Hochschule Karlsruhe
Technik und Wirtschaft
UNIVERSITY OF APPLIED SCIENCES

Practical Report

Submitted by
Santiago Ramos
Pilar Samaniego

Hochschule Karlsruhe
Technik und Wirtschaft
UNIVERSITY OF APPLIED SCIENCES

Certificate

This is to certify Santiago Ramos and Pilar Samaniego of **Hochshule Karlsruhe Technik und wirtschaft** has successfully completed the practical work with the partial fulfillment of the requirement for the completion of **EU4M Microtechnology course**. The practical work has been carried out by him/her in the year 2019-2020 winter semester.

Under the guidance of

Signature	Signature	Signature
Bernard Beck	Riya Davis Arrangassery	Prof. Olivier Schecker
Cleanroom in charge	Lecturer for the course	Head of the course

Acknowledgements

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I would like to thank Frederik Römer for helping us to complete the practical session successfully

Experiment 1

Photolithography (Negative Resist)

Aim:

To Obtain a snow sensor with negative photolithographic techniques on a silicon wafer

Procedure:

Photolithography (Negative resist)

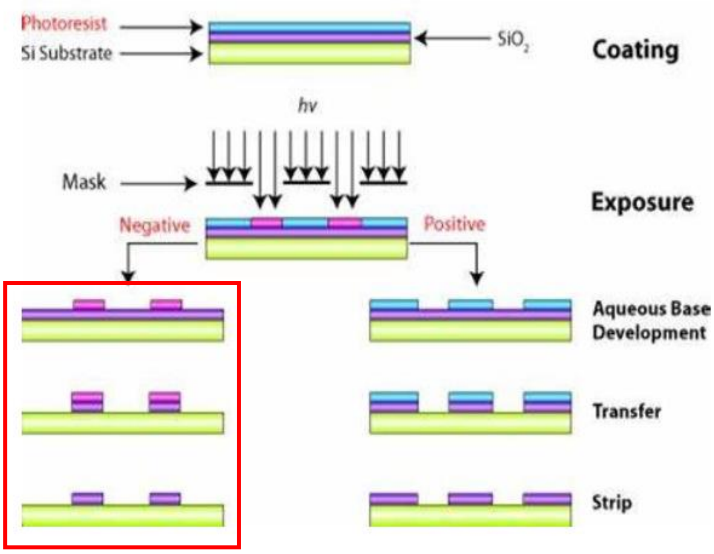


Figure 1. Photolithography Process

- **Dehydrating the wafer:** The first step is drying the silicon wafer in order to evaporate all the water molecules that could be on the surface. For that, the wafer is located over a hot plate at 100°C for 1 minute.

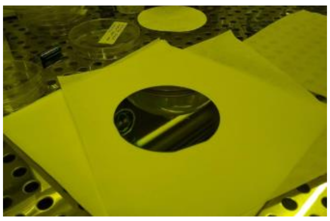


Figure 2. Dehydrating the wafer

- **Resist Coating:** In this step, a resist layer must be incorporated on the surface of the silicon wafer. In order to achieve this resist layer, the wafer is centered in a rotating plate. Then, the resist in a liquid form is applied over the wafer's surface and spinning at 2500 RPM for approximately 2 minutes. The thickness of the resist layer depends on the velocity and the viscosity of the resist. In this case the achieved thickness was 7 µm.

Figure 3. Resist Coating

- **Prebake:** The wafer is located again in the hotplate, but this time for 7 minutes until the resist is completely dried.
- **Exposure:** In order to generate a patron on the surface of the wafer, UV light is used as source. In addition, a mask is necessary to expose the desired part of the wafer. In this case a negative mask is used so that the exposed area remains, and the wafer is exposed to the UV for 15 seconds.

Figure 4. Exposure

- **Development:** For development of the resist, after the exposure the wafer is submerged in the developer solution until the patron appear on the surface of the wafer. This process takes around 1 to 2 minutes. Finally, the wafer is put inside deionized water for 1 minute.

