Etching selectivity and passivity of Al2O3 layers

Advanced NEMS laboratory

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1 Introduction

The performance of micro- and nano-mechanical devices depends essentially on the materials they are made of. Indeed, the behavior of materials at the nanometer scale can result in different results compared to the macroscopic scale. Moreover, in the case of a NEMS-MEMS device used in a liquid medium, the right selection of materials is imperative to obtain a satisfactory measurement quality: The mechanical domain concerns the resonance properties, the electrical one is mainly for transduction, where electrodes are used. Indeed, the impermeability at this scale of the conductive metal parts must be guaranteed for a liquid-purpose device. One suggested solution is to consider a passivation layer. The presence of a thin layer of non-conductive material between the conductive parts and the liquid satisfies this role, without considerably affecting the mechanical properties of the device, nor the electrical properties that are associated with NEMS-MEMS prerequisites. A good candidate is an atomic layer deposition (ALD) of alumina (Al_2O_3). Its mechanical properties have been widely studied [2]. In order to incorporate it into the device, its compatibility with clean room microfabrication, which is mainly defined by the selectivity, must be guaranteed. Therefore, the project focuses on etching properties of the atomic layer deposition (ALD) of Al_2O_3. For this purpose, etching processes such as plasma etch with sulfur hexafluoride (SF_6), gas etch with xenon difluoride (XeF_2), wet etch with MIF developper (726 MIF) as well as ion beam etch (IBE) were performed. Then, the second part of the project focuses on the passivation properties of Al_2O_3 thin layers. An attempt to study the passivation of Al_2O_3 in contact with different liquids (distilled water, acetone, isopropanol) allows to understand more about the electrical modeling and the feasibility of such an approach. A detailed presentation of the experimental setup as well as the phenomena observed are presented as results of the study. This project allows to learn more about the novel passivation properties of Al_2O_3 and to incorporate it into NEMS-MEMS for future use.

2 Experimental methods

The project focuses mainly on the microfabrication processes, held in the Center of MicroNanoTechnology (CMi), EPFL. Etching selectivity is an essential criterion to confirm the relevance of using Al_2O_3 as a passivation layer. Indeed, the release process must not affect the passivation layer in any way. In addition to that, the device, of which an example of application can be the one detailed in the paper [1], may be composed of a multitude of different materials. Each component has a characteristic thickness that plays a determining role in the mechanical and electrical properties. To begin with, it is necessary to determine if it is possible to apply a passivation layer of Al_2O_3 with the atomic layer deposition (ALD) process, at different thicknesses, on materials such as Si and platinum (Pt). The latter is the main component of an electrode: it must be passivated when the device is used in a liquid medium in order to maintain the electrical properties unchanged.

There are 4 different etching methods that are studied: plasma etch with SF_6, gas etch with the use of XeF_2, wet etch with the 726 MIF developer, and the use of a broad-beam ion etch. The use of SF_6 via the equipment *AMS200* and of XeF_2 thanks to the *SPTS Xactix X4* is mainly used for a release process (which allows to etch the silicon wafer in particular), where the selectivity of Al_2O_3 must be confirmed. The aim is to determine if the etching affects the Al_2O_3 thin layers directly or by the presence of etching byproducts. A summary of the equipment used throughout the project is presented in the following table. The parameters to be considered for each machine, appearing in the process flow 1 and 2, are detailed in the sections dedicated to microfabrication and in the results.

	Machine	**Use in the project**
1	Süss ACS200 GEN3	Automatic coating and developpment of photoresists
2	Heidelberg MLA150	Mask-less aligner, UV-laser exposition of patterns on photoresists
3	Alcatel AMS200 DSE	Optimized Deep Reactive Ion Etching (DRIE) system for Silicon
4	SPTS Xactix X4	XeF_2 Silicon etching system
5	Tepla GigaBatch	High frequency plasma for photoresist stripping, wafer surface cleaning
6	Beneq TFS200	Atomic layer deposition (ALD) for thin dielectric or metallic layers
7	Veeco Nexus IBE350	Broad-beam ion etcher
8	UFT remover 1165	Clearing layers of photoresists, use of Remover 1165
9	Filmetrics F54	Automated thickness mapping system

Table 1: Overview of the machines used for process flow 1 and 2 held at CMi, EPFL. Details about parameters are described in the dedicated sections.

There are several ways to determine the etch rate of a material. Since Al_2O_3 is not an opaque material, it is possible to determine its thickness using an optical based approach. Indeed, the etch rate from each method may be determined by measuring the total process time and the thickness variation of the Al_2O_3 thin layer with the help of initial and final thickness measurements. Indeed, the *Filmetrics F54* makes it possible to measure thicknesses with precision: the amplitude and periodicity of the reflectance of a thin film is determined by the thickness of the Al_2O_3 film and the optical constants of the material as parameters to consider. According to the resulting signal, a mathematical model fitting allows to confirm the specific *Spectral Reflectance*

for Al_2O_3 and thus to determine its thickness. This method is widely used throughout the project to determine the thickness according to the number of ALD cycles and the etch rate.

Atomic layer deposition of Al_2O_3 is the core of the project: the thickness is defined by the number of cycles, depending on the temperature of the chamber. It is then possible, with a certain margin, to deposit thicknesses of 30, 50 and 100 [nm] of Al_2O_3 on silicon and platinum surfaces.

