Exercise 2
Photolithography

Photolithography is one of the main technological steps used during the semiconductor device's production. It is a two-stage process, in which the pattern from the physical source (mask) can be transferred to the wafer's surface by means of the thin layer of light-sensitive emulsion spread on the wafer. As a result selective processes (like etching, doping, metalization) can be applied on the silicon wafer.

Typically, two methods of photolithography are used (see Fig. 1.).

1. In **<u>subtractive method</u>** the layer to be processed is grown first (for instance thermal oxide), and then the emulsion is spread. After the emulsion is exposed through the mask and developed, the layer is selectively etched. Eventually, the remaining emulsion is removed. The shape from the mask remains copied on the grown layer.

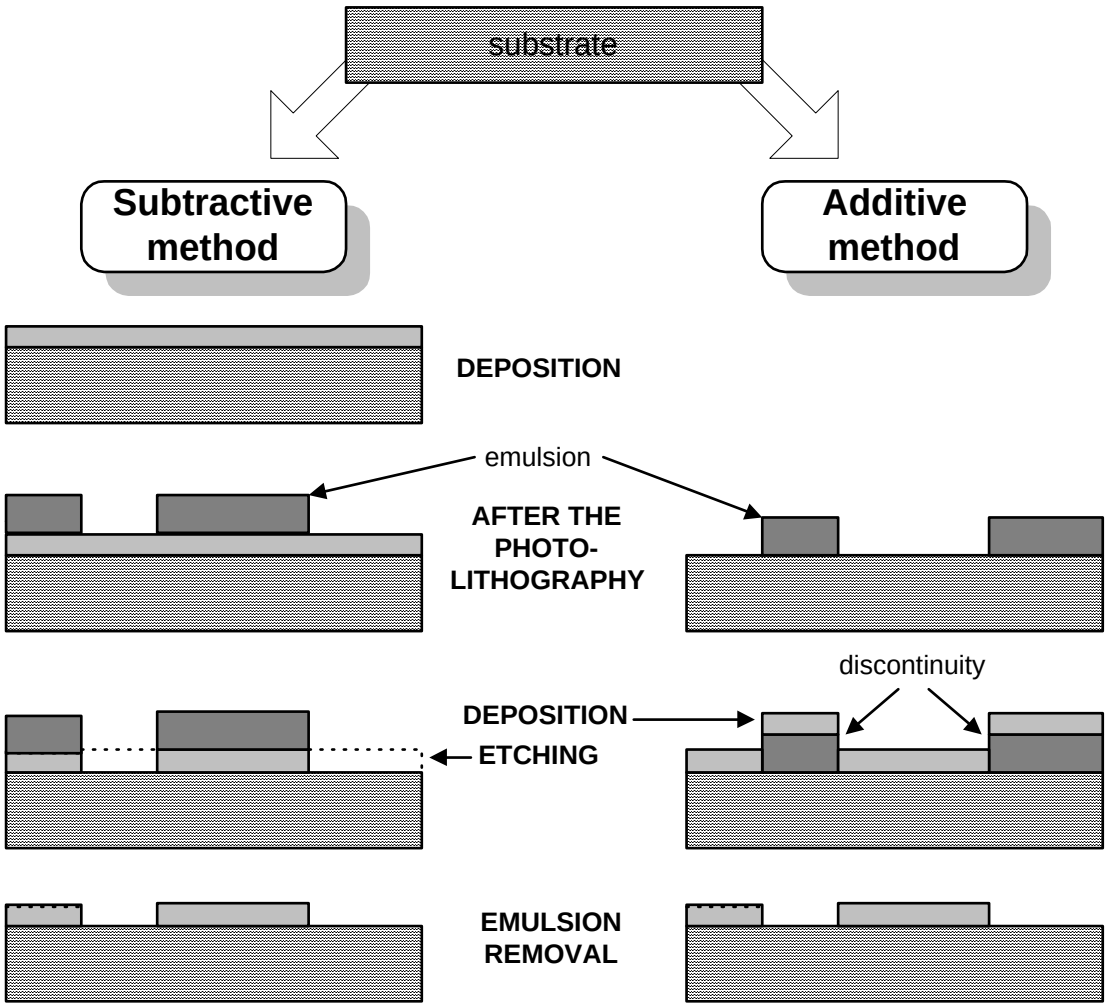

Fig. 1. Methods of the shape copying

2. In **additive method** (called "lift-off") the emulsion is spread, exposed and developed first. Then the layer is deposited. The discontinuity of the deposited layer (which is thinner than the emulsion layer) allows to dissolve the remaining emulsion and to remove the redundant parts of the layer. The advantage of this method is that it consists of one less step than the previous one. On the other hand gaining of the proper discontinuity may be difficult, and no high-temperature processes are available, and that is why the subtractive method prevails.

As well as in the typical photography, there are two kinds of light-sensitive emulsions (photoresists) that can be applied during photolithography: positive and negative ones.

- When the positive emulsion is used, the exposed parts of photoresist become rinsed during the development and the shadowed parts remain on the wafer. The image on the wafer is identical to the one from the mask.
- Reverse situation occurs, when the negative emulsion is used: the shadowed parts of photoresist are rinsed during the development and the exposed ones remain on the wafer – see Fig. 2.

