Engineering Project: Architecture file

SUSPENDED HYDROPHOBIC SILICON MEMBRANE (SHSM)

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Glossary

C
CMS: Columnar Microstructures
CFx: Carbon Fluoride
L
LED: Light-Emitting Diode
M
MEMS: Micro-Electro-Mechanical System
SEM: Scanning Electron Microscopy
P
PECVD: Plasma-Enhanced Chemical Vapor Deposition
R
RF: RadioFrequency
S
SiO2: Silicon Dioxide
SHSM: Suspended Hydrophobic Silicon Membrane

Introduction

The aim of the Silicon Hydrophobic Suspended Membrane (SHSM) project is to develop a system that filters gases while retaining water, making osmosis a reality on a nanometric scale. This approach draws its inspiration from the lotus effect observed on a nanometric scale, which we are implementing thanks to a phenomenon identified in cryogenic plasma etching, known as columnar microstructures (CMS).

The project focuses on the design of a hydrophobic silicon membrane incorporating nanostructured functionalities. The project requirements include achieving an etch depth of 450µm, combined with a width of 5 mm on the back side, and an etch depth of 50µm on the front side, implementing the creation of columnar microstructures (CMS). The substrate chosen for this system is 4-inch, double-sided poly silicon (Si).

These specifications are designed to ensure the successful design of a hydrophobic silicon membrane. It should be noted that the production of SMDs using cryogenic plasma etching is a key element in reproducing the lotus effect on a nanometric scale, thereby conferring hydrophobic properties on the membrane. In addition to the technical aspects, a scientific paper or article is planned to reflect the significant advances made.

In short, this project will open up promising application prospects, particularly in the fields of Micro-Electro-Mechanical Systems (MEMS), microfluidic systems and photovoltaic systems.

Functional overview of the project

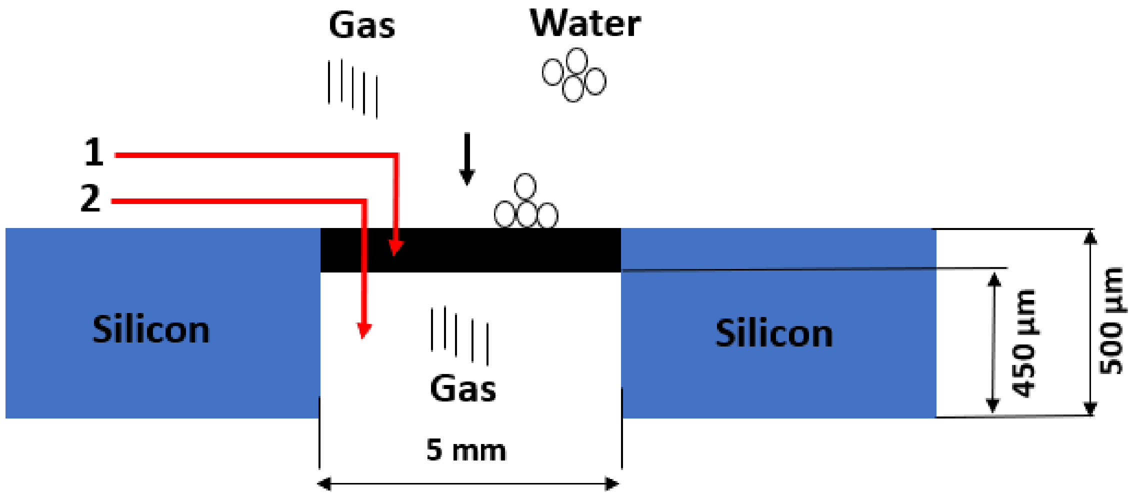


Figure 1 : Descriptive Diagram

The diagram presented provides an overview of the project, highlighting its main objective, namely to achieve selective gas filtration. A closer look at the diagram reveals that the hydrophobicity of the membrane is maintained, giving the system the ability to stop water.

The annotations numbered 1 and 2 on the diagram correspond respectively to the etching associated with hydrophobicity and the deep etching. In concrete terms, the plan is to etch the top 50µm and deep etch 450µm. This diagram therefore reveals two main functions that are crucial to the project: etching the front side by 50µm with hydrophobicity and etching the back side by 450µm. These elements constitute the fundamental pillars for achieving the objectives set.

Part 1: Front side etching + hydrophobicity

1. Background and objectives

The first phase of the project aims to achieve an etch depth of 50 micrometres, targeting a porosity of between 10 and 20%. The underlying objective is to achieve a significant density of columnar microstructures (CMS) on the front side of the silicon membrane in order to impart hydrophobic properties to the membrane. This approach is based on the idea that the creation of pores in the structure favours the non-spreading of water droplets, leading to hydrophobic properties. It also allows the selective passage of gases, to ensure filtering functionality.

At the same time, the use of a CFx solution for polymerisation is envisaged to avoid excessive spreading of the drops during the process, which could compromise the uniformity of the microstructures. The CFx solution would be applied to form a protective layer, helping to maintain the shape of the columnar microstructures.

2. Process

The membrane manufacturing process involves a well-defined sequence of steps. This section will detail the specific process flow followed to achieve etching of the side place and incorporation of hydrophobicity. This will include the cryogenic plasma etching technique used and the crucial manufacturing parameters. A clear explanation of this process will provide an understanding of the key stages in the development of the membrane.

1. Process flow:

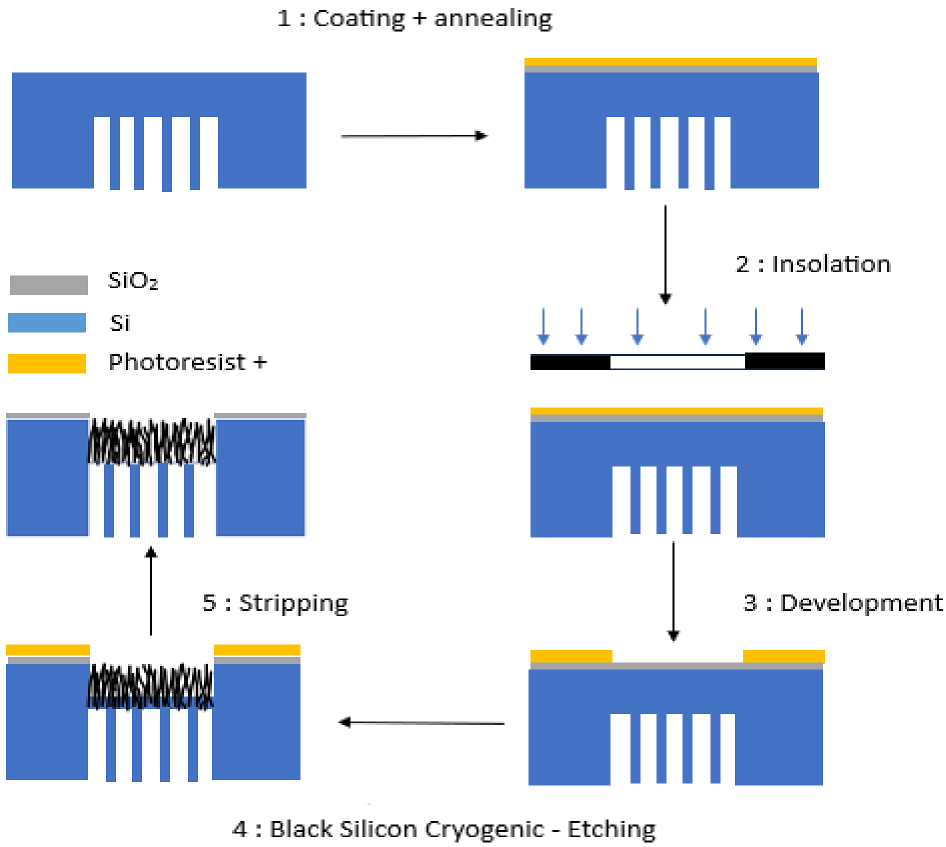


Figure 2 : Process flow of front side etching.

2.1 Step 1: Coating + annealing

The process begins with the application of the positive resist. It is advisable to start depositing the resist in the centre of the substrate to avoid the formation of droplets that could leave unwanted marks on the wafer. To ensure even distribution of the resist on the substrate surface, rotation is applied at a set speed and for a set time once deposition is complete. By heating the photoresist and substrate to 115°C, the annealing phase hardens the photoresist, ensuring better contact with the substrate.

2.2 Step 2: Insolation

This stage involves exposure using the UV-kub machine. The UV-kub guarantees uniform exposure using 365m UV LEDs, suitable for substrates up to 4 inches. The sample holder offers soft-contact or gap modes. At full power, the LEDs generate an intensity of 25 mW/cm2. The aim of this experiment is to define the profile required for etching black silicon or columnar microstructures (CMS). The mask for etching the front side is shown in Appendix 3.

2.3 Step 3: Development

Development allows UV-exposed photoresist to be selectively removed after exposure. A suitable developer dissolves the exposed photoresist, revealing areas of the substrate where the photoresist has been cured during exposure. This process creates a pattern or template for subsequent etching steps, helping to form the desired structures on the substrate.