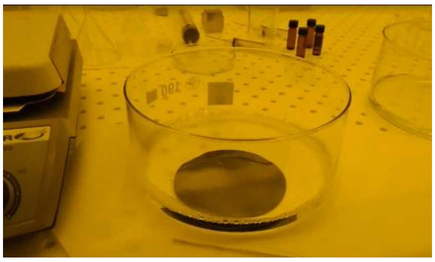
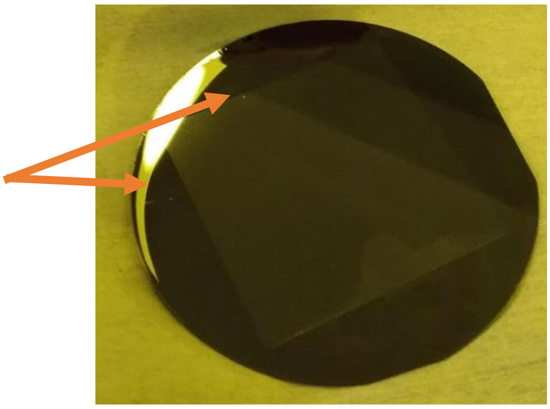


Figure 5. Development

Results:

- Even though the clean room is a suitable for this kind of process, the parameters must be controlled strictly to achieve the desired results. For example, over the surface of the wafer some particles could be seen that affect the process.



Conclusions:

- The photolithography process evidence the flexibility that can be achieved. Either with positive or negative mask and the multiple patron and different sizes that can be achieved demonstrated why is one of the most used techniques.
- Photolithography can etch a pattern into an integrated circuit with a single beam of ultraviolet light and does not require any additional materials. This allows photolithography to be highly efficient while produce very small circuits.

Experiment 2

Evaporation

Aim:

In order to make an electrical contact Al has been deposited with Evaporation Techniques

Procedure:

Evaporation Process

- **Vacuum:** For the evaporation process two vacuum pumps are necessary. The first pump aims to reach 1mbar. After that, the second pump is activated and reach vacuum in the order of $1x10^{-6}$ mbar. This vacuum condition is necessary in order to ensure that the evaporated particles can reach the surface of the wafer without interference of other particles (high mean free path).

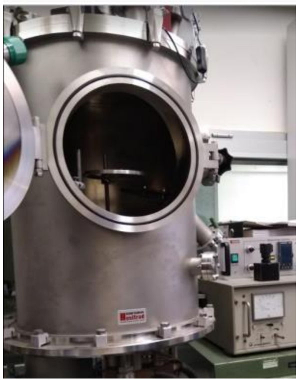


Figure 6. Chamber of Pressure

- **Crucible:** This component holds the metal to be evaporated. In this case aluminum pellet are used. The used crucible allows 176A and 2.6V and with a tuning factor of 100 Ka(1kA=100nm). The process must be led under controlled condition to avoid the fracture of the crucible.

Figure 7. Aluminum Pellet

- **Evaporation:** The current for the crucible is controlled with the current generator.

Figure 8. Current Generator

The current must be increased progressively until reach the melting point and the aluminum start to evaporate. Then the gas molecules are added to the wafer surface until the desired thickness is achieved or the aluminum completely melt.

- **Thickness and rate evaporation:** Once the aluminum start to melt the evaporation rate increase until reach the 20 Å/s and then decrease again until zero. For the thickness measurement a quartz crystal is used. This crystal oscillates with a known natural frequency and the mass that adhere to the crystal decrease the natural frequency and with that relation the mass and the thickness can be computed.