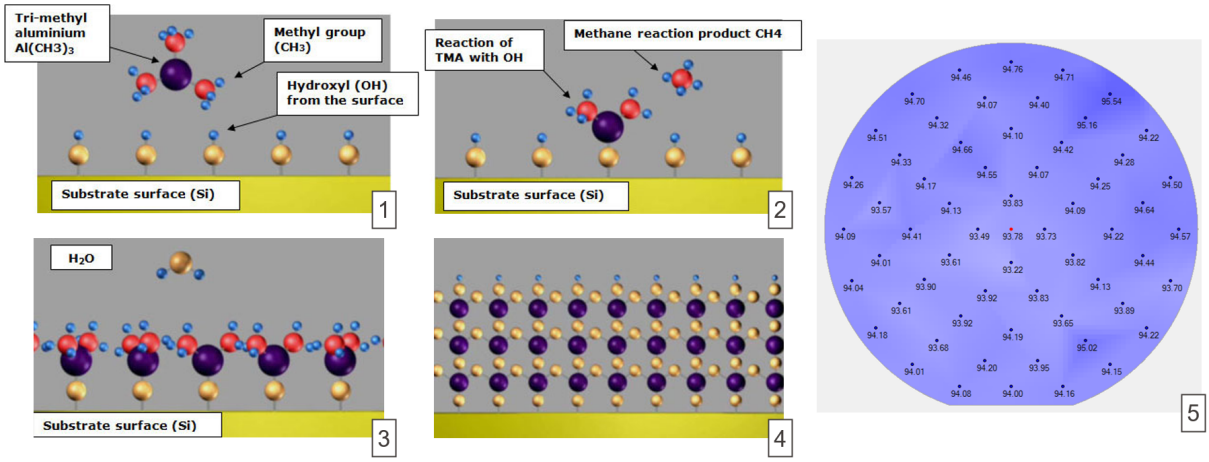


Figure 1: Overview of 1 cycle of atomic layer deposition process with the use of *TFS200* equipment. (1): On a silicone surface (also applicable for platinum), hydroxyl (OH) groups allow the binding of tri-methyl aluminium (also called TMA) molecules, present as a gas in the chamber at 200 $°C$. (2): The methly and hydroxyl groups form methane as byproduct of the reaction. (3): The second step is the dispersion of H_2O gas molecules in the reaction chamber. Methane is formed again in order to have hydroxyl groups for the next cycle. (4): After several cycles, a thickness of Al_2O_3 is obtained. (5): Multiple measurements with the *Filmetrics F54* show a homogeneous deposition on the whole wafer. The total thickness depends on the amount of cycles. It has to be modified in order to obtain the desired result. The figures are from the CMi (EPFL) resources available to users.

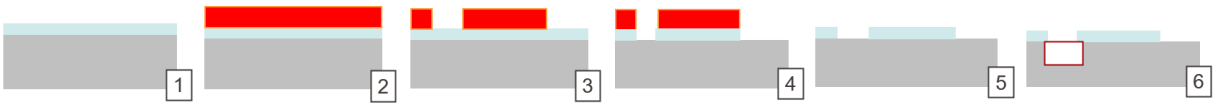
The determination of the etch rates of Al_2O_3 for each etching method are intermediate results. It is essential to have these etch rates established for all materials constituting the device. Indeed, in the case of the ion beam for example, the etch occurs on the overall surface, and at different angles of inclination of the rotating plate. Every material has its own particular etch rate. To begin with, the etch rate must be determined for the etch processes that directly affect the Al_2O_3 layer. It is the case for anisotropic etch with SF_6 via the Bosch process, the wet etch with 726 MIF developer and the ion beam etch. (As previously stated, the SF_6 and XeF_2 etch are mainly used for release). It is then necessary to determine whether the Al_2O_3 layer is subject to deterioration or not. The aim is to confirm the compatibility of a passivation layer made of Al_2O_3 not only for the release process but also with all other materials in the device. This study was conducted in the Section 2.2. The determination of the characteristic etch rate for Al_2O_3 in particular allows to establish and confirm then a functional process flow in the first part of the project. In the case where the Al_2O_3 would not be affected by the XeF_2 etch and by the isotropic SF_6 etch (with the support of a study at the edge of the areas where the etch was made), the continuation of the project would not be compromised by the selectivity criteria. The results, which include major improvements of the first part of the project, are then taken

up for the second part of the project to study the passivation properties of Al_2O_3.

Then, the next step of the project is the application of Al_2O_3 as a passivation layer on conductive components of the electrode, composed of Silicon, Silicon oxide (SiO_2), Titanium (Ti) and Platinum (Pt). Al_2O_3 is applied on top of the platinum layer. The final objective is to study the passivation properties by the deposition of liquid on the passivated conductive surfaces. For this purpose, a second process flow (named process flow 2) allows the microfabrication of such a design. Then an experimental setup in the laboratory permits to measure the electrical characteristics according to a predetermined model. Any electrical change according to the model is then manifested by the effect of the liquid that has been deposited on the Al_2O_3, which plays the role of passivation on the platinum layer. Distilled water, acetone and isopropanol are the liquids studied for passivation.

