Photomask Fabrication: Designing of Test Structure

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***Abstract*— Fabrication has now become an inevitable part of manufacturing industry. Ranging from the simple power supply to complex, layered designs, fabrication is widely accepted and implemented on a very scale level. With current existing technologies, it is practically possible to fabricate chips with numerous methodologies. Depending on the requirements, one could opt any of the existing processes of fabrication. This paper deals with one such recent and efficient fabrication methodology usually termed as "Photomask Fabrication." The paper shall discuss the designing of test structures for fabrication which involves the implementation of photomasks. The paper shall discuss the various intermediate steps and sub-processes involved in designing and implementation of photomasks. For highlighting the results, three broad and essential devices opt as follows: MEMS Devices, SAW Devices and PHOTONIC Devices and this involves the implementation of the widely used drawing package tool of AutoCAD for designing of the test designs. Therefore, the paper implements and compare the test structures for the photomask fabrication for the above-mentioned structures via the AutoCAD designing tool.**

Keywords—Fabrication, Photomask fabrication, AutoCAD, test structures.

1. INTRODUCTION

The photomasks are implemented such that they fabricate the devices via the concept of optically transferring of patterns. For this, photomasks are usually lithographic templates and are being coated with Chrome with the base material of glass. The appropriate database is used to store the AutoCAD Designs which is then transmitted to an appropriate tool. This tool varies with the requirements, and in our case, the tool used is the laser beam. Later, the pattern of the developed image is transferred as a template over which, etching is performed. The remaining process of cleaning and removal of remaining of photoresist is performed. All these set of operations are performed in a clean room.

The cleanroom refers to a controlled environment with minimum pollutant level such that it could support the required level of scientific research and manufacturing. Before entering the designated room, the user needs to wear the required clean-room clothing. For such specific purpose, we have a separate room termed as "grey room."

The high-efficiency particulate air (HEPA) and ultra-low particulate air (ULPA) filters to play the crucial role of maintaining the air quality regarding the level of pollutants. Special equipment is used such that they cause the minimum level of contamination within the operating room. Separate particle counters are used within the room to measure the real-time particle level, and the level of microorganisms is measured via environmental monitoring means.

Reserved ISO1 to ISO9 ratings have been reserved for classification of these clean rooms, and this rating level is based on the level of present particles. One could find the minimum level of particles in ISO1 rated room and reverse is the case with ISO9 rated one.

In [1], there has been a description of in-line photomask fabrication process such that the wafers of the thickness of around half of length and half-inch photomasks are transmitted to airtight containers via a maskless exposure system. [2] involves the modifications one should bring out in the process of dry etching to turn the fabrication process more efficient. In [3], there has been a detailed implementation of the fabrication process of multi-crystalline silicon cells. [4] introduces a better and efficient photomask fabrication method via the concept of ion implantation. The level of thickness, ion species, and type of resist have been discussed well enough in this paper. In [5], there has been the implementation of high-resolution photomask fabrication process via the electron beam lithography (EBL). Considering the fact, that this could cause some level of critical distortions, it discusses the implementation of the process of sub-scheduling as well.

The paper has been organized as follows, Section 2 elucidated the photoresists and techniques related to it. Test structure for devices have been illustrated in section 3. Fabrication results with CAD has been described in section 4 and section 5 concludes the work while casting light upon the future scope of the study.

2. PHOTORESIST

Every level of physical or chemical change resulted due to any radiation exposure is witnessed by the photoresist itself. This process only results in any pattern of the material. The resist used is a solution being coated on a MASK substrate and then soft baked. The resultant product from this subprocess is a uniform thin film which is generally of 0.5µm thickness.

