ANNUAL JOURNAL OF ELECTRONICS, 2014, ISSN 1314-0078

Design and Fabrication of ”Matrix” MEMS Device

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Abstract - **This paper presents the design and development of library elements used for design and fabrication of MEMS devices and MEMS based, piezoresistive sensor for micro-force measurement. The output of the physical design is foundry ready and can be sent to any foundry in CIF or GDS II format. Boron diffusion process combined with deep reactive ion etching (DRIE) technique is used to form the side direction force sensors. The monolithic MEMS prototypes have been micro machined.**

Keywords – **MEMS, new technology, sidewall embedded piezoresistors**

I. INTRODUCTION

MEMS devices take very important part of advanced sensor systems. There are lots of areas of application: medicine, space technologies, airplanes, automotive, optical communications, etc. The important feature of each MEMS is high accurate. MEMS devices can operate with micro sized objects. There are MEMS that can operate with nano sized objects. MEMS design requires software systems with advanced library elements and a lot of analyses. Fabrication process requires equipment with high resolution. Here design and fabrication of a novel MEMS technology is presented.

II. DESIGN ENVIRONMENT

MEMS devices are part of each electronic sensor used for measuring strain, pressure, etc. and can be designed using a specific software [1]. Many different software systems exist worldwide but the most used are Xplorer and MEMS Pro of SoftMEMS company (Xplorer for UNIX platforms and MEMS Pro for Windows platforms) Fig. 1.

Xplorer is fully integrated in the Cadence Virtuoso design platform. Software components have been added to the Cadence functionalities currently used in the IC domain, to effectively design microsystems with Virtuoso.

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 in CIF or GDSII format to any foundry.

MEMS Xplorer DS provides a set of libraries containing 34 components from which complete MEMS devices can be built. User-defined libraries (device generator libraries) and libraries components (device generators) can be built as well [2].

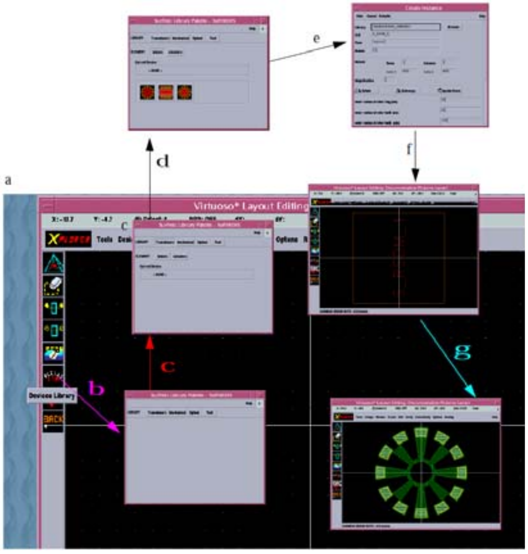

Fig. 1. MEMS Xplorer design environment

The user-defined libraries include basic and advanced device generators for Bulk and the Surface micromachining technologies. All device generators are located under the technology library directory.

A new MEMS element can be created part by part using various user-defined library elements. They can be made of spirals (logarithmic; archimedean; hyperbolic); torus (parametric; interactive); ellipse (parametric; interactive) and other curves and figures (forms). The tool used for this purpose is called Easy MEMS which is a part of MEMS Xplorer. The different kind of device generators can be separated into three types which are: mechanical; optical and tranducers.

There are multiple ways of using the Easy MEMS tool. You can either enter the desired parameters or interactively draw the layout. In most cases, the generated shape parameters can be edited once the drawing process is finished.

Each new library element has PCell and parameter file. First the parameter file must be created. Once parameter file is created the PCell has to be created.

The parameter file of a device generator is a text file containing all its needed variables declaration. All these variables are mandatory: if any of them is being deleted or modified, the program will fail to create the related PCell.

III. LIBRARY ELEMENTS

Library elements for a novel MEMS technology are necessary to be created. They are created using Xplorer software and the specifications described into the technology. For these library elements a new user-defined library must be created.

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The base designed elements of the user-defined library are: resistors; piezoresistors; metal areas and membrane. Each of them is created using a few layers (Metal; Poly; Contact and Pin). The elements are sorted in several groups. Some of the elements are presented in Fig. 2, Fig. 3 and Fig. 4.