2.1 Process flow 1: etching study

The process flow 1 consists of 6 steps, summarized in the table below. The atomic layer deposition of Al_2O_3 to be reached is fixed at 100 [nm]. For this process flow, 1000 cycles at *TFS200* allow to reach a thickness of 96 [nm], which is considered satisfactory. Initially, the ECI 3007 photoresist at 1 [μm] was found to be too thin for a 60 minutes operation at developer 726 MIF. To overcome this problem, the photoresist ECI 3027 was chosen and the thickness was set at 4 [μm]. The stability was guaranteed and no deterioration was observed. For this particular photoresist, the recommended exposure energy is 380 [J/cm^2]. Since Al_2O_3 is not opaque, the laser power may not be strong enough to fully expose the patterns because of the reflectivity. For this reason, a margin of 20 % has been applied for the exposure, the total energy is increased to 460 [J/cm^2]. The development can be done automatically with the help of the *ACS200* or manually, with an initial post-exposure bake of 100 °C during 90 seconds, then 20 to 30 seconds per [J/cm^2] of photoresist in the 726MIF developper. Since the Al_2O_3 must also be etched in the same developper, there is no need to change the wet etch medium between the development and etch of the Al_2O_3. The wafer is held in the developper until the end of the etch process.



Step	Process	Properties	Equipment	Observations
1	Al_2O_3 ALD	1000 cycles	TFS200	Al_2O_3 thickness = 96 [nm]
2	Photoresist coat + expo	ECI 3027 4 [μm], 460 [J/cm^2]	ACS200, MLA150	+20% expo energy PR thickness increase
3,4	Develop + Al_2O_3 etch	PEB 100 °C, 90 [s] 60 [min] etch time in total	AZ 726 MIF Filmetrics F54	+20% duration Etch rate: 2[nm]/min
5	PR remove		UFT Remover 1165	No Al_2O_3 degradation
6	Etching	1: Si release, isotropic, 2[min] 2: SOI accu 4+, Bosch [3min] 3: XeF2, 45[s], 40 cycles, 6 Torr	1,2: AMS200 3. Xactix X4	

Table 2: Summary of the microfabrication steps for process flow 1, with improvements in observations.

To determine the etch rate, the wafer with 96 [nm] of Al_2O_3 had to be left initially for a certain time in the developer. Then the thickness after etching is measured with the *Filmetrics F54* instrument. The difference of thickness after a duration gives an etch rate of ***2 [nm/min]*** of Al_2O_3 in the developer 726 MIF. After leaving the wafer for a duration of 60 minutes (including the 20% margin), the photoresist had to be rinsed and removed with UFT Remover 1165.

To identify the effect of the SF_6 and XeF_2 on the Al_2O_3 layer, a first test is held without any lithography. This allows us to investigate the effect of these gases directly on the Al_2O_3. Then the lithography process as detailed above was done to study possible effects of byproducts during the etching of the silicon. The etch performed are as follows: isotropic SF_6, anisotropic Bosch process SF_6 with the use of *AMS200* and with XeF_2 with the help of *Xactix X4*.

	Etch	**Equipment used**	**Process name**	**Description**	**Duration**	**Effect on Al_2O_3 layer**
1	SF_6	AMS 200	Si release	Isotropic etching of silicon	2 [min]	
2	SF_6 + C_4F_8	AMS 200	SOI accu 4+	Bosch process	3 [min]	0.3 [nm]/min centre, 0.5 to 0.66 [nm]/min in edges
3	XeF_2	Xactix X4	45 [s] pulse, 40 cycles, 6 [Torr]			

Table 3: Summary of the etch applied, the machine used, the duration and its impact on the Al2O3.

A measurement with the *Filmetrics F54* allows to determine the final thicknesses of Al_2O_3 after each etch. Note that the etch with SF_6 and XeF_2 does not affect the thickness of Al_2O_3, which is not the case of an anisotropic etch with the Bosch process: the wafer edges appear brighter to the *Filmetrics*, suggesting that the etch rate depends on the distance to the center: at the center, ***0.3 [nm/min]*** of Al_2O_3 is observable, while ***0.5 to 0.66 [nm/min]*** was determined for the edges of the wafer. Since the Bosch process includes the use of two gases, C_4F_8 could be the origin of the etch since SF_6 alone does not give any thickness variation.