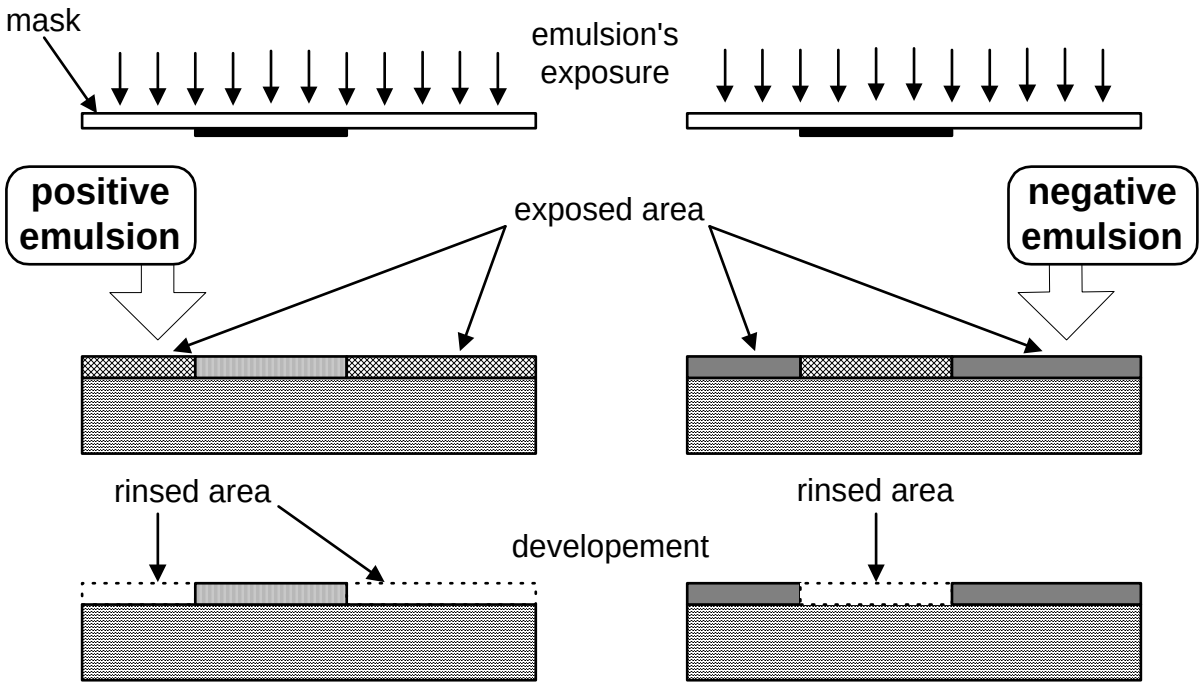

Fig. 2. The difference between the results of exposure of positive and negative photoresist through the same mask.

Thin and smooth film of emulsion on a wafer's surface is obtained by spinning of the wafer after wet emulsion is dropped on it. The emulsion is then dried during pre-baking (at temperature ~100^{o}C) and can be exposed to deep ultraviolet light passing through a mask in so-called "mask-aligner". The distance between mask and wafer in mask aligner is reduced to 10-25μm in proximity mode or totally cancelled in contact mode. Mask-aligner also assures the possibility of matching the position of mask with wafer's position, which is necessary in further lithography steps. Exposed wafer is then developed, dried and post-baked (at temperature 130^{o}C - 180^{o}C). Finally, the wafer can be processed inside photolithographically opened area (for example silicon oxide can be etched) and after processing the remaining emulsion can be removed by means of proper solvent.

The aim of the exercise is to perform complete photolithography process using the wafers oxidised in Exercise 1. It includes deposition of the thin photoresist film on the wafer's surface, exposure, development and etching of the unprotected silicon dioxide. The subtractive method of photolithography and positive emulsion will be used.

CAUTION:

During the exercise, protective clothing including a face mask, rubber gloves and apron must be worn due to safety and purity requirements.

To perform the photolithography one should:

1. Make sure that the mask-aligner in turned on since it needs approx. 20 minutes to heat up.
2. Turn the spinner on and check out its settings. The optimal values are 5000RPM for spinning speed, 0 for acceleration (highest acceleration) and 30sec. for operation time.
3. Using a tweezers put the wafer on the center of spinner table and apply the vacuum. Drop a few drops of primer (adhesion promoter) on the wafer and start the spinner. After the primer has been spread drop approx. 400μl of the photoresist on the wafer's center utilizing disposable syringe and restart the spinner.
4. Pre-bake the wafer in the oven at temperature 100^{0}C for 2 minutes in order to dry the emulsion film.
5. Position the wafer on the mask-aligner table, load the mask considering its proper side and perform the exposure of the wafer through a mask.

6. Develop the wafer by putting it into a glass with proper developer for 1-4 minutes. Rinse the wafer with deionised water and dry it using compressed nitrogen.
7. Examine the process quality under the microscope. Consider the edges sharpness, photoresist smoothness and continuity and possible contamination.
8. Post-bake the wafer in the oven at temperature 130^0C for 2 minutes in order to strengthen the remaining photoresist.
9. Perform the silicon dioxide etching using the mixture of HF and NH_4F in proportion 7:1. Consider that approximate silicon dioxide etching rate is 60nm/min. At this stage, only teflon or another plastic tools can be used.
10. Remove the remaining emulsion film using acetone, rinse the wafer with deionised water and dry it with compressed nitrogen.
11. Examine the result of the photolithography under the microscope.

WARNING:

Any of your actions must not be performed without the supervision of the lab staff. This is for your safety only!