The photoresist mainly comprises of three different level of components. The first material is the "matrix material" which acts as a base body. The second one is the "inhibitor," the photoactive ingredient and finally, the "solvent." As stated above, the coating applied is the "spin coating" where the mask is spinning with the order of around 1k rounds which eventually results in a distribution of centrifugal force. The photomask plate includes four unique layers, and the four layers are termed as follows:

a) Photoresist

b) Chromium oxide

c) Chromium

d) Glass

where each layer has a separate level of thickness. the chromium oxide should support features like a good level of strength, toughness and a good level of density. As the requirement varies, the types of the photomask plate also vary. Two of the most commonly used types are Soda-Lime and Quartz. The factor of optical transmittance and thermal expansion are the deciding factors behind every opted base material. Ideally, lower the value of thermal expansion, better is the material for the use of photomask plate.

In general, six levels of processes are involved in the photomask fabrication. These are defined under the categories of Designing, Conversion, Exposure, Development, Etching, and Stripping. Each process involves essential steps involved in the fabrication process. The designing involves the initial step of setting the layout of the pattern the user requires. As stated before, the AutoCAD drawing tool is widely used for the designing part. Unfortunately, the final extension format of the CAD-based designed file is not compatible with the machine we use for the further fabrication process. Therefore, the obtained .DXF is converted to a machine controllable format, and this involves several steps.

The exposure step performs the act of transferring the pattern, which is being designed via the AutoCAD tool over the selected photomask. The blank photographic plate (also known as a photomask) is made to be exposed to the LASER beam to transfer the machine understandable AutoCAD design. The development phase then involves treatment of the resist with the selected solvent. The not so necessary regions are removed by the user in this phase. The remaining metallic coating is then removed on the subsequent etching process. The majority of the feature shaping is done during this process. The final process involves the stripping, which ensures that the final remaining photoresist is etched away and the whole process is ended with the cleaning of the obtained result.

3. Test Structures For Devices

Every test structure plays an essential role in designing of some commonly used structures. It might be the case that the desired final structure differs from these test designs, but this structure shall surely play a crucial role in designing some of the critical features of the overall structure.

As stated before, these test structures are defined for MEMS structure, SAW Structure, and PHOTONIC Structures. As the name suggests, surface acoustic wave (SAW) devices is a surface wave of acoustic type traveling along the material's surface and are commonly used in electronic systems in forms of filters, oscillators, and transformers.

PHOTONS is common in most of the optics field of science, are used in the field of detection, processing of information,