2.4 Step 4: Etching CMS

This involves cryogenic etching to obtain columnar microstructures (CMS). This etching is carried out in an Alcatel 601E type inductively coupled plasma (ICP) reactor at Gremi, using a gaseous mixture of SF_6/O_2. This cryogenic method offers greater precision in the creation of microstructures, enabling the desired specifications to be achieved.

2.5 Step 5: Stripping

The stripping step takes place after the structures have been produced on the substrate. This step removes any residual layer of masking material, usually a photoresist or polymer, that may have been used to protect certain parts of the substrate during the previous stages of the manufacturing process.

3. Results and prospects

The third section focuses on the tests carried out, the equipment used, and the results obtained. It details the methods used to assess the performance of columnar microstructures (CMS), highlighting the specific instruments used. The results, particularly in terms of the hydrophobic properties and dimensions of the CMS. Finally, the prospects envisaged for resolving any problems detected will be outlined, highlighting the possible adjustments and improvements to be made to optimise the experimental protocol within the framework of the project.

3.1 Experimental

The experiments are carried out in an Alcatel 601E type inductively coupled plasma (ICP) reactor. In this device, an SF_6/O_2 gas mixture is introduced at the top of a plasma source using mass flow regulators (up to 1000 sccm of SF_6 and up to 200 sccm of O_2). The reactor's dielectric tube is made of alumina, reducing sputter contamination compared with quartz. This design helps to minimise oxygen contamination. Electrical power of up to 3000 W can be coupled to the plasma source.

The sample used during the CMS etch tests is as follows:

1 piece of unmasked silicon with an average area of 9 cm^2; This sample is bonded to a SiO_2 plate using a thermal transfer adhesive to ensure good thermal contact between the sample and the sample holder.

In the cryo-etching process, the SiO_xF_y passivation layer protects the silicon from chemical etching caused by fluorine radicals. Under normal etching conditions, ion bombardment, arriving perpendicular to the surface, eliminates the passivation layer or prevents its formation. If the protection of the silicon by the passivation layer becomes too effective against ion bombardment, CMSs appear on the silicon surface.

CMSs appear during an overpassivation regime. This regime is reached when the oxygen content in the plasma is sufficient and at a cryogenic temperature of around -100°C when the incoming thermal power (ion energy and density) is low. In view of these observations, the parameters for test 1 were chosen as follows:

a. **Test 1**

Table 1: Cryogenic process parameter Test 1

Parameters	Data
O2	22 sccm
SF6	200 sccm
Temperature	-118 °C
Bias	-20 V
Power (source)	1000 W
Time	30 min
Pressure	3 Pa

Figure 3 shows SEM images of these CMSs after etching. Figures 1 (a) and (b), respectively, show the side view and the top view of the microstructure after a 30-minute treatment (1000 W source, -20 V bias, O2/SF6 = 0.11, 3 Pa pressure). The dark areas correspond to the bottom of the CMS and the white part corresponds to the top of the microstructure. In this case, the typical diameter of the holes is about 1µm, and the typical height reaches 14.85 µm with a porosity of 32.58%.

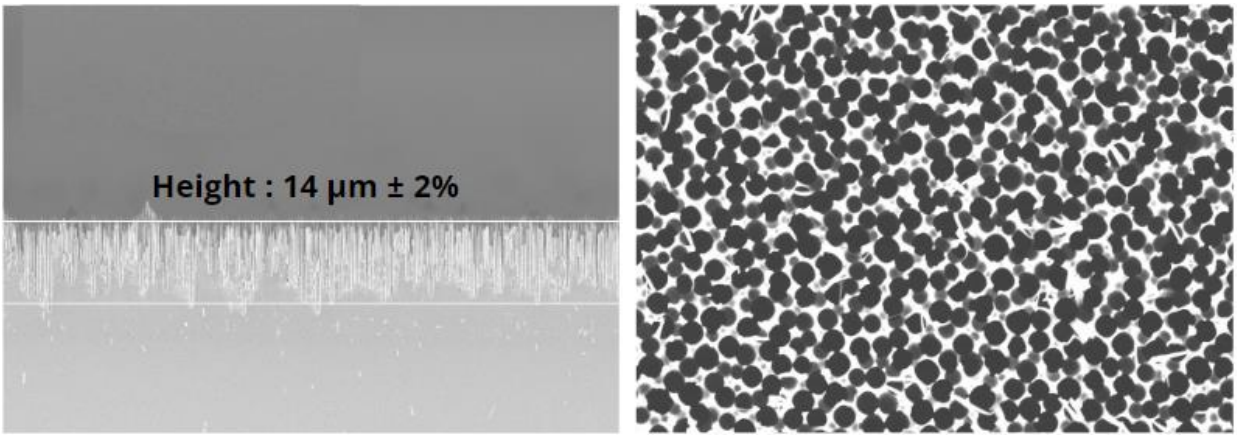


Figure 3: SEM image of the CMS (a) side and (b) top views (Time = 40 min, Bias = -30v, Power = 100Ow, O2/SF6 = 0.08, Temperature = -118, Pressure = 3 Pa)

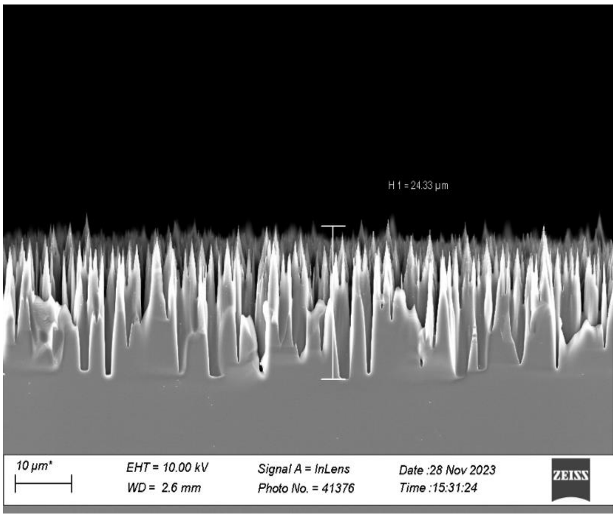
In view of the results obtained and with the aim of reaching a depth of 50µm, the following manipulations were carried out by adjusting the O2/SF6 ratio to 0.08 and a polarisation of -30 V. This modification was undertaken in order to minimise overpassivation and therefore optimise the etching of columnar microstructures (CMS) and increase ion bombardment. A series of three tests were carried out, keeping this ratio constant while varying the etching time from 10 to 40 minutes. This strategic approach enabled us to assess the sensitivity of the results to different exposure times.

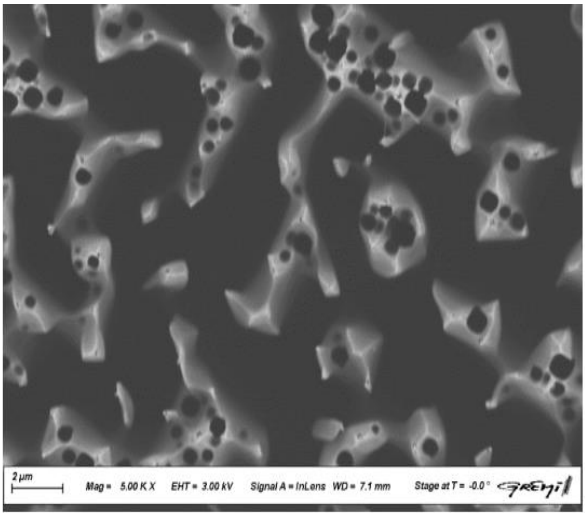
b. **Test 2:**

Table 2: Cryogenic process parameter Test 2

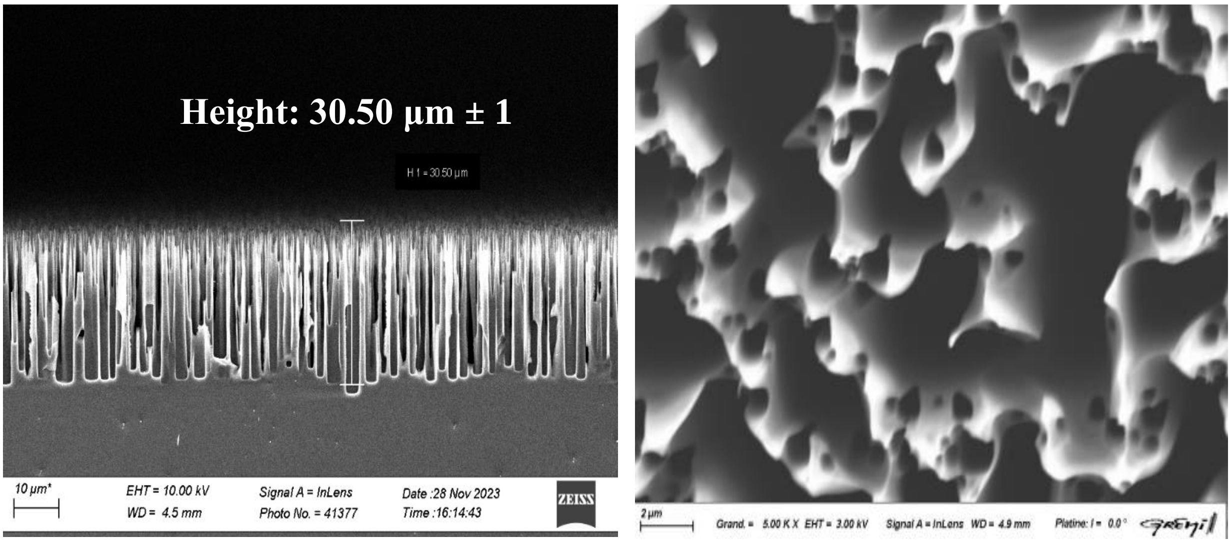
Parameters	Data
O2	16 sccm
SF6	200 sccm
Temperature	-118 °C
Bias	-30 V
Power (source)	1000 W
Time	10, 20 et 40 min
Pressure	3 Pa

