SU-8 Polymer Based Bio-MEMS Micromachining:A Review

M.V. Devaiah,
Research and Development Center,
Department of Mechanical Engineering
ACS College of Engineering
Bengaluru,India
(devaiah.mv@gmail.com)
Dr. S. Anand Kumar,
Research and Development Center,
Department of Mechanical Engineering
ACS College of Engineering
Bengaluru,India

ABSTRACT

Technological devices fabricated from polymer based materials are gaining special attention for prospective bio-medical applications. Specifically, the micro-machining of polymers materials would serve as an integral part for bio-medical microelectronic mechanical systems (bioMEMS) devices. It is due to the unique availability of numerous fabrication methods applicable to polymer materials. Hence, an investment and cost involved in fabrication of such miniaturized parts could be drastically declined resulting in greater benefit compared to conventional silicon based MEMS. Further, most of the polymeric materials demonstrate biological and chemical inert characteristics required for situations such as *in vitro* (lab on a chip (LOC)) and *in vivo* (implants) conditions. In this paper a review on the advancement of polymeric materials suitable for MEMS applications are focused. Also, the techniques for deposition, removal and release process for a commonly used epoxy-based negative photo resist (SU-8) bio-medical MEMS application are discussed.

Keywords - Bio-MEMS, Bio-Medical Applications, Micromachining Techniques, SU-8

I. INTRODUCTION

Technology has been improving from decades and there is no end for technological revolution. Technology has been evolving in all the streams of automotive, rocket science, mechanical and even in medical there is no such stream as such where in technology haven't been included or not evolved. This topic is all about BIOMEMS the term BIOMEMS is abbreviated as biomedical micro electromechanical system which is also known as lab-on-chips (LOC). BIOMEMS are used in the field of medicine also called biomedical field these are electronic device which are being inserted into body to analyze any defects or imbalance in the body. These types of systems are electrically driven with the source of battery and other transducer in the circuit. MEMS based sensors are been widely used in the field of medicine BIOMEMS have been used and successfully implanted in the human body to record and analyze each and every minute variation for example ; pacemakers are the device which helps in contraction of heart muscles. When the heart beat decreases pace makers sends electrical signal in order to make the heart muscles contract. All these are nano or micro-electronics components and circuit the circuitry part of these components are not visible to naked eyes because they are very minute [1].It is not possible to manufacture by humans or by robotic arm a special kind of design matrix is followed to obtain such minute circuit known as photolithography.

Photolithography is derived from a Greek word which states photo means light litho means stone graphy means writing. Photolithography is a process in which shapes are transferred from a template onto a surface using light. It was incorporated in 1855 and was invented by Alphonse Poitevin. The process involves many chemical reactions silicon wafer is treated with hydrogen peroxide to remove any contamination a layer of silicon is placed to act as a masking film, the wafer is spun rapidly from1200 to 4800 rpm from 48 to 60 seconds and produces a layer from 0.5 to 2.5 micrometer thick, excess of photo resist is removed through a process called edge removal process, a mask consisting geometry of the circuit and high intensity of UV light is passed which causes a chemical reaction in the photo resistive material and the geometry is implanted.

1.1 SU-8 Polymer

SU-8 is widely used in photolithography as a photo resistive which was patented by IBM in 1989, SU-8 has created a popular low cost alternate method to create thick structures with high aspect ratios. The first reported usage was done in 1997 which was also called as UV LIGA and was later commercialized by MicroChem Corporation and formulated SU-2000 which used cyclopentonane which exhibited good cohesion and adhesive properties. Su-8's has high degree of cross linking capacity which increases thermal and chemical stability, SU-8 is also a proton radiant and has been used in wide range of device due to tune able electrical, mechanical, magnetic and optical properties it is well known for its chemically stable and mechanically robust structure. A detailed information on MEMS reported in[2-6].