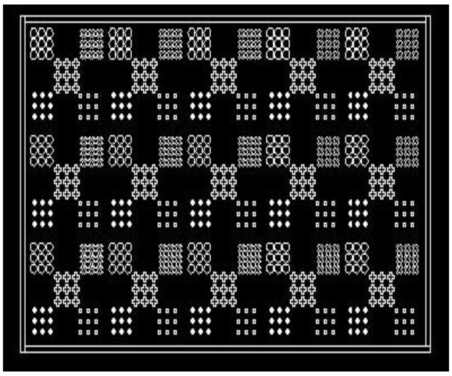


Fig. 1(a) Test structure for PHOTONIC Device

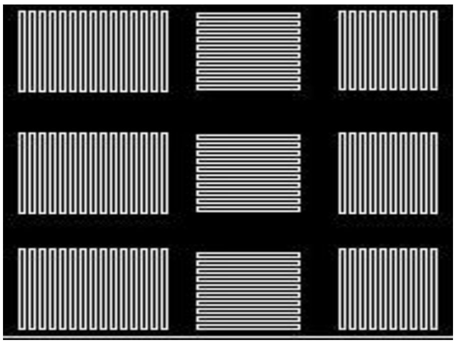


Fig.1(b) Test structure for PHOTONIC Devices

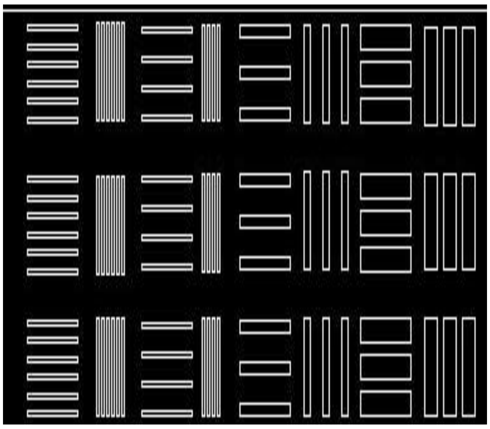


Fig.1(c) Test structure for PHOTONIC Devices

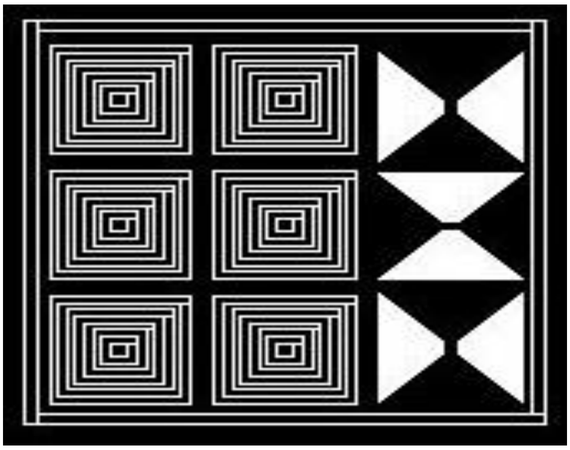


Fig.1 (d) Test structure for PHOTONIC Devices

LASER technology, robotics and many more. The designed test structures are depicted in Fig. 1.

The MEMS structures are terms as Micro-Electro-Mechanical Systems, which involves micro-fabrication for their fabrication. With numerous possibilities, the MEMS devices could be as simple as possible, with no such moving elements, and could be highly complex systems. As given in the figures, we could observe that a single device type can include several test structures depending on the requirements of the user. The typical structures and alignment marks used in MEMS devices are also given. As shown, all the test structures vary with the device under consideration.

The same for the MEMS are given as follows: Other than this, there are other several test structures used for MEMS devices and are illustrated in Fig. 2.

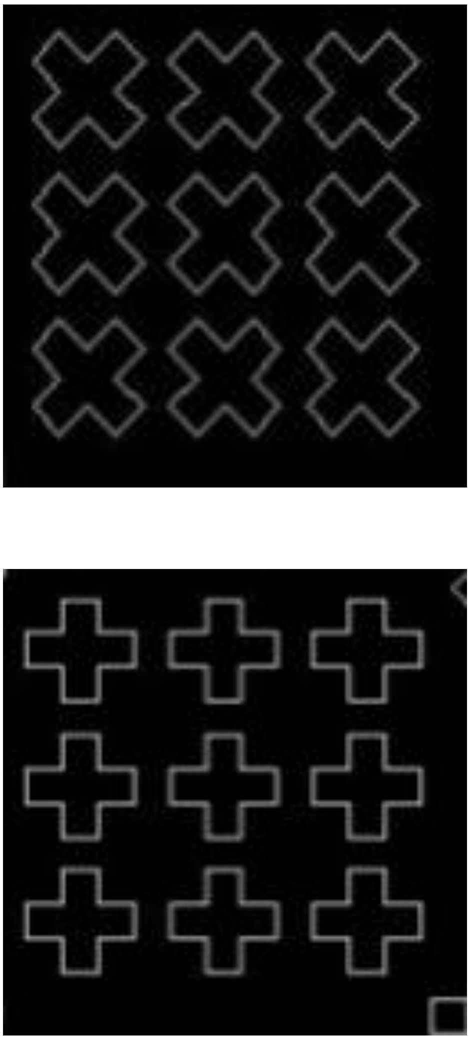


Fig. 2. Structures for MEMS devices

4. Results

Once the development phase is implemented regarding designing of test structures, we implemented the other process cycles of exposure and etching. The process of development and etching plays a crucial role in defining the overall pattern the user wants to design. Therefore, both the development phase and etching phase based intermediatory outputs have been given in Fig. 3.

The above superset of the developed test structure includes numerous sub-test structures required for the development of SAW or PHOTONIC or MEMS devices. Working on a specific basis, the developed structures specific to the device type the paper is considering on, the following results were obtained.