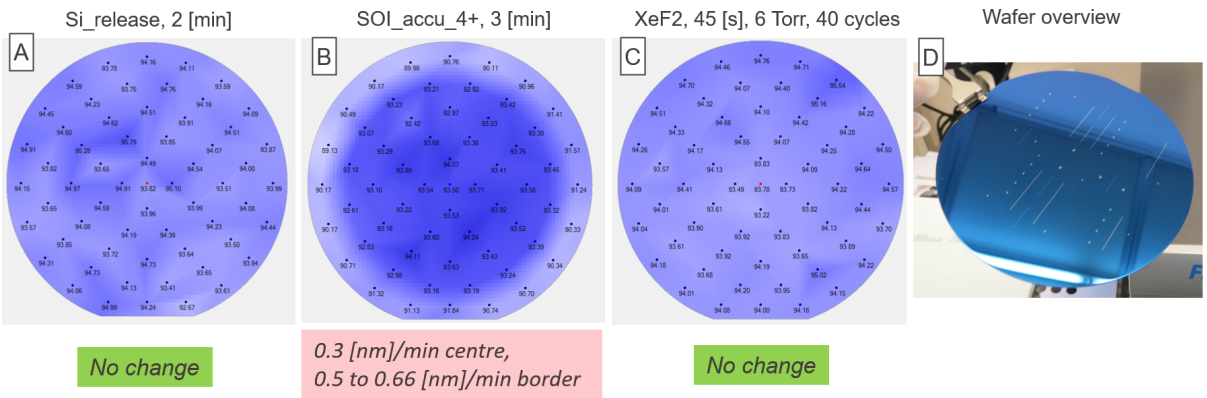


Figure 2: Overview of *Filmetrics F54* result for the following etch methods as well as a visualization of the wafer. (A): result after 2 minutes of isotropic etch with SF_6, no change. (B): 3 [min] of anisotropic etch with SOI_accu_4+ with two different etch rates obtained. (C): no change for an etch at XeF_2. (D): wafer with a 96 [nm] layer of Al_2O_3 (1000 cycles equivalent), after the etch, ready for an edge study.

The aim is to determine the quality of the etch and possible deterioration by byproducts from the etching of other materials (as for the release of Si by SF_6 or XeF_2). Any consequence on the Al_2O_3 layer near the edges where the etch was applied would be visible. The thickness variation of Al_2O_3 is investigated after an etch of the silicon which is the layer just below. It may permit to determine if the passivation layer is affected by byproducts showed up during release. Al_2O_3 is not affected by the etch of SF_6 and XeF_2. The analysis is qualitative only. Indeed, the *Filmetrics* measurements does not allow to measure accurately the thickness of the passivation membrane and the silicon. The quality of the Al_2O_3 membrane is not affected, which confirms the trouble-free use of SF_6 and XeF_2 as release process.

2.2 Process flow 2: passivity study

Once the first part of the project about the etching properties is validated, it is then possible to continue the investigations concerning the passivation properties of Al_2O_3. For the second part of the project, it was first necessary to imagine how passivation would be investigated. It was decided to reproduce conductive tracks: on a silicon wafer, silicon oxide (SiO_2), titanium (Ti) and platinum (Pt) and different thicknesses of Al_2O_3 is considered. The use of *TFS200* for the atomic layer deposition on the upper platinum layer permitted to obtain the desired layer thickness. The silicon oxide does not make part of the track. For this purpose, the system has a pair of pads that are large enough to allow the measurement of the electrical properties. The tracks are composed of a square surface whose size is a parameter in the study. It was thought to find a probable correlation between the size of the sensing squares, the passivation properties of the Al_2O_3 toward different liquids and the quality of microfabrication. Both the water, the acetone and isopropanol have distinct properties such as wettability, that may spread beyond the area of interest. For this reason, Al_2O_3 is deposited on a wide band, connecting groups 1 to 6. The ideal case is to measure the changes in electrical properties when the liquid is deposited on the corresponding square surface. The overflow of liquid should not bias the results. However, it is important to note that a larger surface could compromise the passivation. The probability of having a defect in the ALD process increases with the surface.

For 1 wafer:	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**
Square size [μm]	9000	8000	7000	6000	5000	none
For all wafers:	111888	120047	120039	111889	111884	120100
Al_2O_3 thickness [nm]	100	100	50	50	30	30

Table 4: Overview of the characteristics of each group, as well as the passivation thicknesses assigned to the wafers. The turquoise coloring (111888) is the one used for the determination of etch rate: it is devoid of SiO_2 layer.

The process initially consists of a silicon wafer with 500 [nm] SiO_2, 100 [nm] Ti and 15 [nm] Pt. The etch is carried out only with ion beam etch (IBE). For this purpose, the AZ10XT-07 photoresist is compatible for this use and has been applied on the platinum. It is essential before conducting the first etch to make a reflow of 2 minutes at 125 $°C$, in order to smooth the edges of the photoresist after the development. Indeed, IBE is a physical process: during the etch process, the angle of inclination of the beam with respect to the wafer surface changes. Initially at -10 degrees, the angle of inclination during the second part of the IBE is set to -70 degrees. Thus there are 2 etch rates during the same process, summarized as a single one over the whole IBE duration. The etch is performed under medium power, where the IBE350 parameters are set to 500 [V] and 800 [mA]. Once the conductive tracks are microfabricated, the *UFT Remover 1165* permits to remove the photoresist. Then, a first pass with *Tepla300* ensures a surface quality without any photoresist residue. The next step is to use atomic layer deposition with *TFS200* to obtain the 3 desired thicknesses of Al_2O_3. A second photoresist is applied on the wafer to define the regions where the Al_2O_3 must play a role of passivation on the tracks, accompanied by a second reflow of 2 minutes at 125 $°C$. It is possible with the help of an end point detection to know if a particular layer has been totally etched or not. Therefore, there are some margin to optimize the etch time with ion beam etching (IBE). Finally, the second resist is removed in the same way with a final pass with *Tepla300*.