1. Micromachining techniques

2.1 Photo-Patterning Technique

The main advantage of SU-8 polymer when compared to others is its simplicity to obtain thick films which varies over a large range of thickness. SU-8 can be spun less than 500 micrometer thickness and multiple spins can be achieved till 1.2mm of thickness. It is possible to obtain multiple exposure steps on multiple different layers and later on combined to form a single development of layer[7-10].This method is obtained by spinning the SU-8 layer and expose it then the next layer is spun and exposed.It is continued until the final layer is obtained, all the unexposed are developed in a single step simplifying the fabrication process.During this process the subsequent overlying layer must be smaller than the adjacent layer in order to prevent the exposure of lower layers. The usage ofthe diluted SU-8 concentration in the lower layers which would make the lower layer less sensitive to absorb UV light which in turn will be less exposed to unwanted UV light.Fig. 1 demonstrate the sequential procedure and steps involved in the fabrication of the micro-needles employing the photo-patterning method.

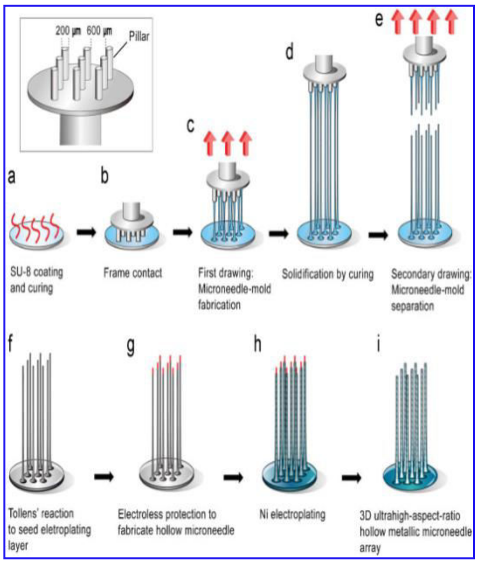

Fig. 1 demonstrate the sequential procedure and steps involved in the fabrication of the micro-needles employing the photo-patterning method of SU-8. (**a**) deposition of SU-8 by spin coating method; (**b**) frame pattern contact for drawing; (**c**) drawing of deposited SU-8 polymer layer; (**d**) curing through thermal cross linking of drawn SU-8; (**e**) secondary drawing to develop micro-needle pattern; (**f**) development of the seed layer using electroplating; (**g**) fortificationof micro-needles at the tips; (**h**) electroplatingof nickel; and (**i**) establishment of hollow micro-needle by eradicating SU-8 and tip protection layer [11].

2.2 Removing Techniques

The chemical stability of SU-8 makes removal of cured SU-8 very difficult, practical removal techniques like peeling or breaking can be done but to remove SU-8 typical wet type etches called as pirhana etch and fuming HNO_3 can be used. Ozone solution can also remove SU-8 (see Fig. 2) but removal rates are too slow, ozone steam can increase the rate of removal but ozone solution with other solutions may not be compatible with other materials present in device. Physical methods like water jetting and laser patterning can also be used to it results in roughness because of deposited roughness.

The **UV-300H** is a 300 mm UV-Ozone system that includes all the features of the table-top systems. Substrates are placed into the ozone chamber.The distance of about 1 – 11 mm is maintained between the sample stage and ozone manifold to optimize the process.

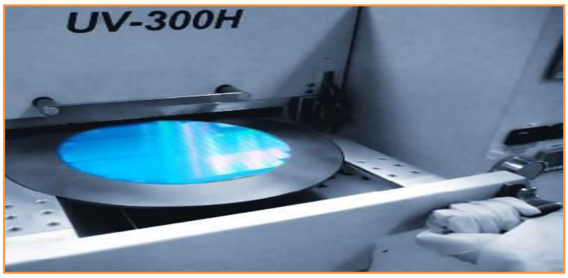

Fig. 2UV-Ozone cleaner for 200 mm or 300 mm wafers [12]

2.3 Release techniques

SU-8 can be separated by using release layers such as aluminium, titanium, chromium from the substrate to create free film devices. However by using potassium hydroxide etch to remove SU-8 the heat required would eventually create an internal stress and create micro cracks.SU-8 can also be peeled of when the adhesion is poor this would avoid exposure to chemicals and etch which in turn affects its structure, omni-coat is proposed by MicroChem corporation which is widely used to remove SU-8 which is removed by developer.

