APPLICATIONS OF PHOTOLITHOGRAPHY FOR THE MANUFACTURE OF SOLID MEMS BODIES

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Abstract: *Photolithography has a significant role in the mass production of MEMS microcomponents. It is used in the preparation of the wafer substrate for the subsequent steps of making a MEMS / NEMS. For this purpose a photosensitive layer is applied on the surface of the silicon wafer. The process takes place in successive stages. Through photolithography a wide variety of structural geometries can be achieved.*

Keywords: *Photolithography, MEMS, silicon wafer, photosensitive layer.*

1. INTRODUCTION

Photolithography has the same working principle as lithography with the exception that the reproduction of the image on a mask, called a photolithographic mask, is done using light, on a substrate (eg silicon or silicon oxide), relatively flat. The substrate is covered with a thin layer of light-sensitive photosensitive material called photoresist. Photolithography is also called optical lithography or UV lithography. In the beginning, for the reproduction of the image on the mask, the light radiation was used, which is why, for photolithography, the term was photogravure [11].

Today, the term lithography refers to the transfer of predefined shapes or images on a 1:1 scale, from a template (physical or virtual mask) to the surface of a substrate (Fig. 1). Through the technique of lithography, the transfer of motifs from the template is done on very well defined areas and on smaller and smaller surfaces, for example. 90 [nm], 65 [nm], 45 [nm], etc.

The transfer of the images is done with the help of a complex of components formed (Fig.1) from a substrate (silicon pill), a thin film of material resistant to irradiation, called resistance, deposited on the entire surface of the substrate, a transfer agent of information represented by a source of irradiation and a mask that selectively transmits the information on the substrate.

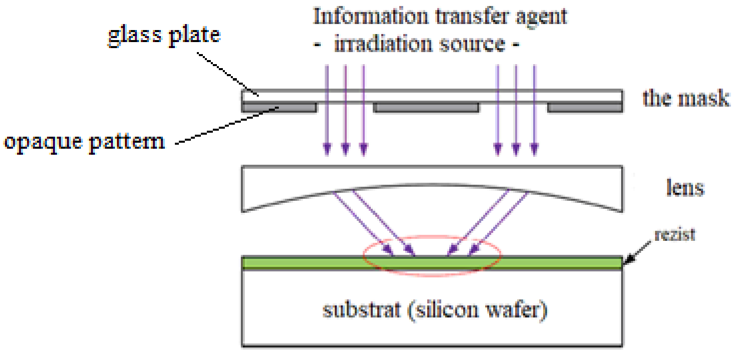


Figure 1: Working principle in photolithography for image transfer, after [14]

Depending on the type of radiation to which the resistance is sensitive, several lithography methods are used:

- optical photolithography - exposure with light radiation;
- electronolithography - electron beam exposure;
- roentgenolithography - X-ray exposure;
- ionolithography or ion lithography - exposure with ion beam.

The performance of a lithographic system is characterized by the following parameters (Tab.1) [11]:

- the working resolution "R" expressed by the minimum size that can be transferred to the resistor, with high fidelity;
- working speed: number of wafers (diameter (100-200) [mm]), per hour;
- the phenomenon of limiting miniaturization.

Table 1: Performance indicators for various lithographic processes, after [11]

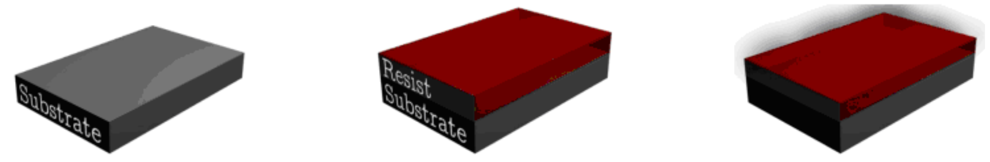
Performance indicator	The lithographic process				
	Otical, Ultra Violet close λ = 0.2 [mµ]	EUV (Extreme Ultra Violet) λ = 0.01[mµ]	Radiation X λ= 1[nm]	Electronic beam (SCALPEL)	Ionic beam
The phenomenon of limiting miniaturization	Diffraction in resistance	Diffraction in resistance	Considerations of geometric optics	The scattering of the beam in resistance	The scattering of the beam in resistance
Working speed (no. of wafers (100-200 diameter [mm]) / hour	tens	tens	tens	tens	over tens
Resolution R [mµ]	1	0,1	0,1	0,1	0,01
Cost of mask (manufacture, maintenance)	little	high	Very high	high	high