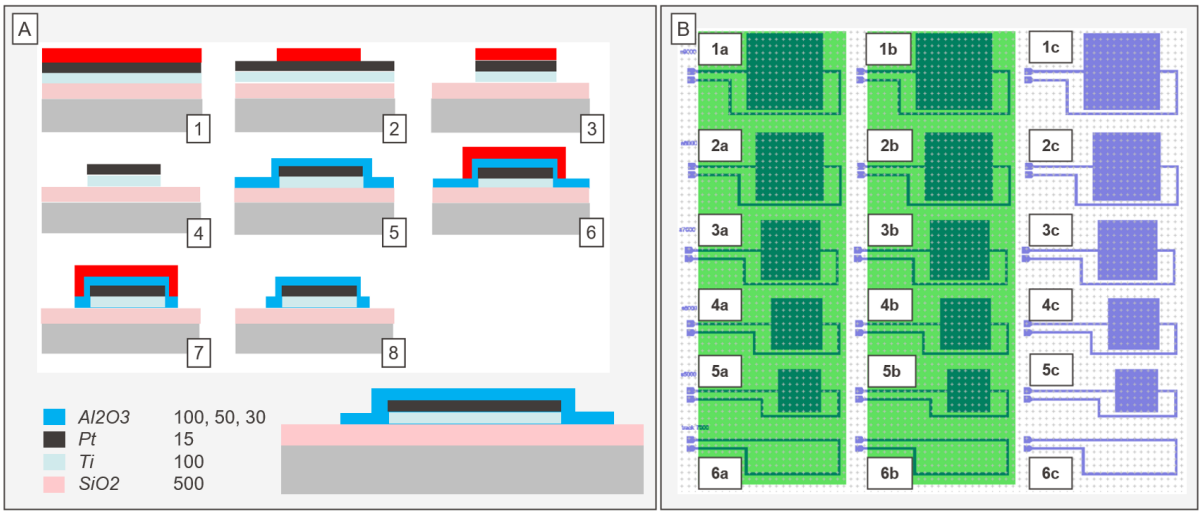


Figure 3: Overview of the microfabrication process flow 2, the composition in cross-section of a track, thickness in [nm], including a top view of the tracks (designed with the software *Clewin 5*, with the groups labeled from 1 to 6 for the sizes. The columns "a" and "b" are covered with Al_2O_3, "c" is not.

Step	Process	Properties	Equipment	Observations
1, 2	Coat, expo	AZ10XT-07, 1 [μm], 160 [mJ/cm^2]	ACS200, MLA150	+20% expo energy
3	IBE	Reflow 2 [min] @125°C, (-10) + (-70)	IBE350 (medium)	100 [nm] Ti + 15 [nm] Pt 1:45(-10) + 1:45(-70) SiO_2: 50[nm] etched
4	PR remove	1 [min] O_2 High plasma, Remover 1165	Tepla300, UFT remover	
5	ALD Al_2O_3	2x 100, 2x 50, 2x 30 [nm]	TFS200	100 [nm] = 1115 cycles 50 [nm] = 560 cycles 30 [nm] = 335 cycles
6	Coat + expo + develop	AZ10XT-07, 1 [μm], 160 [mJ/cm^2]	ACS200, MLA150	+20% expo energy
7	IBE	(-10) + (-70)	IBE350 (medium)	Etch rate, time per angle [min]: 100 [nm] = 1:45(-10) + 1:45(-70) 50 [nm] = 0:50(-10) + 0.50(-70) 30 [nm] = 0:30(-10) + 0.30(-70)
8	PR remove	1 [min] O_2 High plasma, Remover 1165	Tepla300, MLA150	

Table 5: Summary of the second process flow with dedicated observations for each step

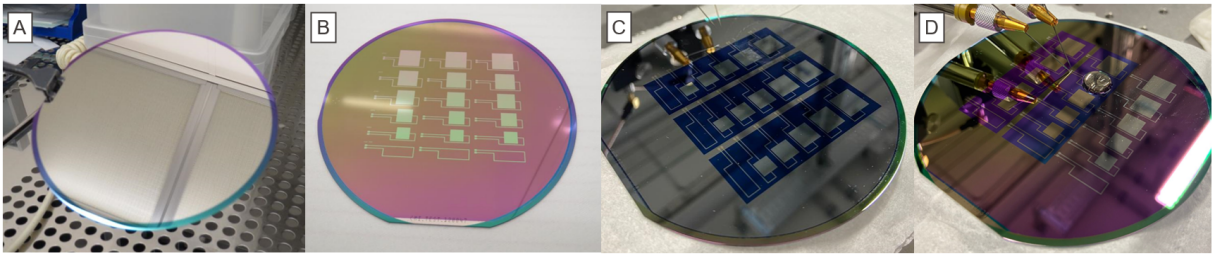


Figure 4: (A): initial wafer with platimum on top. (B): after the first etch (step 3), the conductive tracks are visible on the SiO2 layer. (C): the wafer 111888 had allowed to determine etch rates. (D): the final wafer, with the ALD of Al_2O_3 on the first two columns, with the presence of liquid.

