

# Mask Layout Design of Single- and Double-Arm Electrothermal Microactuators

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**Abstract** - In this paper, the mask layouts of the single- and double-arm electrothermal microactuators have been designed using the CleWin layout editor. The designed masks will be used for the development of training materials for a course on MEMS fabrication within the framework of the EduMEMS project.

**Keywords** – mask layout design, single-arm electrothermal microactuator, double-arm electrothermal microactuator, Micro-Electro-Mechanical Systems (MEMS), mask design software, layout editor CleWin.

## I. INTRODUCTION

Micro-Electro-Mechanical Systems (MEMS) integrate mechanical and electronic components on a single semiconductor microchip. The mechanical components can have dimensions from 20  $\mu\text{m}$  to 1 mm [1-5]. One of the critical MEMS components is a microactuator which converts energy into mechanical motion (Fig. 1). The application of the microactuators is very broad and various and also constantly increases. They are used in robotics, control devices, aerospace engineering, biomedicine, dosimetry, in measurement instrumentation, game technologies, automotive industry etc. The main mechanisms used for receiving the actuation (motion, deflection and force) in such devices are as follows: electrostatic, magnetic, piezoelectric, hydraulic and thermal. Since electrothermal actuation gives simple controllable actuation mechanism which is compatible with standard microelectronics. Therefore, electrothermal microactuators are one of the most used and perspective control devices in MEMS [6-9].

The developed microactuator can be fabricated using MEMS process that includes at least one releasable, conducting layer [10,11]. For the fabrication of the electrothermal microactuator, masks are needed. The masks can be made from the created layout or mask patterns. The designing of the layout is a very time-consuming and very important process. The size of elements in the layout determines the cost of the device manufacturing and its shape determines the structure and functional behaviour of the device. During manufacturing, a photolithographic (photolithographic printing) process is used to transfer the layout patterns from the masks to wafer. The fabrication process forms patterns through the

masks on the wafer surface that creates a device structure. A series of identical devices can be patterned on the wafer. The MEMS manufacturing process is efficient because we can produce many identical devices on a single wafer. The change of the masks determines what patterns will be laid down on the chip. Thus, we determine the device that will be created [3,4,6-9].

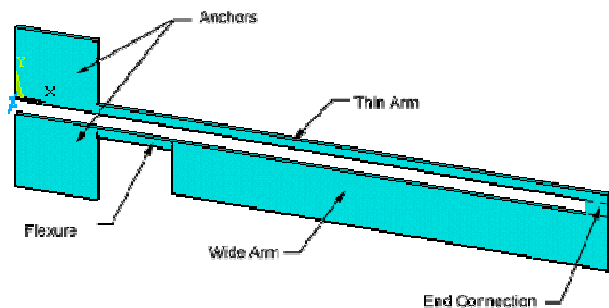


Fig. 1 Construction of the electrothermal microactuator

## II. REVIEW OF SOFTWARE TOOLS FOR MASK LAYOUT DESIGN

Currently, there is a large variety of software tools for the mask layout design both of the conventional integrated circuits (IC) and microelectromechanical systems (MEMS). These software tools include both specialized CAD systems and small specific programs. Some of them can be only purchased, and others are distributed for free or can be downloaded for free for non-profit or educational use. In the following list, available software tools for the mask layout design are presented:

- MyChip Station is a design system which includes physical layout, verification and translation tools: LayEd: IC, MEMS, FPD Layout Editor, MyDRC: Hierarchical Design Rule Checker, LayNet: Hierarchical SPICE Netlist Extractor & Electrical Rule Checker (ERC), MyLVS: Layout and Schematic Netlist Comparator, CifGDS: CIF/GDSII/DXF Translator [12].
- CoventorWare is a powerful specialized CAD system intended for MEMS design, simulation and layout making. It is expensive enough, but provides a lot of modelling capabilities [13].
- LASI (LAYout System for Individuals) is a free software which is intended for the design and mask layout creation of integrated circuits and MEMS. As has been mentioned on the website of the software

maker, this system is developed mainly for educational use. There are available versions of this software system for both Windows and Linux operating systems. LASI can be used as additional aid software tool along with commercial systems. It allows doing the mask layout work on any Windows desktop or laptops. The designed layout can be transferred into GDSII format. LASI includes drawing editor program and several utilities. The utilities contain converters for such formats as GDS, CIF and DXF [14].

- LinkCAD is a powerful CAD translator which supports different file formats. It is used to convert design files to PostScript format or from AutoCAD DXF file formats to GDS [15].
- SoC GDS is a multi-platform (GUI and CLI) layout viewer and processor supporting OpenAccess and GDSII, LEF file formats [16].
- Artwork Conversion Software has a suite of software tools such as CAD translators, high speed viewers for CAD data bases such as GDSII, Gerber, DXF, MEBES, OASIS, ODB++ for output to desktop or wide-format printers and plotters. It also provides tools for processing large IC layout databases: Qckvu3 GDSII, OASIS and MEBES viewer; QISLib, GDSII and OASIS library for viewing, editing, and fracturing [17].
- MEMS Pro is a CAD system for the design and analysis of micro-electro-mechanical systems (MEMS). It includes T-Spice Pro module with schematic editor (S-Edit), mixed MEMS/IC simulator (T-Spice), libraries of schematics and layouts of MEMS devices, L-Edit Pro module with layout editor (L-Edit), technology manager and 2D/3D modeler. L-Edit Pro contains a hierarchical and custom mask editor for MEMS and IC design (L-Edit), EasyMEMS tool and MEMS Libraries Easy MEMS. L-Edit allows designers to create MEMS primitives. The EasyMEMS tool helps to automate tasks for creating MEMS mask layouts. The MEMS libraries of the EasyMEMS tool are linked to user-specified or foundry design rules to ensure manufacturability. The EasyMEMS library includes thermal, mechanical, optical, fluidic, and electrostatic devices. The EasyMEMS library has a powerful interface for automatization, customization and extension of the layout editor command and function set using the C language [18].
- LayoutEditor is a cross-platform software tool (available versions for Windows, Linux and Mac OS X operating systems) intended to edit designs for MEMS and IC fabrication. It has various functions such as font generator, C++ macros, python scripting, boolean operations, design rule checker, netlist driven layout and LVS. The LayoutEditor also supports a wide range of different file formats such as Calma GDSII, OASIS, OpenAccess, DXF, CIF (Caltech Intermediate Form), Gerber (RS-274X), LEF, DEF, Lasi, SOURCE and many more [19].