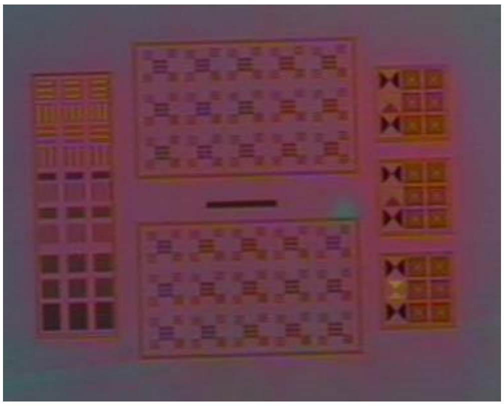


Fig. 3. Development of test structures

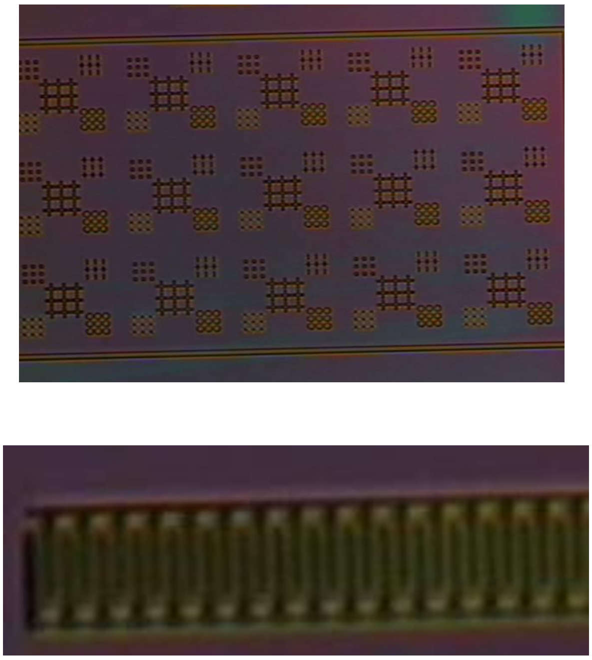


Fig. 4. Developed MEMS Structure

Once the development phase is done, an etching process is implemented. The obtained image is somewhat as depicted in Fig. 5. Considering the SAW Devices, the drawing image generated for the pattern is depicted in Fig. 6 as follows. The later processes gave the results as shown in Fig. 7 as follows.

Considering the final considered device, the PHOTONIC devices being developed after the etching process are given as follows in Fig. 8.

5. Conclusion

Efficient implementation of the fabrication process is highly necessary for every structure manufacturing. With the application of this fabrication technology in the field of manufacturing of light emitting/receiving devices, display machines, motherboards and many more, it has turned out to be a highly reliable and versatile fabrication process. Dealing with daily requirements of fabrication, SAW devices, PHOTONIC ones and the MEMS devices do play an essential role. Dealing with such device types on regular basis, the paper highlights their fabrication using the fabrication technology of photomasks. The paper mentions the role of drawing tool in this fabrication process and highlights the intermediate outputs obtained from the AutoCAD. Once these CAD files are generated and converted into a compatible format, they are being transferred for pattern generation. The paper not only focusses on the description the subsequent steps of the photomask fabrication but also obtained the desired results via the concerned fabrication methodology. Both development and etching phase is discussed along with their corresponding fabrication results to highlight the level of change in the obtained pattern during these subsequent steps. The paper, thus, considers both the theoretical as well as the practical aspects of the photomask fabrication and implements the desired development of test structures with precision