Serie 1 :





Serie 2 :



Serie 3 :

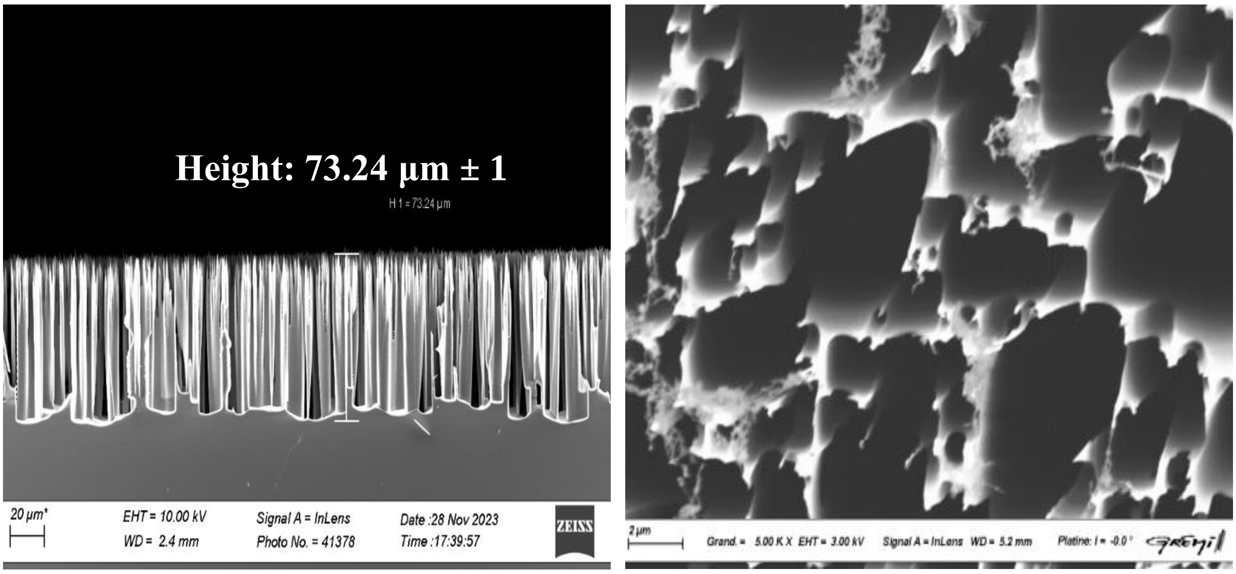


Figure 4 : SEM image of the CMS (a) side and (b) top views (Time = 40 min, Bias = -30v, Power = 100Ow, O2/SF6 = 0.08, Temperature = -118, Pressure = 3 Pa)

Series 4, 5 and 6 show scanning electron microscopy (SEM) images of the columnar microstructures (CMS) obtained during the second test. Sub-figures (a) and (b), representing the side view and top view of each series respectively, illustrate the evolution of the microstructure after treatment times of 10, 20 and 40 minutes (source 1000 W, bias -30 V, O2/SF6 = 0.08, pressure 3 Pa).

The observations indicate that the ratio O2/SF6 = 0.08 favours more pronounced etching, as expected. The height of the CMSs increased from 24.33 µm in the first series to 73.24 µm, exceeding the desired target of 50 µm. However, porosity increases significantly in series 1, 2 and 3, exceeding 32.58%. As a result, the structure may not be hydrophobic, as the reduced density of the CMSs could lead to droplet spreading. These results highlight the importance of balancing CMS height with porosity to achieve the desired hydrophobic properties.

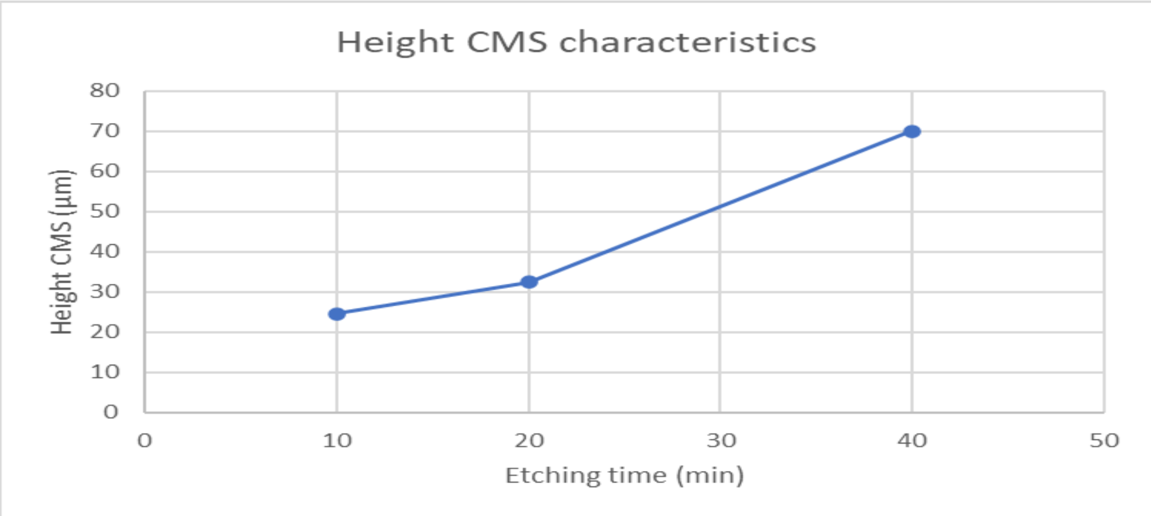


Figure 5: Evolution of CMS height as a function of etching time (Time = 10, 20, 40 min, Bias = -30v, Power = 1000w, O2/SF6 = 0.08, Temperature = -118, Pressure = 3 Pa)

c. **Test 3:**

For the remainder of the project, manipulations were undertaken with etch times between 10 and 30 minutes to assess the impact of changing the O2/SF6 ratio to 0.08 and reducing the self-biasing voltage to -20 V on the characteristics of columnar microstructures (CMS). However, the results were similar to those of the previous test, so a new approach was adopted to study the influence of temperature variation in order to recreate the structure shown in figure 3, but at a temperature of 120°C, a bias of -20V and for a time of 30 min.

Table 3: Cryogenic process parameter Test 3

Parameters	Data
O2	22 sccm
SF6	200 sccm
Temperature	-118 °C
Bias	-30 V
Power (source)	1000 W
Time	30 min

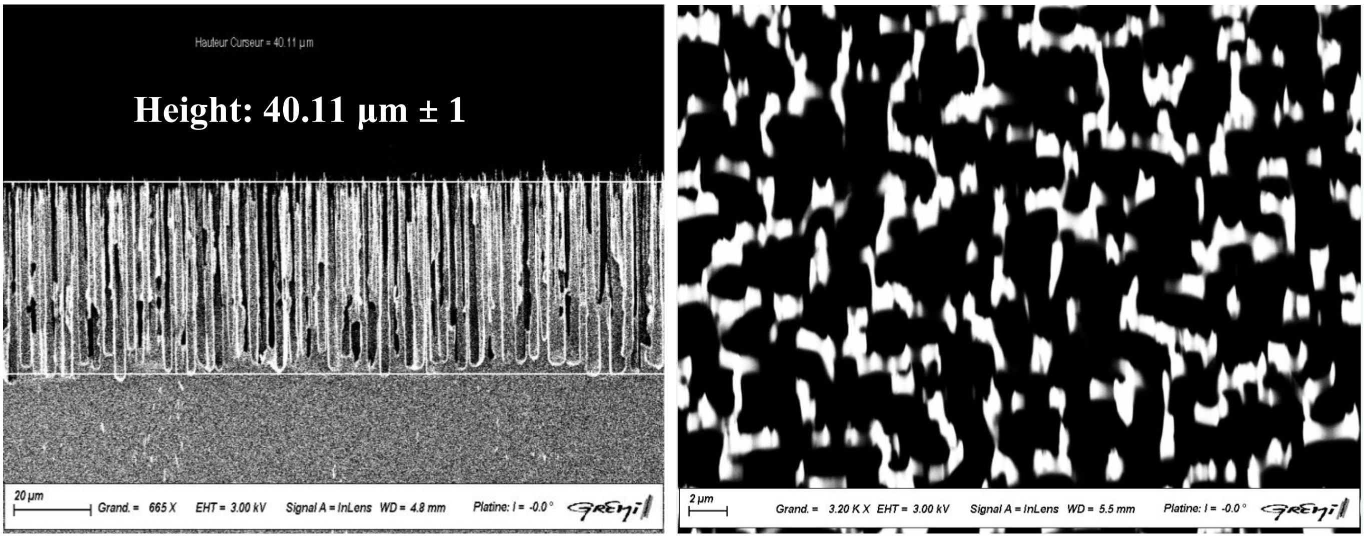


Figure 6 : SEM image of the CMS (a) side and (b) top views (Time = 30 min, Bias = -20v, Power = 1000w, O2/SF6 = 0.11, Temperature = -120 Pressure = 3 Pa)

Figures 6 show scanning electron microscopy (SEM) images of columnar microstructures (CMS) obtained during the second trial. Subfigures (a) and (b), representing the side view and top view of test illustrate microstructure formation for a processing time of 30 minutes (source 1000 W, bias -20 V, O2/SF6 = 0.11, pressure 3 Pa, Temperature = 120 °C).