In the next graph we can see the evaporation rate as a function of time during the process:

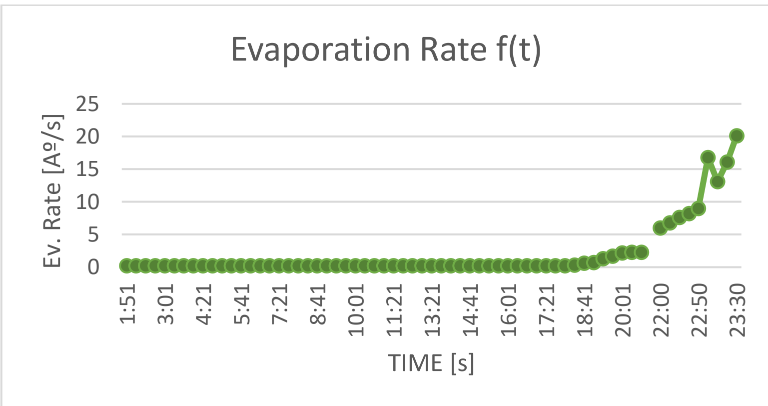


Figure 9. Ev. Rate vs Time during the process

- Finally, in order to keep just the aluminum within the patron the wafer is put in a chemical solution that removes the aluminum over the resist layer.

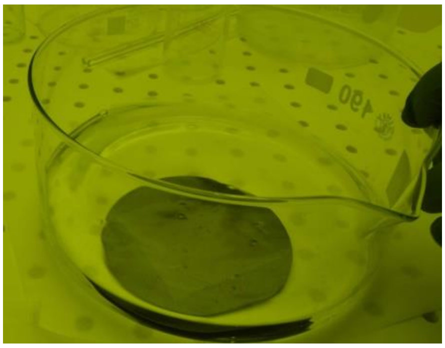


Figure 10. Dissolvent

Results

- The evaporation process was successful done. Reaching the expected result.

Conclusions:

- Although evaporation process is not common in production today it is cheap in comparison with modern techniques and can achieved good results. There is limitation with the edge coverage due to the orientation of the evaporated particles.
- During the evaporation a real-time thickness measurement is needed which is done by a quartz crystal microbalance, the frequency of oscillation is proportional to mass of deposited material (and thus thickness).
- After the etching process, the aluminum out of the desired patron couldn’t be removed from the wafer surface as expected and the process was repeated with another wafer. This experiment shows the importance of the steps to complete the whole process, so that if any mistake occurs can lead into a bad deposition of the metal over the surface.

Experiment 3

Photolithography (Positive Resist)

Aim:

To Obtain a snow sensor with positive photolithographic techniques on a silicon wafer

Procedure:

Photolithography(+Positive resist)

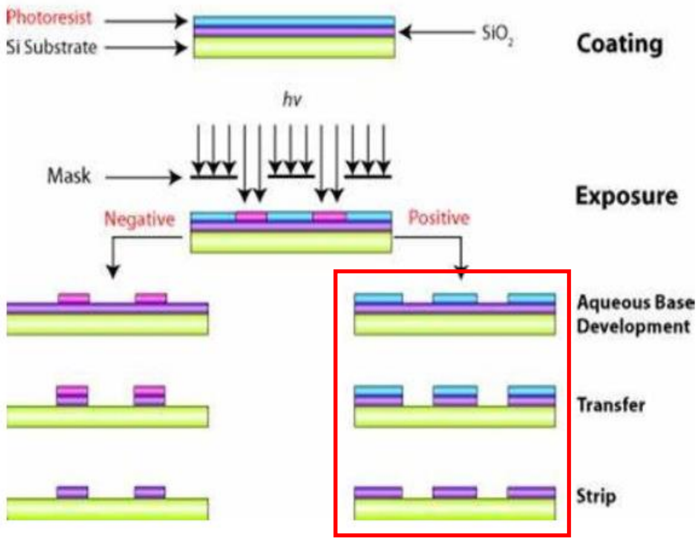


Figure 11. Photolithography Process

- **Primer Coating-Adhesion:** In order to get a good adhesion, the wafer's surface spinning at 4000 RPM for approximately 60 seconds.
- **Dehydrating the wafer:** The next step is drying the silicon wafer in order to evaporate all the water molecules that could be on the surface. For that, the wafer is located over a hot plate at 150°C for 5 minutes.