By observing the end point detection on Figure 5, it is possible to determine which layer is undergoing an etch process. Around 1:45 of the experiment, two phenomena appeared during the second IBE on the Al_2O_3 layer: the latter has been totally etched and exhibits a rapid jump in (B), while at the same time, a change in the "Silicon" index in (A) indicates that the SiO_2 layer has been reached. Then, comparing the values of SiO_2 before and after the second IBE, a variation of 50 [nm] is to be noted (C). For a total initial thickness of 500 [nm], this represents 10 % of the SiO_2 thickness. It is acceptable but this indicates that there is room for improvement concerning the IBE medium under (-10) and (-70) configuration. A solution might be to decrease the duration of each phase. A compromise must then be established between the certainty of having no more Al_2O_3 and the safeguarding of the thickness of the next layer.

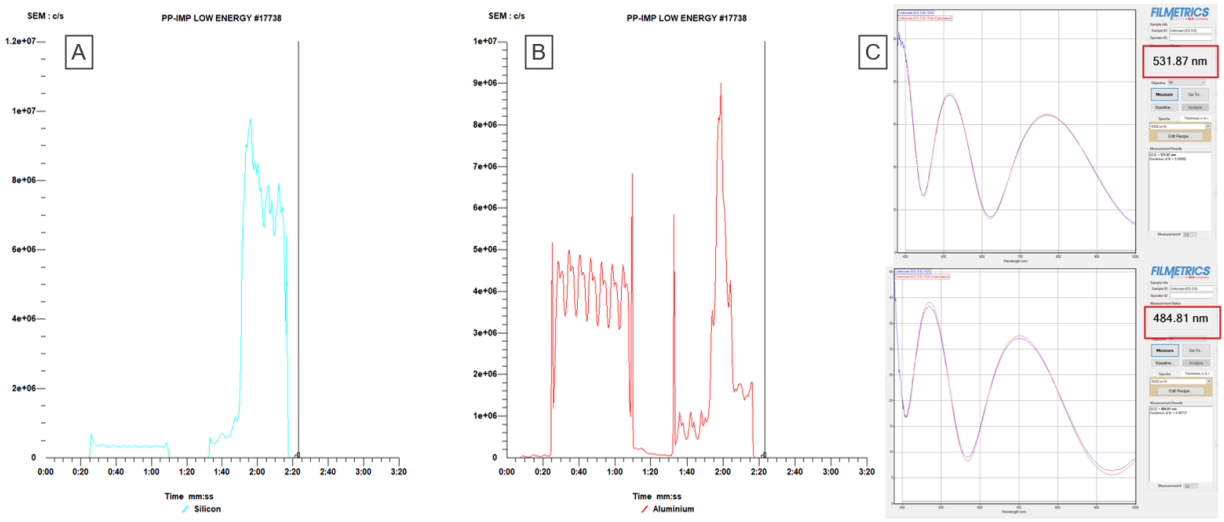


Figure 5: (A), (B): endpoint detection of silicon and aluminium respectively. (C): *Filmetrics* measurements of SiO_2 thickness variation.

One of the main reasons why IBE is usually done at two angles of incidence after a reflow is to avoid getting redepositions of material on the sides of the photoresist. The height of such redeposition can exceed 200 [nm], which can be fatal for Al2O3 thicknesses of 30, 50 and 100 [nm]. Indeed, this redeposition of material can be in direct contact with the liquid, which may compromise the experiment. To confirm the absence of such a phenomenon, Figure 6 shows the edges of the pads at different scales. The fact that there is no marked thickness on the edges of the titanium pad demonstrates the benefit of a reflow coupled with a two angles of incidence IBE etch.

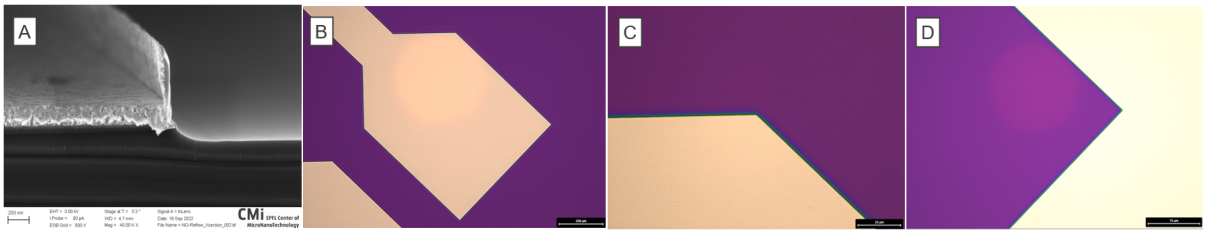


Figure 6: (A) The redeposition phenomenon (source: CMi), (B), (C) and (D) are observations at different scales of the pads and locations where the edges are pronounced. Redeposition is not observed.