Observations indicate that the change in temperature from -118 to 120°C affects the density of the CMS. In addition, for a time of 30 min, we obtained a CMS height equal to 40.85 um, confirming the desired objective. Porosity is reduced in comparison with series 1, 2 and 3 of test 2, but is in the form of needles rather than holes in cross-sectional view as in top view, which could affect membrane stability.

In view of the results, it was decided to start with the basic process shown in figure 3 (cryogenic process), giving a stable structure at a height of 14 micrometers, and to etch up to 50 micrometers using the Stiger process.

d. **Test 4: Cryogenic and Stiger Process**

Figure 7 shows scanning electron microscopy (SEM) images of columnar microstructures (CMS) obtained during manipulations. Subfigures (a) and (b) illustrate the formation of the microstructure for a treatment time of 20 minutes.

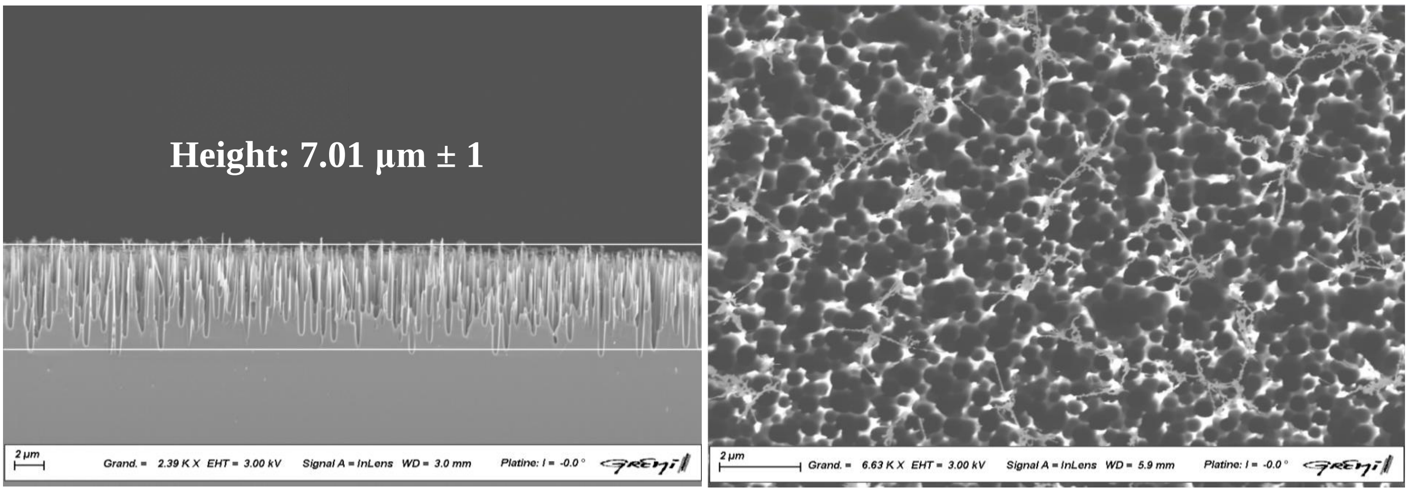


Figure 7 : SEM image of the CMS (a) side and (b) top views (Cryogenic Process (2 min) : P = 3 Pa, Bias = -20v, Power = 1000w, O2/SF6 = 0.11, Temp = -115 °C and Stiger Process (20 min) : SiF4 = 22 sccm, O2 = 22 sccm, Etching = 5 s and Passivation = 1 s)

The results do not meet expectations because, after alternating between the two processes, the etching height remains unchanged; however, a high density of CMS holes is achieved. The failure to achieve objectives in these initial manipulations could be explained by the lack of control over the alternation phase between the cryogenic process and the Stiger process.

3.2 Prospects

For the next step of the project, the manipulations keep going with the basic process shown in figure 3 (cryogenic process), giving a stable structure at a height of 14 micrometers, and to etch up to 50 micrometers using the Stiger process. In addition, the study of a CFx solution for polymerisation will be undertaken.

Part 2: Back side etching

1. Background and objectives

Etching the rear side represents a crucial step in the manufacturing process, aimed at creating an optimal support for the membrane suspension. This phase involves precise etching to a depth of 450µm and a width of 5mm. Key objectives include precisely achieving these dimensions, preserving the structural integrity of the material, as well as designing a robust support capable of withstanding mechanical stress. By succeeding in these objectives, the etching of the backside will contribute optimally to the creation of a functional support, ensuring the proper suspension of the membrane in the final device.

Various processes can be used to carry out this etching, such as the cryogenic process, the Bosch process and the Stiger process. Each of these processes offers specific advantages, as summarised in the table below:

Table 4: Advantages and disadvantages of plasma etching processes

	Cryogenic etching	Bosch etching	STiGer etrching
Advantages	* Continuous process: high engraving speed * Clean process * Anisotropic etching	* Allows operation at room temperature * Robust process	* Reduced step times compared to the Bosch process * Robust process * No need to clean the walls
Disadvantages	* Process sensitive to temperature variations * Permanent use of liquid nitrogen * Sensitive to variations in oxygen flow rates	* Scalloping on the walls * Decrease in Vg * Need to clean the reactor walls	* Scalloping on the walls

Although the Bosch and Stiger processes are recognised for their robustness, they have the notable disadvantage of causing scalloping effects along the edges, which compromises the ability to obtain vertical edges, and it is not possible to observe the appearance of SMDs using these techniques. It is precisely to overcome this limitation that we have opted to use the cryogenic process. The latter, characterised by its innovative approach, offers a more favourable solution by minimising the undesirable effects on the edges, thus ensuring the production of vertical contours, and meeting our specific etching requirements in a more optimal way.

Problem identified: Although cryogenic etching performs well, a problem persists in obtaining etches with vertical edges due to the phenomenon of static cladding, amplified by the 5mm etch width. During the plasma etching process, the cladding, with its thickness of around 200µm, penetrates the etched material due to the width being large enough to contain the cladding. This leads to deformation at the edges, as illustrated in the figure below.

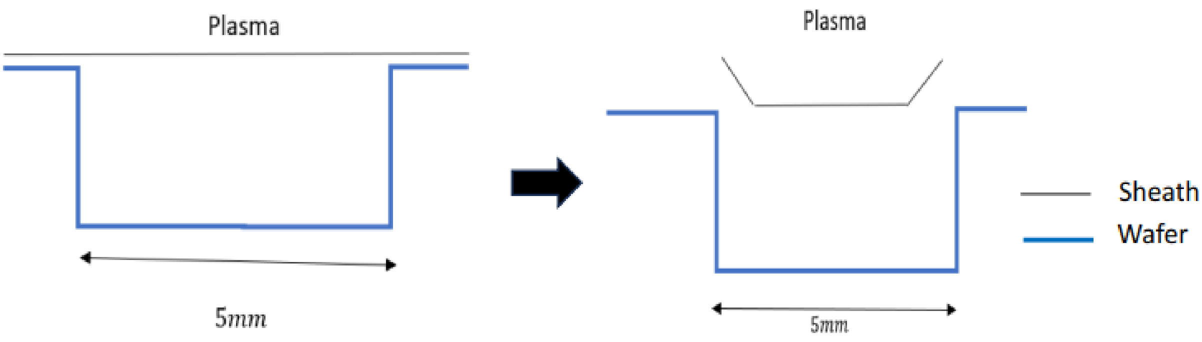


Figure 8: Descriptive diagram of the sheath problem during deep etching of 450 micrometers.

Solution:

To remedy this problem, it is necessary to adopt the use of a mask to prevent infiltration of the sheath at the edges. Elements relating to mask selection are described in the next section.

2. Choosing or making a mask

A mask is used to transpose a specific pattern onto a material. As mentioned previously, to solve the sheathing problem, the use of a mask is essential, and this should prevent the sheathing from infiltrating along the edges. To this end, a mask in the form of a grid is chosen (see appendix), as it is highly effective in preventing the introduction of sheathing along the contours, as illustrated in the figure below.