2. TECHNICAL REQUIREMENTS

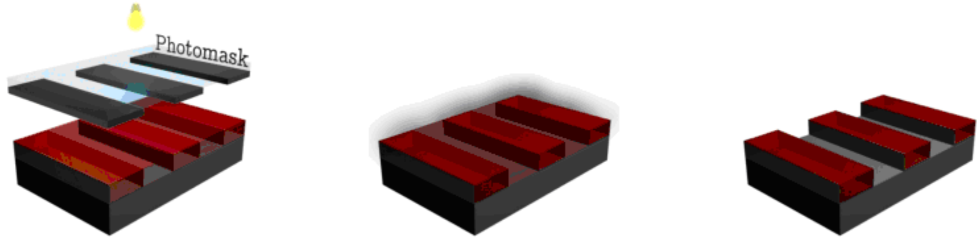
2.1 THE BASIC STEPS OF PHOTOLITHOGRAPHY

The individual steps involved in the photolithographic pattern transfer are schematically depicted in figure 2 [3], [12], [6]:

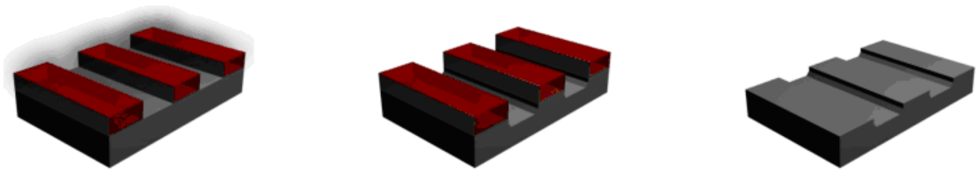
a. Cleaning and surface preparation;



a. Cleaning b. Resist Coating c. Pre - bake



d. Exposure e. Post - Exposure Bake f. Develop



g. Hard - Bake h. Process (e.g., Etch) i. Strip

Figure 2: Lithographic process steps, after [2]

b. Resist coating;

c. Pre-bake and alignment;
d. Exposure;
e. Post-Exposure Bake (PEB);
f. Develop + ADI (after development inspection);
g. Hard bake;
h. Process;
i. Strip;
j. Measurement and final inspection.

2.2 CHARACTERISTICS OF THE PHOTOLITOGRAPHIC PROCESS

Common factors for lithography are [1], [5], [4], [10]: type of resists; thickness of resists; mask alignment; wafer surface, resist adhesion; exposure energy; temperature; development time.

For the proper development of the photolithography process, a series of requirements are required regarding the photoresist's choice, the alignment of the masks, the choice of the photolithography method, etc. The photoresist must have the following main properties [3], [13], [7], [14]:

- photochemical properties. Stability and solubility in the action of chemical agents, acids and bases; The stability of the photoresist depends mainly on the chemical composition, its thickness and its uniformity on the substrate;
- optical properties. High photosensitivity to radiation. Three main wavelengths [7] are currently used in photolithography: 365, 248 and 193 [nm]; The lithographic imaging system depends on an ideal projection from the photo mask onto the image plane; the range of emitting angles of the projection lens.
- a resolution power R (characterizes the minimum image size that can be obtained) corresponding to the purpose pursued. In summary, „photolithography resolution is limited by the diffraction of the light used for exposure” [4];
- mechanical properties. Good adhesion to the surface of the substrate or to the surface of the material deposited on the substrate, viscosity.