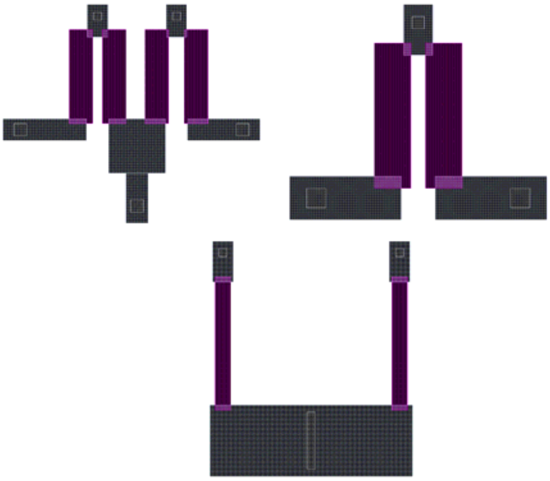


Fig. 2. Piezoresistors

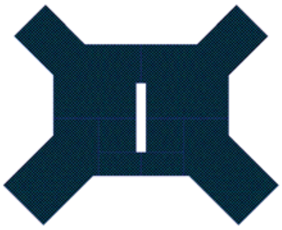


Fig. 3. Membrane

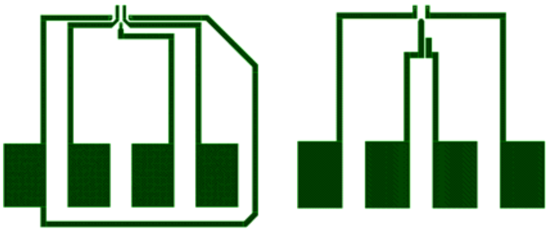


Fig. 4. Metal Areas

Depending on the required type of resistance value, the resistance has a different length and depth, respectively. The resistance width is constant. Metal areas (Fig. 4) are used as electrical connection between MEMS device and the sensor. The MEMS device is part of the sensor. Metal areas configuration have to provide bridge connection to form resistant divider (Fig. 5).

If any additional layers are necessary during the library cells creation they can be added to technology file together with their function.

During manufacturing, the monolithic MEMS prototypes have been micro machined by using double-side polished n-type <100> silicon wafers with a resistivity of 4-6 Ω.cm and (Total Thickness Variation) TTV < 2μm. In order to provide piezoresistive properties of diffusion layers, the sheet resistivity was set at range of 250 ± 20 Ω/□ and the resistors have been oriented in [100] direction [3].

Completely designed MEMS device is submitted as a layout in a GDSII file format to a factory for manufacturing.

If any new device generators are necessary to be created, they can be created layer by layer and added to the new user-defined technology.

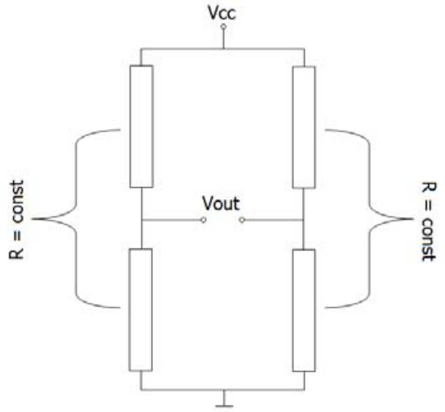


Fig. 5. Resistant Divider

IV. MEMS FABRICATION

MEMS devices are designed using already created user-defined library.

Different fully designed MEMS device structures are placed in one layout. The output of the physical design is exported in CIF or GDSII format. The exported MEMS design is being sent in a factory.

In the factory several counts wafers are fabricated. The MEMS structures onto plates are preforms for MEMS devices. The wafers with the MEMS preforms are given back to the MEMS Development Company for post operations.

In the MEMS Development Company during MEMS chip creation diffusion piezoresistors (Fig. 6) are formed by preliminary building of piezoresistors' contacts.

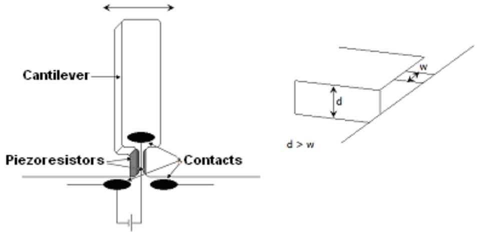


Fig. 6. Cantilever

In this company the fabrication process begins with a set of operations which are made in order to being formed Al high-alloyed contact areas in the silicon bulk (the material of the contact areas is aluminum). In the next step holes with vertical walls and depth are formed by DRIE Si (Fig. 7) [4].

During MEMS formation process the first operation is to dig two holes with 12μm depth to form the resistors [4]. There is a certain distance between the resistors. The walls of the holes are alloyed in order to be achieved resistivity with certain value (first lithography). If the depth of the holes is bigger, the resistors will have better characteristics. The depth of the hole basically is defined by the equipment used for the digging of the hole. The holes are made by TRENCH technology. TRENCH technology is described in details in [4].