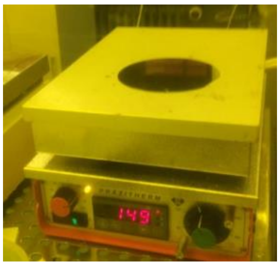


Figure 12. Dehydrating the wafer

- **Resist Spincoating:** In this step, a positive resist layer must be incorporated on the surface of the silicon wafer. In order to achieve this resist layer, the wafer is centered in a rotating plate. Then, the resist (1 ml) in a liquid form is applied over the wafer's surface and spinning at 4000 RPM for approximately 60 seconds. The thickness of the resist layer depends on the velocity and the viscosity of the resist.

Figure 13. Resist Coating

- **Prebake:** The wafer is located again in the hotplate at 95 °C, but this time for 2 minutes until the resist is completely dried.

Figure 14. Prebake Positive Phot.

- **Exposure:** In order to generate a patron on the surface of the wafer, UV light is used as source. In addition, a mask is necessary to expose the desired part of the wafer. In this case a positive mask is used so that the exposed area disappears, and the wafer is exposed to the UV for 10 seconds.

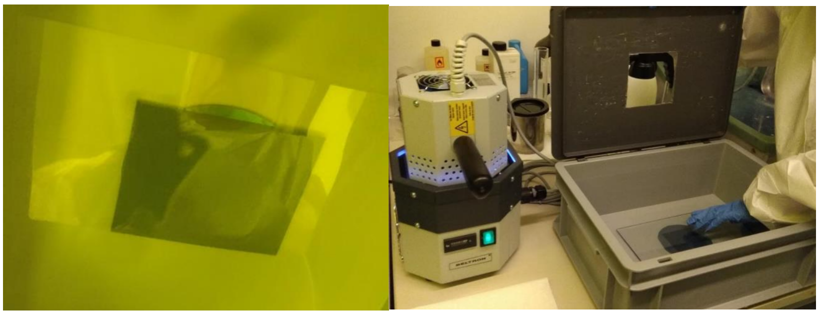


Figure 15. Exposure

- **Development:** For development of the resist, after the exposure the wafer is submerged in the developer solution. This process takes around 2 to 3 minutes. A mixture of one part of AR-300-26 and two of distilled water was used. Rinse with distilled water during operation by shaking the container. After the second dive rinse it in distilled water and dry.

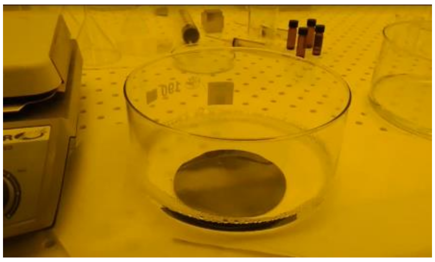


Figure 16. Development

Results

- The snow sensor with positive photolithographic techniques on a silicon wafer was almost successful, it only had a couple of lines on the surface.

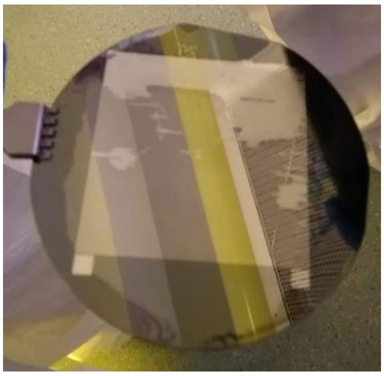


Figure 17. Result of Positive Photolithography

Conclusion:

- The Spincoating process must be carried out with great caution because when adding the mask to the Wafer it must be done very quickly, in a single squeeze. In the end the result obtained contained stripes on the surface that were due to Spincoating.

Experiment 4

Screen Printing

Aim : Print a patron (EU4M Logo) in a substrate using screen printing technique.

Procedure: Screen Printing Process

- **Screen:** The screen for printing can be used a couple of times before the ware of wires affect the quality of the printing process. In this case the screen is made of stainless steel with 325 wires/inch and 30-micron diameter. The angle of the wires is 22.5°.