2.4 Bonding Techniques

Thermo compression is used to bond SU-8 interfaces through commercial die bonding system. This process can enclose micro channels or be used with standard die bonding which is accomplished by SU-8 films following spin coating during the soft bake step. SU-8 can also be bonded with other polymers by use of O_2 plasma treatment which renders the SU-8 surfaces (refer Fig. 3).

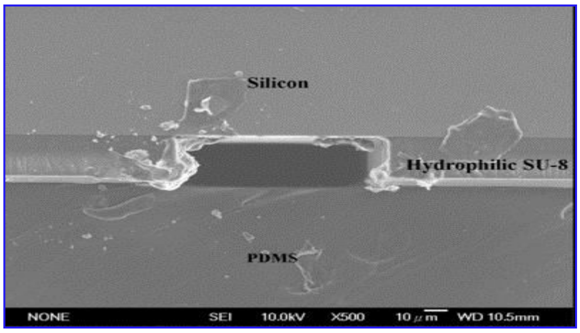

Fig. 3 SEM image shows the bonding location between Si and PDMS substrates. The inserted microchannel is of size 100 X 34 μm^2[13].

2.5 Notable Applications

The ease of fabrication has made SU-8 a popular option to produce in expensive moulds to produce lithography or for MEM applications. SU-8 has been chosen to design micro needle for drug delivery devices. SU-8 has also been investigated as substrate for free film devices, SU-8's are also used in as insect wings and eve in micro air vehicles due to their structural fitness and no water penetration.
Fig. 4 shows an array of 36 numbers of dissolving micro-needles on a fingertip. The micro-needles liquefy within minutes after the insertion into skin to deliver the encapsulated vaccine. The height of the micro-needle is about 900 µm [14].

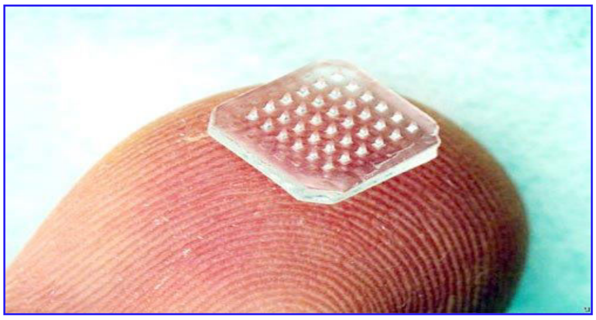

Figure 4. An array of tiny micro-needles on the fingertip to administer the polio vaccine [14].

In addition, SU-8 has been employedto fabricate microfluidic channels for LOC devices [15, 16]. Also, in opticalapplications such as waveguides, mirrors and cladding[17, 18, 19]. SU-8 is also a candidate material to fabricate a self-assembling capsules for drug delivery applications [20]. SU-8 has been employed to create the structural elements for inclined mirrors for optogenetics fields [17].

Further, it is used as a structural layer, as well as attempted has been made to use as substrate for application such as free standing film devices. The characteristics feature of SU-8's elasticity and flexibility made use of in the producing insect wings one of the constituent part in the micro air vehicles [21].
Owing its rigidity and lower water absorption characteristics compared to existing polymer materials, it is used has a covering material for bio-medical pressure sensors [22] as well as flexible neural probes in the micro-fluidic channel for drug delivery application [23].

Concluding Remarks

Development of novel polymer-based devices in the field of polymer-MEMS is rapidly increasing in recent years. However, many processing challenges remain that require further investigation Continued process development is expected to resolve many existing fabrication issues.

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