The photoresist materials (photosensitive resins) used in practice are composed of three main materials [13]: a matrix, a photosensitive compound and a solvent. Following exposure to light radiation, photochemical transformations take place in the photoactive resin, whose main consequence is the change of the solubility of the resin.

Depending on the photochemical effect, in practice two types of photo resists are used (Fig.3):

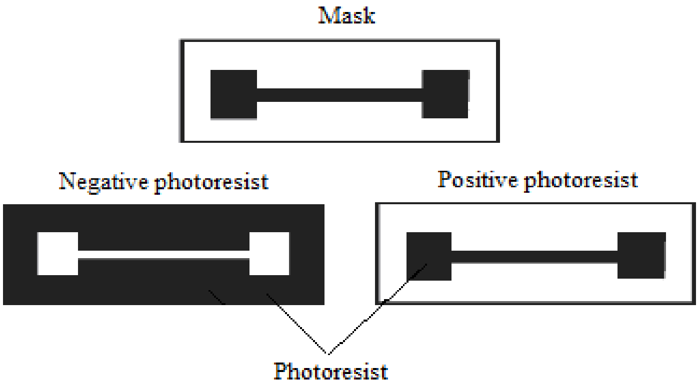


Figure 3: Resulting patterns after exposure and development of a positive- and negative-tone photoresist, after [9]

- positive photoresist characterized by increasing the solubility of the regions exposed to radiation, so that the photoresist is not protected by the photomask. Thus, after exposure and development of a positive photoresist, the opaque image on the mask is transferred to the photoresist as well;
- negative photoresist characterized by decreased solubility of the regions exposed to radiation, so that the photoresist protected by the photomask is removed. Thus, after exposure and development of a negative photoresist, the image on the photoresist is reversed from the opaque image on the mask.

In practice, the photoresist can be deposited in three ways: 1. by immersion, that is, by immersing the substrate. This modality is rarely used; 2. by centrifugation at which the photoresist layer or film is thinner the higher the centrifugation speed; 3. by spraying in the case of the substrate with a marked relief.

In the photolithographic process, the wafer must be realigned to the mask to guarantee accurate overlay of all layers [3]. For this purpose, specific means such as signs or keys between wafer and mask are used (Fig.4).

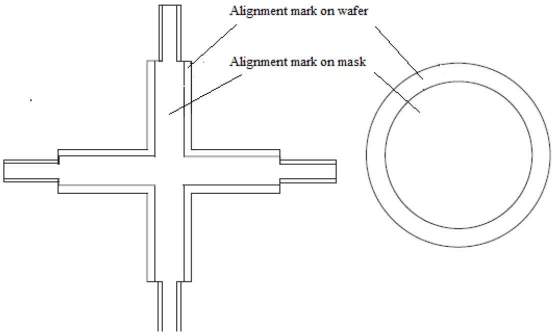


Figure 4: Alignment keys: standard thin resist; for thick resist, after [2]

In practice, three lithographic techniques are used, each with specific features, presented in the literature in the field [8], [5], [1]: 1.contact photolithography where the mask is positioned directly on the substrate; 2. proximity photolithography (proximity) where between the mask and the pad there is an air layer of thickness g = 20… 50 [mm]; 3. Photolithography by projection which involves the use of the optical projection realized between the mask and the plate.

3. CONCLUSION

In the photolithographic process, the following individual steps are involved: a. Cleaning and surface preparation; b. Resist coating; c. Pre-bake and alignment; d. Exposure; e. Post-Exposure Bake (PEB); f. Develop + ADI (after development inspection); g. Hard bake; h. Process; i. Strip; j. Measurement and final inspection. Common factors for lithography are: type of resists; thickness of resists; mask alignment; wafer surface, resist adhesion; exposure energy; temperature; development time. The photolithography process has a number of characteristics: the type and quality of the photoresist; mask alignment accuracy; photolithography method, etc.

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