Data acquisition took place in the laboratory. The tracks were modeled as a resistor in parallel with a capacitor. In order to measure the changes in capacitance C and resistance R of the tracks when liquid is deposited on the Al_2O_3 passivation layer, a 4-wire setup has been implemented. This setup allows to accurately measure the electrical properties of the system. To confirm the quantities with a reference, the impedance and phase values of a system were first calculated, then confirmed by the experimental values. This approach allows to approve the accuracy of the measuring device. The following equations are used to determine the electrical properties of the model in order to confirm the accuracy in the results:

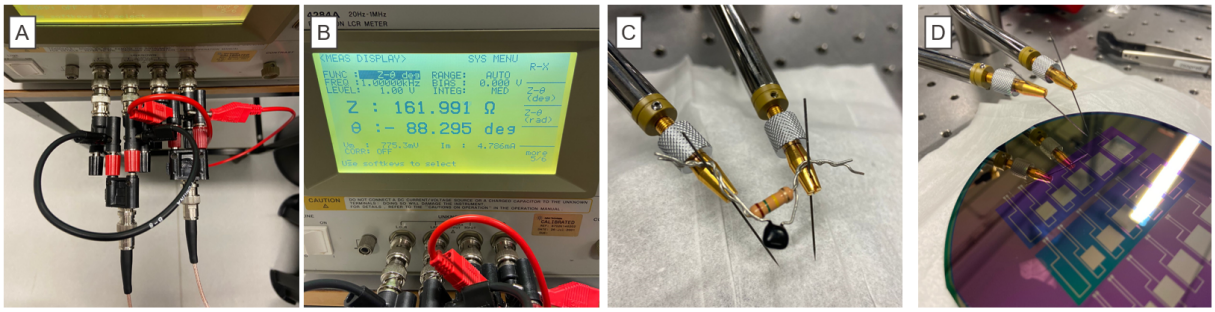


Figure 7: (A): the 4-wire setup to accurately measure the electrical properties of the circuit. (B) and (C) is the confirmation of the capacitance and resistance model in parallel. The experimental setup is ready for taking measurements. (D): the wafer is placed on a flat surface, the pair of needles are in contact on the respective pads, liquid may be poured to measure the variations of the electrical signal.

$$Z_{RC} = R + jX_C = R + \frac{1}{j\omega C} \qquad |Z_{RC}| = \sqrt{R^2 + \frac{1}{(2\pi f C)^2}} \tag{1}$$

$$\phi = arctan\left(-\frac{1}{\omega RC}\right) \tag{2}$$

Model, 1kHz	**Theory**	**Measured (hp4284a)**
R	150 $k\Omega$	148.12 $k\Omega$
C	-90 deg	-88 deg
R,C *parallel*	159.15 $k\Omega$ -89.93 deg	162.08 $k\Omega$, -88.77 deg

During data collection, a negative capacity is measured for all tracks. Indeed, modeling a resistor in parallel with a capacitor is unfortunately not the right approach. Variations in capacitance, which was the main variable under study, are certainly noticeable. But they are negative, suggesting that a wrong model has been implemented in the design, and that the latter is not adapted to the measurement of the capacitance variation. Also, the variations are in the picofarad range (10^{-12}). In terms of impedance, it is imperceptible and the resistance dominates in the orders of magnitude. Measurements of resistance and capacitance variations on all wafers were made. Those of the resistances are presented in the results section while the study concerning the capacitances will be found in appendix.

3 Results

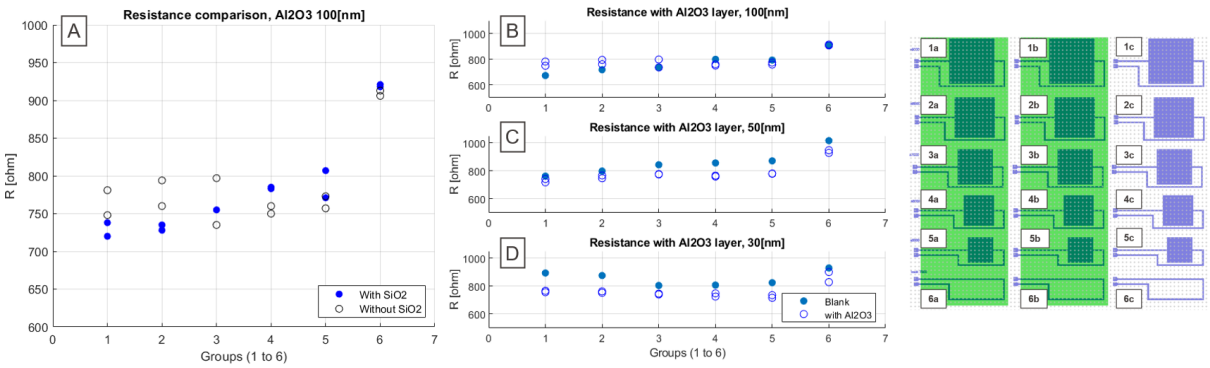


Figure 8: Variation of resistance according to: (A) presence of SiO2 and without SiO2. (B) 100 [nm], (C) 50 [nm] and (D) 30 [nm] of Al2O3, compared to tracks without passivation layer.

4 Discussion

The microfabrication of an Al_2O_3 passivation layer as well as its compatibility with silicon (Si) and platinum (Pt) is confirmed. Indeed, Al_2O_3 is not impacted by the isotropic release to SF_6 (Si release) by the release to XeF_2, which is a good point for its incorporation on a complex device. It was necessary to adapt the phororesist according to the etch: 4 [μm] composed of ECI 3027 for the wet etch, 1 [μm] to AZ07-XT for the etch to IBE. The difference in thickness is explained by the duration of the wet etch at 726 MIF. Neither the thickness nor the quality of the etch on one edge has been negatively impacted. Based on the positive results achieved in the first part, the atomic layer deposition of Al_2O_3 on a platinum layer is feasible, and the ion beam etch (IBE) process is realizable. *IBE350* used in medium with incidence angles (-10) and (-70) prevented redeposition of material, as shown in Figure 6. The etch times were overestimated in order to obtain two distinct categories where there is a passivation layer and another without Al_2O_3. There is definitely an opportunity to decrease the etch time, as the amount of etch is proportional to the time. It is conceivable to minimize the side effects on the other components of the device.