Figure 18. Screen Parameters

- **Patron Printing:** The patron or the structure to be printed on the substrate is produced using Photoplotter

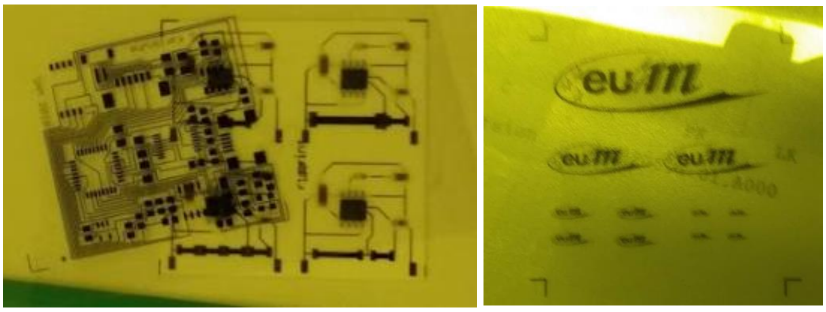


Figure 19. Patron printed

- **Film adhesion:** In order to produce a structure a film (DCF Vision 18) is attached to the screen. For this, the screen is washed with water, so that the film adheres easily. This film has a diameter of 18 micron. After the film rely on the surface of the screen, it is translated to the oven to dry the water.

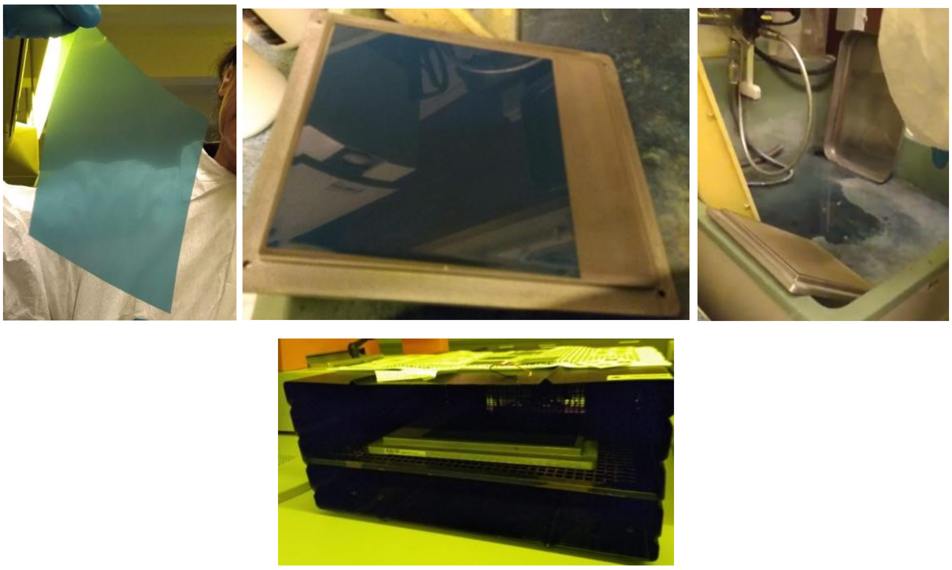


Figure 20. Film adhesion

- **UV Exposure:** the patron must me aligned, for that a sample film is used to adjust the desired patron film. The lamp works with mercury and the intensity increase while the mercury is changing to gas state. The exposure takes 40 seconds.

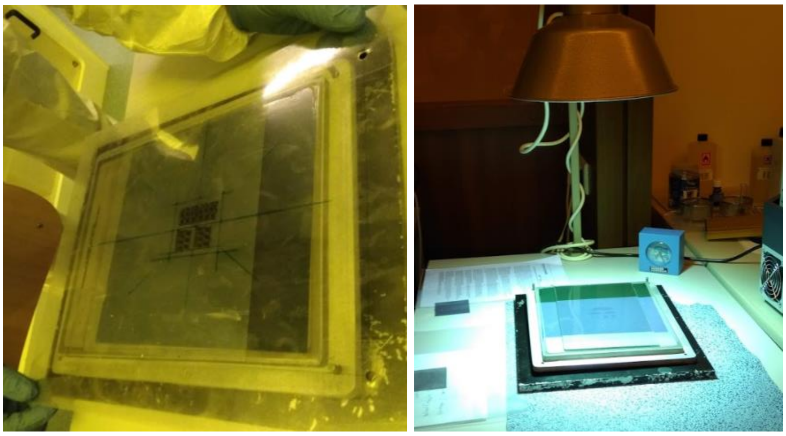


Figure 21. UV exposure

- **Screen washing:** Just the exposed area is soluble in water. After exposure, the screen is washed with pressure water until the film on the exposure area is removed. After that, it is translated to the oven to dry the water again