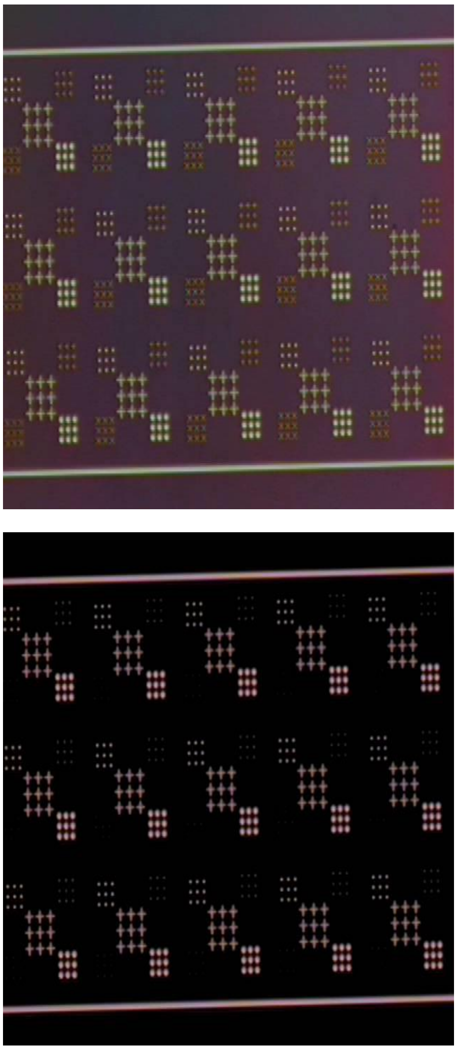


Fig. 5. Developed MEMS Structure after etching

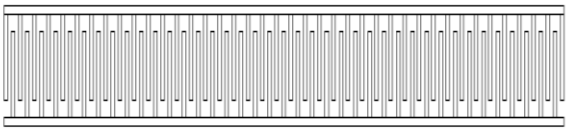
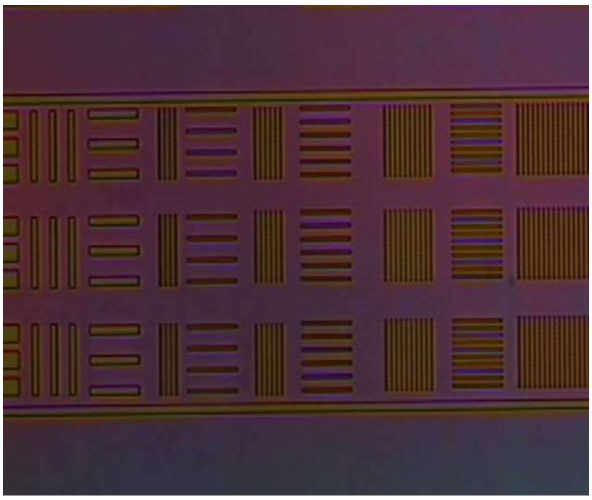
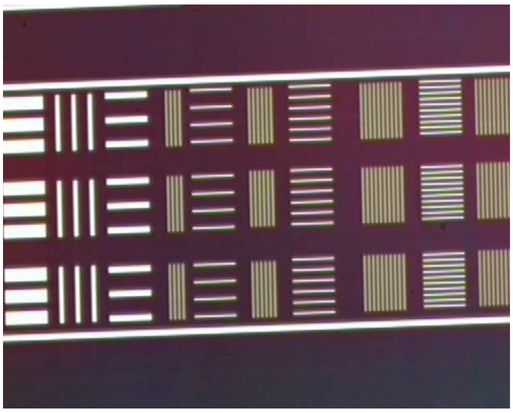


Fig. 6. SAW Structure

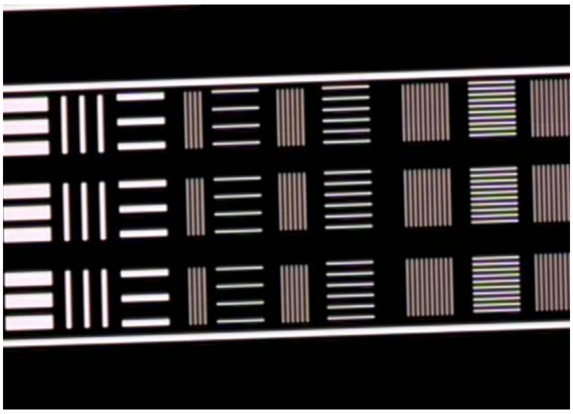
Fig 7. Developed SAW Structure after etching



(a)



(b)



(c)

Fig 8 a) Developed PHOTONIC Structure b) Developed MEMS Structure after etching c) Developed PHOTONIC Structure after etching

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