- CleWin is a powerful hierarchical physical layout editor created for Windows operating system. CleWin supports up to 255 layers. Some of the layers relate to the masks which should be made by a mask manufacturer. Other layers may be used to store shapes that may be useful during the design but do not appear on the masks. For example, the outline of a MEMS chip or silicon wafer should not appear. In principle it can be chosen which layers have to be used for what purpose. The mask manufacturer simply has to know which layers must be used for mask generation. Any mask manufacturer should be able to produce masks from the files created by CleWin. Usually, for mask fabrication the CIF or GDS-II file format is used. DeltaMask will prefer CleWin's CIF format, but other mask manufacturers may prefer GDS-II. Besides the mask dimensions and mask type, e.g. chrome or emulsion, your mask manufacturer will need to know some more information depending on the file type. When using CIF, the mask manufacturer only needs to know the layers from which you want to have masks. CleWin uses the so-called "one call convention". This means that the entire design is defined in a symbol definition and at the end of the file there is one call to this symbol. All other symbols you may have defined are called from within this top-level symbol. CIF layer names are limited in length. Therefore, in CleWin you can specify a "long" and a "short" name for a layer (by double-clicking on the layer button). The long name is used internally by CleWin, your mask manufacturer may only see the short name (unless they also use CleWin). Therefore, be sure to provide your mask manufacturer with the short name of the layers. By default the short names are simply the number of the layer preceded by a capital letter L. When using GDS-II, your mask manufacturer will need to know the name of the "top-level" or "main" symbol. GDS-II files are simply a collection of symbol definitions and there is no simple way to see what symbol is the main symbol. CleWin always uses the name CleWin~Main for the main symbol. GDS-II does not allow layer names. Instead, layers are indicated by their index [20].

After review and analysis of software tools for the mask layout design, the CleWin layout editor developed by WieWeb software has been chosen as the most suitable one for our work. Thanks to close cooperation of WieWeb software with mask manufacturer DeltaMask and the MESA+ Research institute, any mask manufacturer should be able to produce masks from layout files created by CleWin.

## II. MASK LAYOUT DESIGN OF SINGLE- AND DOUBLE-ARM ELECTROTHERMAL MICROACTUATORS

In Fig. 2, 3, the mask layouts for the single-arm electrothermal microactuator designed using the CleWin layout editor are shown.

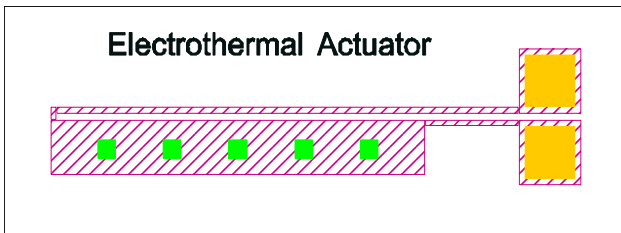


Fig. 2 Layout of the single-arm electrothermal microactuator

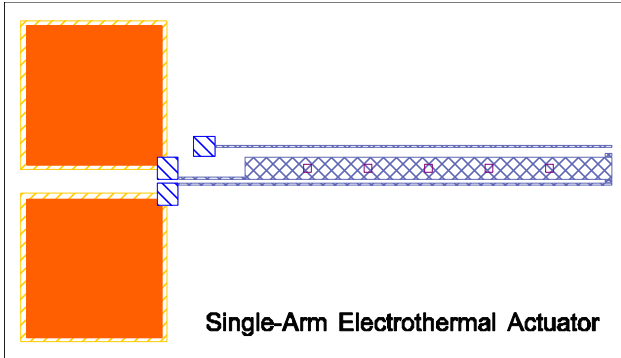


Fig. 3 Layout of the single-arm electrothermal microactuator  
The mask layout of the double-arm electrothermal microactuator designed in CleWin's environment is shown in Fig. 4.

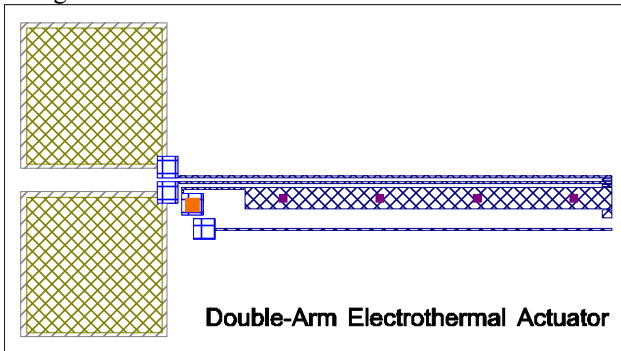


Fig. 4 Layout of the double-arm electrothermal microactuator

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- [14] Electronic resource: <http://lasihomesite.com/>
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#### III. CONCLUSION

Within the framework of the EduMEMS project and taking into account its educational context, the sets of mask patterns (mask layouts) for fabrication of the single- and double-arm electrothermal microactuators have been developed using the CleWin layout editor.

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