited from a performance point of view, to provide tools that operate merely based on JAVA across the Internet. In addition not all of the LIDO components have been turned into components by now. LIDO-PEdit is the first part that is available based on this new technology.

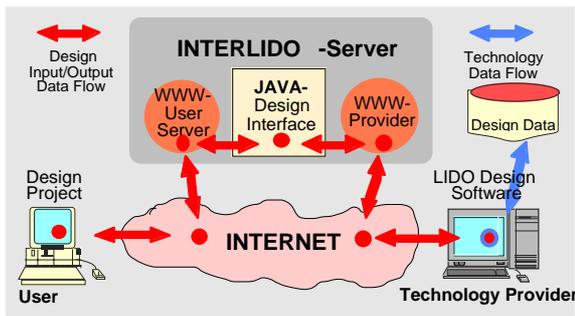


Figure 7: INTERLIDO-network software access

INTERLIDO

An overview of the INTERLIDO system has already been presented in Figure 2.

The LIDO-PEdit system is currently available as an operational prototype of an Internet based design assistant. An implementation in JAVA has been realized and is accessible via <http://www-ttec.rs.uni-siegen.de>. An in-depth description of LIDO-PEdit emphasizing its features to support process sequence design taking economic aspects into account is available in [9].

Here we only give some remarks on the process of using the INTERLIDO-system via the Internet. Figure 7 shows the principles of Internet-based software access, as they are realized in INTERLIDO. The INTERLIDO-Server is a broker system that is used to bundle tools, technologies and user access across the net. Technology providers will provide their design related knowledge in form of icons and

LIDO-PDL descriptions. The LIDO-PEdit functional components will be available on the INTERLIDO-Server and will access the technology related information via the net. The user interface is realized as a JAVA-applet to be run on the user's client computer. In this manner not only sophisticated licensing and software maintenance mechanisms can be provided. It is also possible to implement a separation between design data and technology data that is frequently desired by both design and technology providing institutions.

CONCLUSIONS AND OUTLOOK

Design support for MEMS physical design based on the circle model is best provided by a set of loosely coupled assistants. These assistants lend themselves to implementation using component technology. Using JavaBeans for this purpose provides Internet-access facilities for the components as an add-on. This can be utilized to realize net-based software access. Providing a large base of various assistants for different technologies and different subtasks of the physical design stage may be the basis of a "physical design broker service" providing especially SMEs with tools and technologies for any MEMS solution they intend to create.

Except extending and completing the INTERLIDO component base, research work in Siegen is currently focusing on realizing this sort of Internet-based service.

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