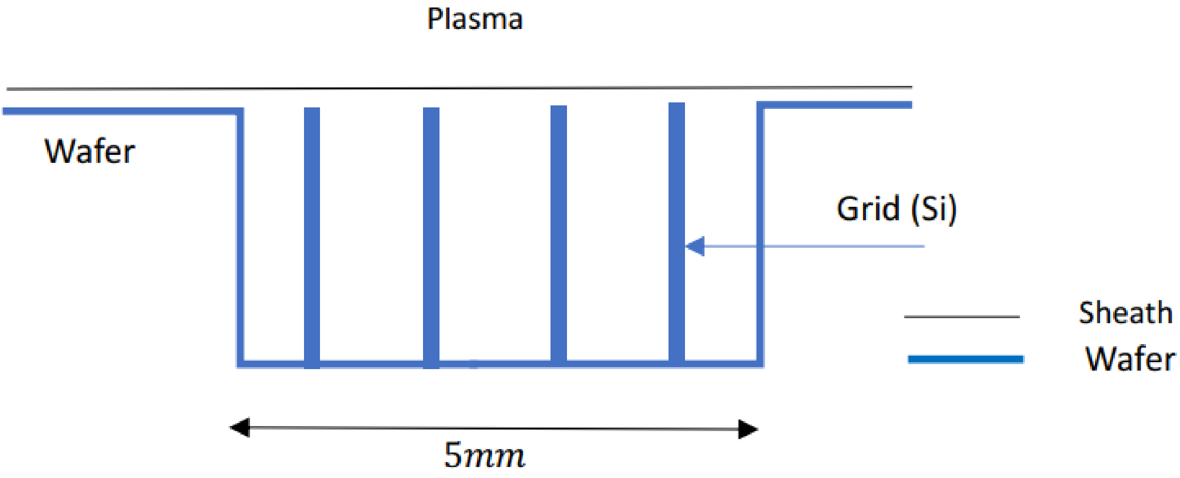


Figure 9: Solution to the problem of Sheath.

3. Process flow

This section presents the entire 450µm deep etch manufacturing process in a comprehensive manner. The main steps in the manufacturing process are shown in Figure 10.

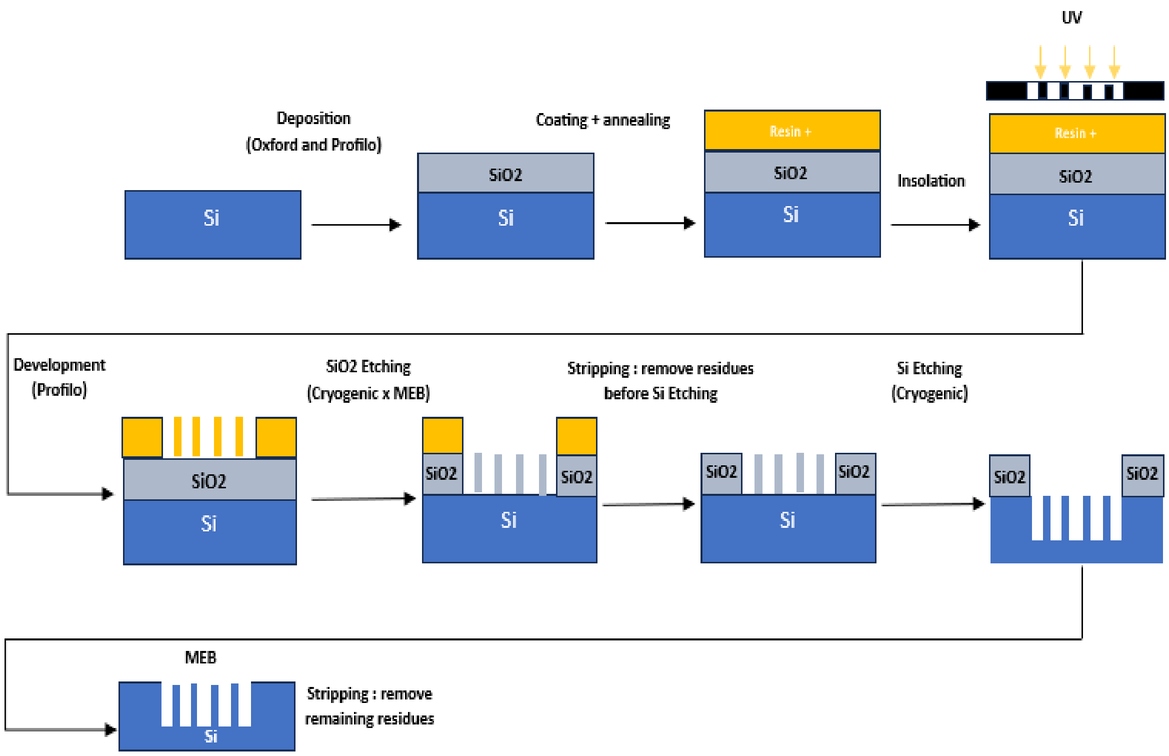


Figure 10: Deep etching manufacturing process.

- 3.1. Description of the process steps

a. Step 1, 2, 3 et 4: SiO2 deposition, coating + annealing, exposure and development

The deposition (1) of SiO2 is undertaken to prevent excessive etching of the silicon, thereby ensuring the stability of the gate structure and the maintenance of the suspended membrane. In order to deposit SiO2 on the silicon substrate, the PECVD (Plasma Enhanced Chemical Vapour Deposition) technique is used via the OXFORD machine. This method uses plasma to activate the chemical reagents, simplifying deposition on the target surface. It should be noted that the precise thickness of the SiO2 layer to be deposited remains undetermined.

Next, the lithography sequence is initiated with the deposition of the resist in step (2). The positive resist is selected according to the mask, where the objective is to maintain the opaque parts of the mask while the other parts must be removed to create an observable grid on the substrate. Similarly to SiO2, the specific thickness of the photoresist layer has not yet been determined. The next phase (3) also involves exposing the photoresist to ultraviolet light and developing (4) the photoresist to obtain the desired patterns on the substrate.

b. Steps 5, 6, 7 et 8: SiO2 etching, Stripping, Si etching and Stripping.

Following the deposition and lithography step, specific areas of SiO2 are etched (5) using the cryogenic process, followed by a stripping step (6) to remove any residual layer of masking materials. A further etch (7) is performed on the silicon using the cryogenic process to a depth of 450µm. Subsequently (8), the remaining photoresist is removed using acetone.

4. Results and prospects

SiO2 deposition

The implementation of the 450µm deep etch is currently in its first phase, namely the deposition of the SiO2 layer. A test was carried out on the OXFORD deposition machine using the PECVD method as well as an analysis with ellipsometry which resulted in a depth of around 1µm. The parameters initialised to obtain this SiO2 deposit are:

- Time: 15 min
- Power RF: 20 W
- Substrate port temperature: 300°C
- SiH4 flow rate: 170 sccm
- N2O flow rate: 700 sccm
- Pressure: 1000 mTorr

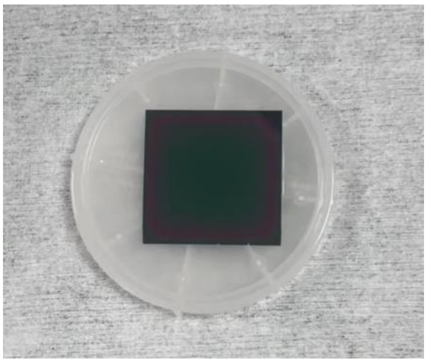


Figure 11: Image of the sample with the SiO2 deposit.

This test was carried out to evaluate the deposition possibilities, enabling the selectivity between the deposited SiO2 layer and the silicon to be determined at a later stage. By varying the etch time, the thickness of the SiO2 layer to be deposited to achieve a deep etch of 450 µm while minimising etching of the silicon substrate can be deduced.

Lithography:

In this part, photoresist deposition is carried out as well as exposure with a mask. The photoresist used is AZ4562 (see figure), a positive photoresist that creates a positive image of the structure (mask) on the substrate, with a minimum layer thickness of 3µm.

Figure 12: Positive Photoresist AZ4562.

The deposition parameters for obtaining a photoresist layer of approximately 3 microns are shown below:

Figure 13: Photoresist deposition parameters.

Once the photoresist has been applied and annealed, the mask is exposed on the substrate. This phase is carried out in the UV-KUV machine using the following parameters:

- Substrate thickness: 550 µm
- Masking distance: 10 µm

- Duration: 23 sec
- Power (%): 60

Once exposure is complete, AZ400K developer, diluted with water, is used for development for 45 seconds, due to the small size of the mask patterns.