Figure 22. Screen washing

- **Paste:** The paste used for this experiment is resistive paste. It is a thixotropic fluid. That is necessary so that during printing the viscosity of the paste is low and after the process end the viscosity increase.

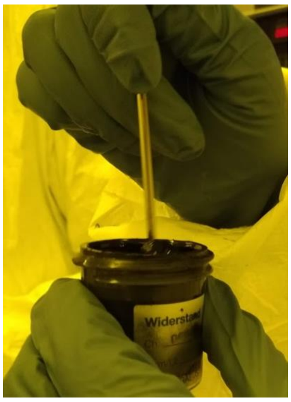


Figure 23. Resistive Paste

- **Screen attachment:** Once the screen is dry (3 minutes in the oven) the screen is attached to the machine. The cameras installed on the machine are used for the alignment of the screen. The distance between the screen and the substate is 0.6 mm. Velocity of the Rakel (60 mm/1.56 s) and the force applied to the Rakel is 40N. The 80% of the success depend of the paste.

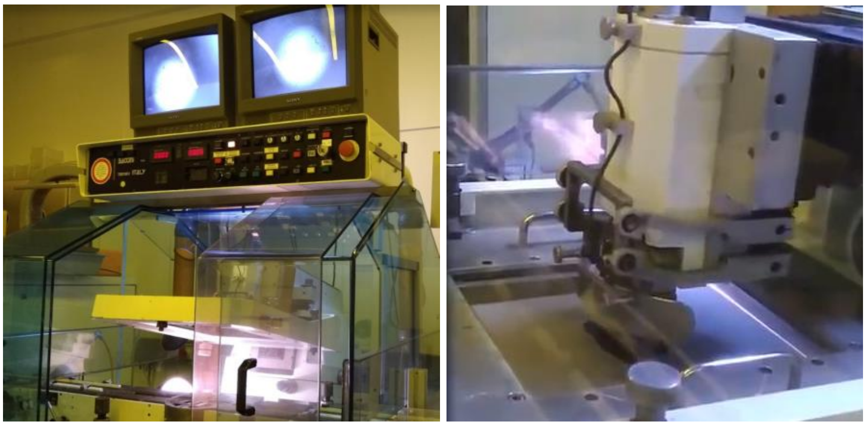


Figure 24. Screen attachment

- **Printing:** The paste is applied to the screen and then the machine automatically with the parameters described bellow distributes the paste over the substrate surface.

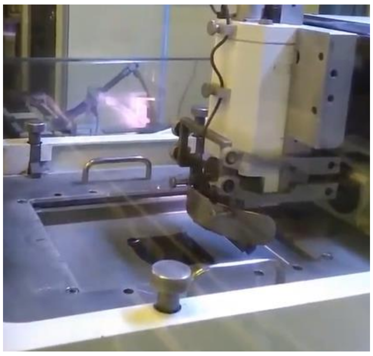


Figure 25. Development

- **Drying:** After the paste is applied, it is necessary to expose the substrate to a thin film temperature profile. First, the substrate is exposed to 120°C for 10 minutes in order to evaporate the solvents. Then the temperature increase until 850°C is reached so that the leveling take place and the paste particles unify.

Figure 26. Development

Results:

- The printing process was successful, and the structure was correct printed. The microscope analysis allows to validate the process.

Figure 27. Results of Screen Printing

Conclusion:

- As part of the thick film technology the screen-printing process is wide used technique due to its flexibility for hybrid circuits design.

- Due to the low cost in comparison with other techniques like thin film technology, screen printing process are suitable for circuit and integration of circuits as far as the required miniaturing grad is not high.