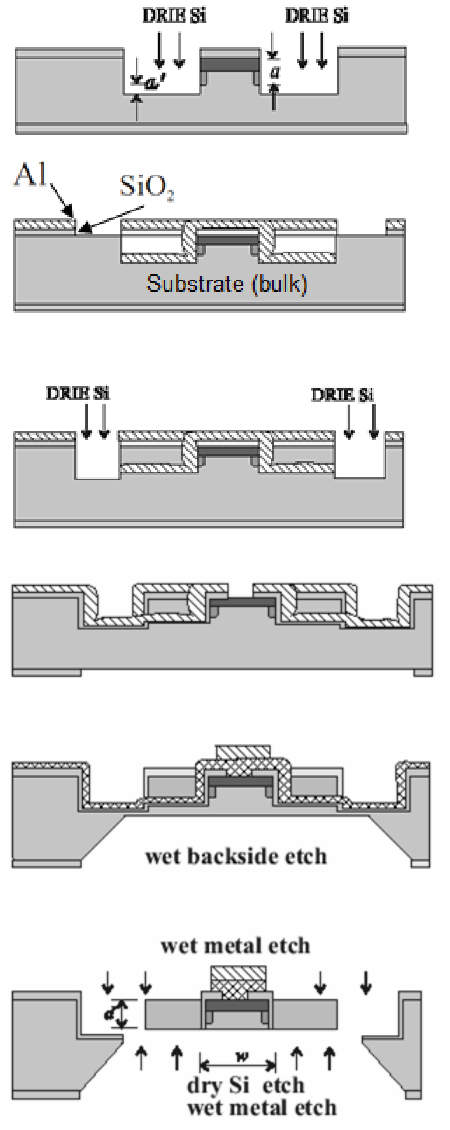


Fig. 7. MEMS formation process

At the back a membrane is made which achieve the bottom of the resistors (second lithography). When the back is etched, the plate surface edges at the four corners. The etching is made with speed 50µm/h.

The cantilever is formed on the third lithography. The resonance of the cantilever is proportional to its width ”W”.

At each step of the manufacturing the ”W” size is decreasing. Therefore, mask correction is needed [5].

The finished MEMS device looks like the one on the Fig. 8.

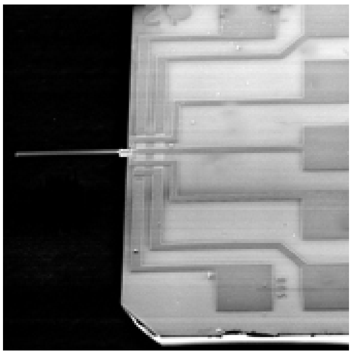
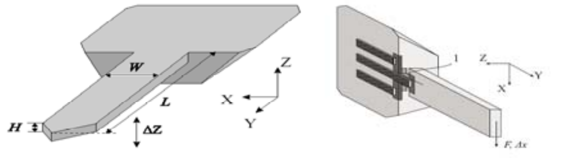


Fig. 8. Completed MEMS device

V. MEMS AREAS OF APPLICATION

For the researches and correct understanding of micro/nano object interactions are needed appropriate microdevices (e.g. Micro Electro-Mechanical Systems - MEMS) which can react to and measure the values describing these interactions. For instance that kind of devices are sensing elements of scanning measure and analytical systems, as well as devices which measure movement and/or force in the range of nm/nN.

The device with sidewall embedded piezoresistors shown in Fig. 9 is made on n-type dual-polish <100> silicon wafers.



(1) (2)

Fig. 9. Device with sidewall embedded piezoresistors. MEMS device with vertical (1) and sidewall (2) work function

In fabrication of MEMS integrated devices with sidewall piezoresistors standard monocristal dual-polish n-type plates with resistance 40 Ω.cm are used.

The technology allows realization of MEMS devices with configuration. Piezoresistive sensors for manage and measure are integrated into the sidewall.

VI. CONCLUSION

MEMS Xplorer design environment is presented; as well as its features and possibilities. New library elements are created and sorted in appropriate groups. These library elements are used when a new MEMS device is designed through the new technology. Whole design and fabrication process (from new library elements creation to fabrication of a new MEMS device) is described. Work principle of sense part (cantilever) is described as well.

Designed MEMS is being sent in a factory as GDSII file format. In the factory are made MEMS preforms on which any necessary post operations will be applied. The wafers with the MEMS preforms are given back to the MEMS Development Company where by post operations a new sensing element is obtained. The post operations include three lithographs. The used silicon wafers are n-type <100>.

When new library element has to be created, its structure layer by layer is created and new parameter file and parametric cell (PCell) are made. After that the new element is inserted into corresponding element category in the new library.

The cantilever of sensing elements using that technology has displacement in horizontal direction. Thus, the sensors have output signal significantly better and no need amplifier circuits to be used. In other words the output signal can be used directly.

ACKNOWLEDGEMENTS

The research is related to the project No BG051PO001-3.3.06-0046 “Development support of PhD students, postdoctoral researchers and young scientists in the field of virtual engineering and industrial technologies”. The project is implemented with the financial support of the Operational Programme Human Resources Development, co-financed by the European Union through the European Social Fund.”

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