The results can be seen in the following figures:

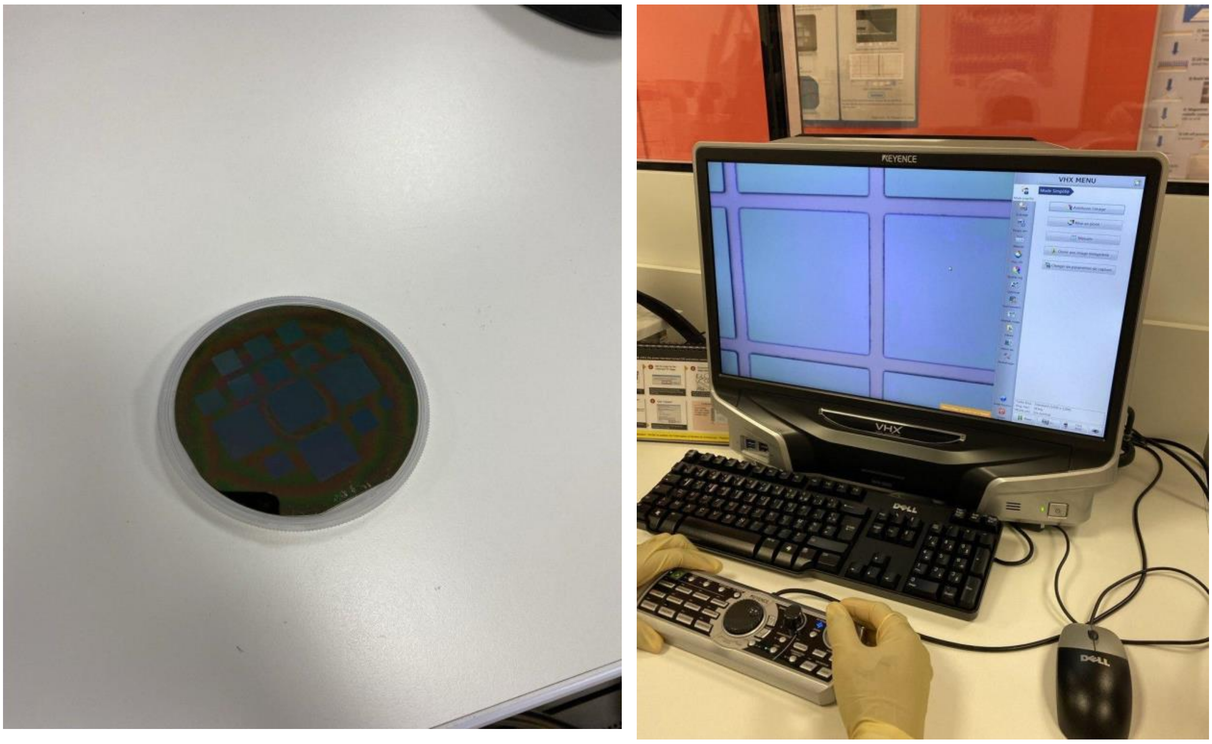


Figure 14: Result after development by the developer using the AZ400K

The measurement was taken using a profilometer, revealing a height of around 2 µm.

Etching SiO2 on the Alcatel machine

A 1 micrometre layer of SiO_2 is etched using a basic recipe that involves the exclusive injection of CHF_3, without the addition of SF_6, at a rate of 30 sccm of CHF_3. The image below shows the wafer after etching:

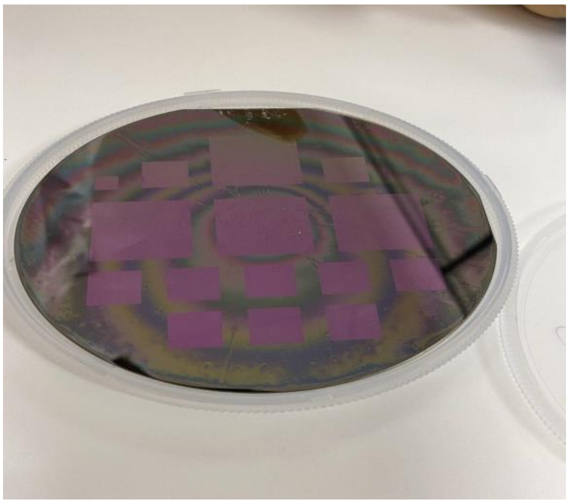


Figure 15: Image of the substrate after SiO2 etching

To check the engraving result, the profilometer is used to measure the engraved depth:

Figure 16: Profilometer measurement of etched depth after SiO2 etching

The measured height is 2.735 µm. By subtracting the photoresist height of 2 µm, approximately 1 µm has been etched, corresponding to the thickness of SiO2 deposited.

Once the SiO2 has been etched, the next step will be to etch the Si during the next project session. This will involve cryogenic etching using the Alcatel 601E machine. The results of this etching will then be verified using a profilometer and a scanning electron microscope (SEM).

Risk analysis.

Table 5: Forecasting analysis

Elements	Function	Mode	Cause	Effect	Evaluation	Detection	Action
Toxic products	Handling products		Wearing gloves, Leaks in pipes	Burns, explosions and poisoning	5	Check the condition of the gloves, Check the pipes, Observe the safety measures (Wear gloves)	Evacuate the premises quickly
Machines	Etching	Machine malfunctions	Incorrect handling	Project delayed, risk of injury	9		Switch off and inform those in charge
		Unavailability of machines	Late bookings, unavailability of machines	Project delays	7	Check availability and make early bookings	
Supports, equipments and other products		Delayed delivery	Out of stock, Delivery distance, Inedible product	Delay in project	7	Check product stock	Find nearest retailer
	Making tests or samples	Failed manipulations	Non-compliance with procedures, machine failures	Burns, explosions, poisoning and project delays	5	Being cautious, Respecting process steps	Faire appel à un responsable

The critical point identified in this Risk Analysis concerns machinery, with a high-risk assessment (rating 9). The risks include machine malfunctions that could cause delays to the project. The most crucial preventive solution involves taking immediate action in the event of a malfunction, including stopping the machine immediately and informing those responsible. However, particular attention should also be paid to proactively managing machine availability, by making advance bookings to avoid any interruptions. Ongoing staff training in the safe handling of machines and the strict implementation of standard operating procedures are essential elements in minimising machine risk. In summary, rigorous machine management, combined with adequate training and advance planning, is imperative to mitigate the identified critical point and ensure a smooth process.

Conclusion

In conclusion, the Suspended Hydrophobic Silicon Membrane (SHSM) project represents an ambitious endeavor aimed at creating a hydrophobic membrane at the nanoscale. The progress made so far is promising, especially in the initial front-side etching phase, where columnar microstructures (CMS) have been achieved. However, adjustments are needed to meet the final specifications for depth and porosity.

The back-side etching, although successfully carried out through the cryogenic process, presents an additional challenge related to static sheath, requiring the use of a mask to prevent undesirable deformations. Preliminary results of SiO_2 deposition are promising, but thorough testing will be necessary to determine the selectivity between the SiO_2 layer and silicon.

The next steps involve parameter adjustments, testing with an O_2/SF_6 ratio of 0.08, and the study of the CF_x solution for polymerization. The deep etching of 450µm with a mask represents a major challenge that will require careful attention to ensure the accuracy of the results.

Anticipating challenges related to machinery and process complexity, proactive risk management is imperative to ensure project smoothness. Machine availability, ongoing staff training, and adherence to standard operating procedures are key elements to minimize these risks.

In summary, the MHSS project holds promising applications in the fields of MEMS, microfluidic systems, and photovoltaic systems. The obstacles encountered so far are inherent to the complex nature of the project, but a systematic approach and judicious adjustments will enable overcoming these challenges and achieving the ambitious project goals.

Useful sources

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Dussart, R. (2005). *Silicon columnar microstructures induced.* Orléans.

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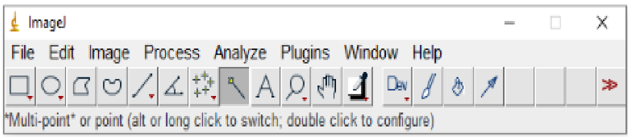
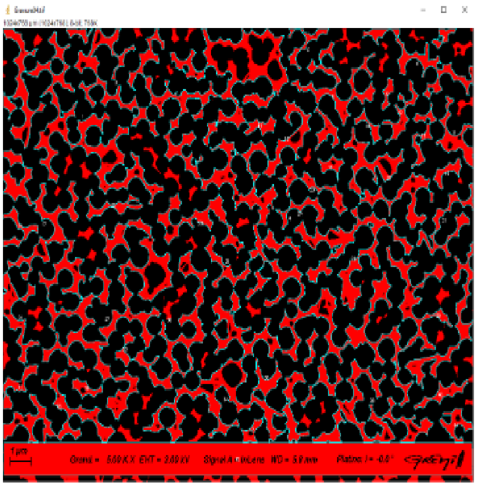
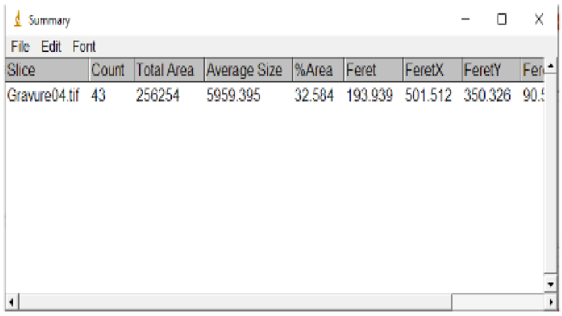
In the MHSS project, ImageJ software (version 1.54d) was used to analyze images obtained during experiments. ImageJ allows for accurate measurement of dimensions and properties of developed columnar microstructures (CMS), such as height, pillar diameter, density, and porosity. Additionally, for task planning, Gantt Project software (version 3.2.3247) was chosen, facilitating the efficient management of the project.

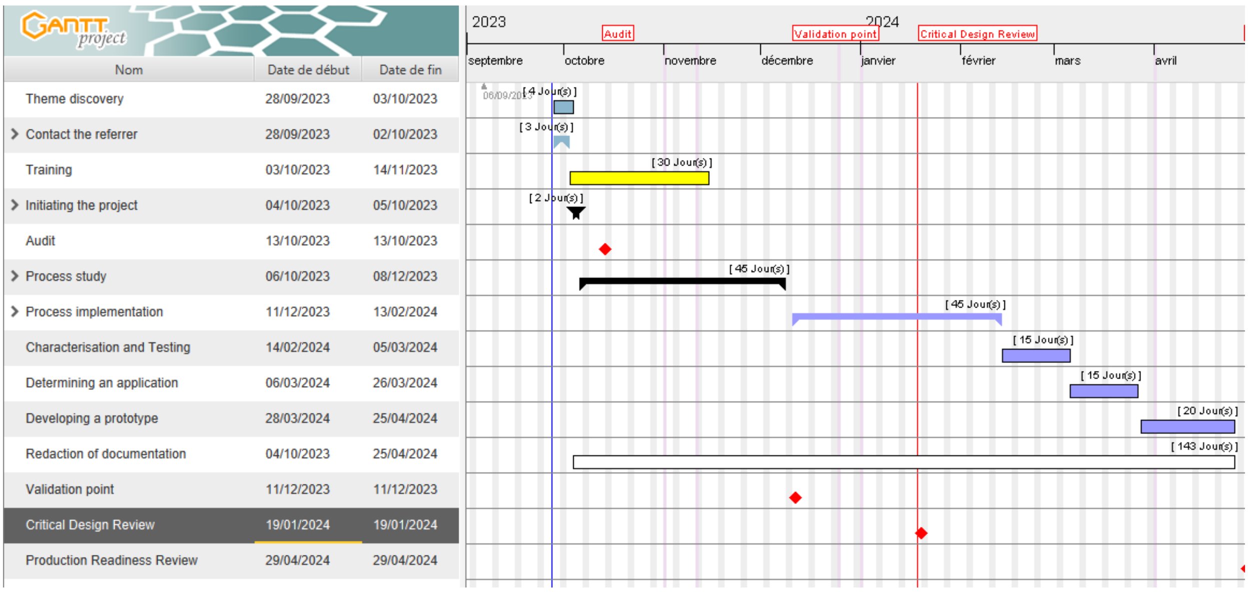
Annexe 1: Porosity Measurement and Gantt







Slice	Count	Total Area	Average Size	%Area	Feret	FeretX	FeretY	Fer…
Gravure04.tif	43	256254	5959.395	32.584	193.939	501.512	350.326	90.…



Nom	Date de début	Date de fin
Theme discovery	28/09/2023	03/10/2023
Contact the referrer	28/09/2023	02/10/2023
Training	03/10/2023	14/11/2023
Initiating the project	04/10/2023	05/10/2023
Audit	13/10/2023	13/10/2023
Process study	06/10/2023	08/12/2023
Process implementation	11/12/2023	13/02/2024
Characterisation and Testing	14/02/2024	05/03/2024
Determining an application	06/03/2024	26/03/2024
Developing a prototype	28/03/2024	25/04/2024
Redaction of documentation	04/10/2023	25/04/2024
Validation point	11/12/2023	11/12/2023
Critical Design Review	19/01/2024	19/01/2024
Production Readiness Review	29/04/2024	29/04/2024

Annexe 2: Corporate Social Responsibility (CSR)

The Silicon Suspended Hydrophobic Membrane (SHM) project is firmly committed to Corporate Social Responsibility (CSR), incorporating practices and principles aimed at maximizing positive impacts while minimizing potential negative impacts associated with manipulations and processes.

- Material Selection: Choosing silicon as the base material for the membranes demonstrates a commitment to sustainability. Silicon is an abundant and widely recyclable material, contributing to reducing the project's environmental footprint.

- Sustainable Innovation: Exploring solutions such as the use of a CFx solution for polymerization contributes to a more sustainable manufacturing of microstructures, thereby minimizing potential environmental impacts.

- Optimization of Machine Utilization Time: CSR is inherently linked to energy efficiency. In our operations, we optimize machine utilization time by planning effective production cycles, thus minimizing energy consumption while maximizing productivity. This approach contributes to reducing our overall carbon footprint.

- Rational Use of Gases: Gas handling in the etching process is managed carefully to minimize emissions and ensure rational use. We closely monitor gas consumption, promoting efficiency while reducing environmental impacts.

Annexe 3: Summary Table

Functions	Assignment	Percentage of Completion
Design of Front-Side Etching Mask	Meaguy/Bilal	100 %
Implementation Process Flow	Yavo	100 %
Use of Alcatel 601E (Cryogenic Etching)	Meaguy/Bilal	80 %
Use of Oxford (PE-CVD; SiO_2 Deposition)	Yavo	75 %
Front side etching	Bilal/Meaguy	60 %
Back side etching	Yavo	5 %
Scanning Electron Microscopy (SEM) Analysis	Yavo/Bilal	80 %
Profilometer Analysis	Meaguy	80 %
Hydrophobicity	Yavo	5 %

Annexe 4: Self-assessment of Acquired / Enhanced Skills + Level.

Yavo:

Within the MHSS project, I have developed my skills through several key activities:

1.1 Establishment of the Process Flow and SEM Analysis:

-Skills: Expertise in establishing the process flow and interpreting SEM images.

-Level: Proficiency

1.2 Cryogenic Etching, PE-CVD, Ellipsometry Characterization:

-Skills: Handling advanced equipment, understanding etching and deposition processes, optical characterization.

-Level: Proficiency

1.3 Contact Angle Characterization:

-Skills: Evaluation of hydrophobic properties, interpretation of contact angle measurements.

-Level: Discovery

In summary, my involvement in the project has strengthened my skills, progressing from a discovery level to proficiency, particularly in the areas of cleanroom microfabrication and characterization of nanostructured materials.

Méaguy:

The implementation of the hydrophobic membrane project allows me to develop expertise in the field of nano and microtechnologies, showcasing skills such as:

1.4 Expertise in Designing Masks for Specific Etching Applications.

-Level: Expertise

1.5 Advanced Skill in the Use of Cryogenic Plasma Etching (Alcatel 601E) to Generate Columnar Microstructures.

-Level: Proficiency

1.6 Demonstrated Ability to Operate in Various Processes, including lithography, resist development, and other crucial steps of the process flow.

-Level: Proficiency

1.7 Capability to Thoroughly Interpret and Analyze Test Results, including SEM images, and adjust parameters accordingly to enhance process performance.

-Level: Proficiency

1.8 Mastery of Deposition Technologies, especially PECVD for SiO2, and substantial experience in characterizing deposited layers.
-Level: Proficiency

In addition to microfabrication skills, this project has allowed me to develop project management skills. In summary, I have acquired and consolidated a set of specialized skills, ranging from mask design to the characterization of deposited layers, including adept handling of advanced equipment such as the Alcatel 601E. These skills demonstrate advanced expertise in the field of microfabrication and contribute significantly to the success of this project.

Bilal:

Participating in the hydrophobic membrane initiative has afforded me the opportunity to refine a diverse array of skills in nano and microtechnology, as illustrated below:

1.12 Proficiency in Mask Layout for Etching Purposes:

Acquired Skills: Developed an adeptness in engineering masks for etching applications.

Mastery Level: Highly Skilled

1.13 Utilization of Cryogenic Plasma Etching Equipment:

Acquired Skills: Skilled use of the Alcatel 601E etcher to sculpt precise microstructures.

Mastery Level: Highly Proficient

1.14 Versatility in Microfabrication Processes:

Acquired Skills: Ability to proficiently navigate numerous stages of microfabrication, including lithography and resist processing.

Mastery Level: Highly Proficient

1.115 Interpretative Analysis of Experimental Data:

Acquired Skills: Keen interpretation of results, such as scrutinizing SEM images to fine-tune fabrication parameters.

Mastery Level: Highly Proficient

1.16 Knowledge of Thin Film Deposition:

Acquired Skills: Extensive experience with PECVD for SiO2, including detailed analysis of the thin films.

Mastery Level: Highly Proficient

Beyond technical expertise, the project has also been instrumental in developing my project coordination competencies. In essence, my collaborative efforts have led to a robust set of skills that range from precise mask construction to in-depth material analysis, all critical to the sophisticated field of microfabrication and the collective success of our project.

Annexe 5: Resume Yavo

Yavo CHABEHOU

Stage assistant ingénieur – Alternance

CONTACT

+ 33 07 66 03 17 23
armandchabehou@gmail.com
3 rue Charles de Coulomb
45100 Orléans, France
@yavo chabehou

LANGUES

Français : Excellent
Anglais : Niveau B1

COMPÉTENCES

- Physique des matériaux
- Travail en salle blanche
- Gravure cryogénique, PECVD
- Caractérisation : MEB, Profilomètre
- CMOS, FD-SOI, Fin-Fet, LED GaN
- Pulvérisation magnétron
- Photolithographie
- C/C++, Qt, Python, SQLite, WordPress, Git
- Esprit d'équipe
- Adaptabilité, créativité et discipline
- Méthodes Agile, Design thinking

VIE ASSOCIATIVE

- Chargé d'affaires à la Junior Entreprise de Polytech Orléans (Polytech Expertise)
- Président de AE2DELN 2021 (Association des étudiants et diplômés en DUT Electronique de L'INPHB)

CENTRES D'INTÉRÊT

- Tennis
- Mangas
- Lecture

PROFIL

Élève ingénieur polyvalent, ma discipline, ma détermination et mon adaptabilité font de moi un candidat dévoué. Fort d'un solide parcours académique et associatif, je suis prêt à mettre à votre disposition mon expertise et mon engagement pour contribuer activement à la réalisation des objectifs de votre entreprise.

EXPERIENCES ET PROJETS

Réalisation et caractérisation d'un capteur Ni100

Polytech Orléans, Orléans | Nov- dec 2023

- Définition du procédé de fabrication (Process Flow)
- Réalisation des étapes de lithographie, gravure, et dépôt par plasma
- Caractérisation électrique

Membrane hydrophobe suspendue sur silicium

Polytech Orléans, Orléans – France | Nov 2022 – Avril 2023

- Etablissement du process flow de réalisation, analyse au MEB
- Gravure Cryogénique, PE-CVD, caractérisation à l'éllipsomètre
- Caractérisation d'angle de goutte

Simulateur de Robot 2D

INP-HB, Yamoussoukro – Côte d'Ivoire | sep - dec 2021

- Développement d'un simulateur de robots 2D sous Tkinter en Python
- Utilisation de la programmation orientée objet, SQLite, Matplotlib

FORMATION

4e année Génie Physique et Systèmes Embarqués

Polytech Orléans, Orléans – France | 2023 - 2024

DTS Electronique, Informatique et Télécommunications

INP-HB, Yamoussoukro – Côte d'Ivoire | 2021 - 2022

Baccalauréat Electronique (série F2)

Lycée Technique d'Abidjan, Abidjan – Côte d'Ivoire | 2018 - 2019

Annexe 6: Resume Méaguy

Méaguy Décastel GOMPOU

21 ans, Célibataire sans enfant

Elève Ingénieur en 4ème année de Génie Physique et Système Embarqués

Ecole Polytechnique de l'Université Orléans

CONTACT

+33 7 84 62 76 71

meaguy-decastel.gompou@etu.univ-orleans.fr

5, rue de tours
45 100 Orléans, France

COMPETENCES

- Grande maitrise de l'électronique de puissance, R&D des circuits de commande et de puissance
- EasyEDA, CubeIDE(notion Basic) , IDE Arduino
- Réalisation de masque avec Layout editor, Photolithographie, Gravure cryogénique et PECVD
- Utilisation des équipements de salle blanche
- Gestion de projet, ARCADIA et ACAPELLA
- Langages de programmation (C++ et QT, C, Java, Python, JavaScript, HTML & CSS, PHP, WLangage, SQL, Assembleur, Visual Basic)
- Programmation des cartes électronique (Arduino,STM8, Raspberry pi, ESP, Lora…)
- SAP BW, SAP BI, Windev, Windev Mobile, Webdev, Android Studio, Git, Github, Pack Office
- Dynamique et organisé, Esprit d'équipe, Sens de l'observation, Attention aux détails Adaptabilité, Autonome…

LANGUES

- Français : Bon niveau (Lu, parlé et écrit)
- Anglais: Niveau B1(690 points obtenu au Test TOEIC blanc)

VIE ASSOCIATIVE

- Membre de l'association Exergie de Polytech Orléans

CENTRES D'INTÉRÊT

- Football et Danse

Stage - Ingénieur été 2024 avec possibilité d'alternance

Durée : 4 mois de mai à septembre

Projets réalisés

Réalisation d'instrument de métrologie numérique :
- Réalisation d'un Photo- luminancemètre et Spectrocolorimètre afin de vérifier les caractéristiques des luminaires.

Réalisation d'une serre connectée avec le module GSM :
- Modélisation et réalisation du système
- Programmation des cartes électroniques et capteurs

Réalisation carte d'extension pour une carte d'évaluation « STM8S Discovery» :
- Modéliser et réalisé le schéma de la carte (PCB)
- Imprimer et souder les composants, faire des tests

Etude et réalisation d'une membrane hydrophobe suspendue en Silicium (encours de réalisation)
- C'est un projet de recherche qui servira dans les systèmes de micro fluide afin de filtrer le gaz et de repousser l'eau.
- Masque de gravure, Photolithographie, Gravure, Dépôt de SiO_2

Expériences professionnelles

Mars. – Aout. 2022 | Groupe SIFCA Abidjan-Côte d'Ivoire
Direction des Systèmes d'information – Développeur SAP BW

Stage de fin d'étude et qualification : Développement SAP BW
- Echange avec le service métier (logistique, comptabilité, RH …) afin de spécifier les besoins et cadrer le projet.
- Chargement des données dans les définitions de tables
- Création d'objets d'information
- SAP BW 7.70, SQL Server 2012, Analysis for microsoft excel.

Juil. – Sept. 2021 | IOT Ivoire Abidjan-Côte d'Ivoire
Direction technique de l'IOT Ivoire -Technicien Bâtiment

Stage d'application :
- Préparation du câblage de nouvelles installations électriques
- Installation de coffret électrique, disjoncteur, contrôle d'accès et de vidéosurveillance

Aout. – Sept. 2020 | INP-HB Yamoussoukro- Côte d'Ivoire
Service Informatique de l'INP-HB

Stage : Développement d'Application Desktop (pour la gestion du corps médical de l'institut)
- Réalisation avec Windev et déploiement à l'infirmerie

FORMATION

2022-2025 | Orléans-France
Diplôme d'Ingénieur en cours: GPSE(Génie Physique et Systèmes Embarqués)
Ecole polytechnique de l'université d'Orléans

2019-2022 | Yamoussoukro-Côte d'Ivoire
DTS grade Licence : STIC(Science et Technologie de l'Information et de la Communication)
Institut National Polytechnique Félix Houphouët-Boigny

2018-2019 | Abidjan-Côte d'Ivoire
BACCALAUREAT SERIE F2: ELECTRONIQUE
Collège Moderne Mamie Adjoua de Yopougon

Annexe 7: Resume Bilal

CONTACTEZ-MOI

Adresse : 1 Place de L'europe, 45000 Orléans

bilalfall1001@gmail.com

06 64 58 80 09

APERÇU DES COMPÉTENCES

- Gestion de projet (Analyse Fonctionnelle, GANTT, PERT, AMDEC, SMART ...)
- Utilisation d'un microscope optique et électronique
- Langage de programmation (C++, Python, SQL, QT...)

LINGUISTIQUES:

- ANGLAIS
- FRANCAIS

PERSONNEL

-Autonomie

-Esprit d'équipe.

-Rigoureux

CENTRES D'INTERET ET ACTIVITES

- Membres de l'association ROBOTEK (association à polytch Orleans qui dirige des projets en électronique et robotique au niveau national)
- Sport football (attaquant de l'équipe de football Polytech orleans)
- Natation

BILAL FALL

ÉTUDIANT INGÉNIEUR EN GENIE PHYSIQUE ET SYSTEMES EMBARQUÉS

PROFIL PERSONNEL:

Étudiant en ingénierie spécialisé en génie physique et systèmes embarqués, cherche un contrat d'apprentissage pour approfondir mes compétences techniques et contribuer efficacement à des projets innovants..

FORMATIONS:

Ecole d'ingénieur Polytech Orléans (Filière GPSE)

Génie physique et systèmes Embarqués 2021/2024

- Spécialisé en électronique, la conception des circuits (gravure de silicium),à leurs programmation sur des cartes numériques communicantes.
- Systèmes embarqés et objet connectés
- Laser et plasma (Nanotechnologies et procédés industrielles)

Université de Picardie Jules Vernes (Filière Maths/Physique)

Licence Physique obtenue avec mention Bien / 2019-2021

- Etude théorique profonde en mathématiques et science physique.

Baccalauréat international scientifique science Physique.

Baccalauréat obtenue avec mention Bien (2017-2018)

EXPERIENCE PROFESSIONNEL:

Salle Blanche laboratoire Gréai Orléans | Fev 2022 -Juin 2022

Projet en ingénierie : Conception d'un capteur de luminiosité (Laboratoir Grémi).

- Conçu et développé un capteur de luminosité innovant, optimisant la gestion de l'éclairage public.
- Appliqué des techniques avancées de photolithographie et de pulvérisation cathodique magnétron pour la fabrication de photorésistances sur silicium, démontrant une expertise technique approfondie.
- Collaboré efficacement au sein d'une équipe multidisciplinaire pour mener à bien le projet, soulignant une forte capacité à travailler en équipe et à communiquer avec des coéquipiers de diverses spécialités.

Entreprise Kiabi France Oct 2020 - Juin 2021

- Compétences en merchandising :Expérience dans la mise en valeur des produits en magasin pour maximiser les ventes.
- Gestion de la relation client : Compétences avancées en communication et en service client pour offrir une expérience d'achat personnalisée.
- apacité d'analyse : Aptitude à analyser les performances des ventes et les préférences des clients pour ajuster les stratégies de vente et de stock.