One consequence of the etch time overestimation during the second IBE process may be noticeable in figure 8. The track resistance with a passivation seems to decrease when the Al_2O_3 thickness increases. Since the resistance of a circuit is inversely proportional to the cross sectional area, in theory the resistance increases when the cross sectional area decreases. A first explanation of this phenomenon is provided by the end point detection of the IBE. As mentioned in 5, there is a surplus at the second IBE. This excess is then reflected on the tracks where there is no passivation (called "Blank" in the results). Otherwise, the resistances do not change after the application of water, acetone and IPA, which shows some passivation of the Al_2O_3 with respect to the resistance. Unfortunately, the characterization of passivation is incomplete because the model applied on the tracks is not the right approach. Since the capacitances are negative, the design of this particular track type may not be suitable for this study.

One difficulty with taking measurements is the wettability of liquids, especially acetone and isopropanol. They tend to propagate in a circular manner over a very large area. In order to be

able to keep the liquid in an area restricted to tracks, silicone parts were made. It adhere to the wafer surface and the water is well contained. This is not the case for the acetone which is able to spread between the wafer and this silicone piece. This effect can be creatively remedied by changing the material or creating notches on the silicone part to contain the acetone spreading.

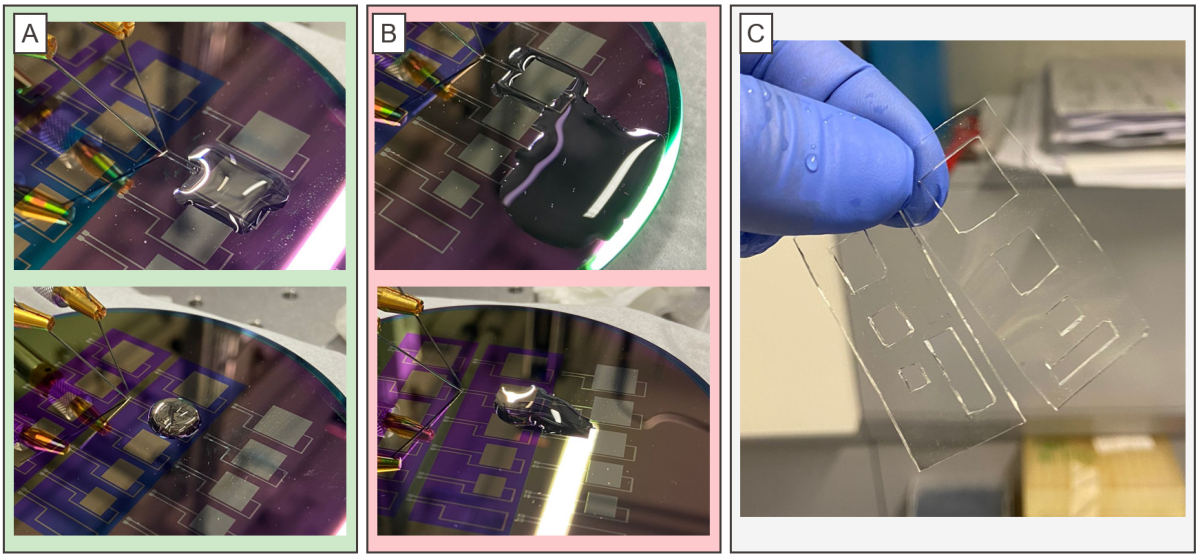


Figure 9: The wettability of liquids makes the measurement phase challenging. It happened, depending on the surface, that the liquid did not remain stable on the area of interest. A suggested solution is to use a silicone device to contain the liquid.

5 Conclusion

Al_2O_3 was studied from the point of view of selectivity first, then passivity. This material is a good candidate for microfabrication, as it is not impacted by conventional etch methods for the release phase, nor by the byproducts that exist during SF_6 or XeF_2 treatment. It is also possible to etch with good quality the thin layer of Al_2O_3 with ion beam, which is a good point. During the measurements for the passivation study, it was difficult to maintain a stable liquid on a surface due to the different wettability of each material composing the wafer. One solution suggested was to use thin silicone strips, which adhere well to the surface, however acetone is able to get in between the wafer and the silicone. This approach can still be exploited by other materials or shapes, which would overcome this problem. The passivity study was incomplete because the track design does not have a capacitive behavior. The study was then mainly focused on the resistance variations. The impact of excess etch at *IBE350* was noted and further underlines the idea that the durations should be further optimized, knowing the respective etch rates. Al_2O_3 remains a good candidate for passivation of electrodes intended for use in a liquid medium. Another approach could be considered for further study of passivation with the help of the results already obtained throughout this project.

6 Bibliography

References

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7 Annexe: capacity variation

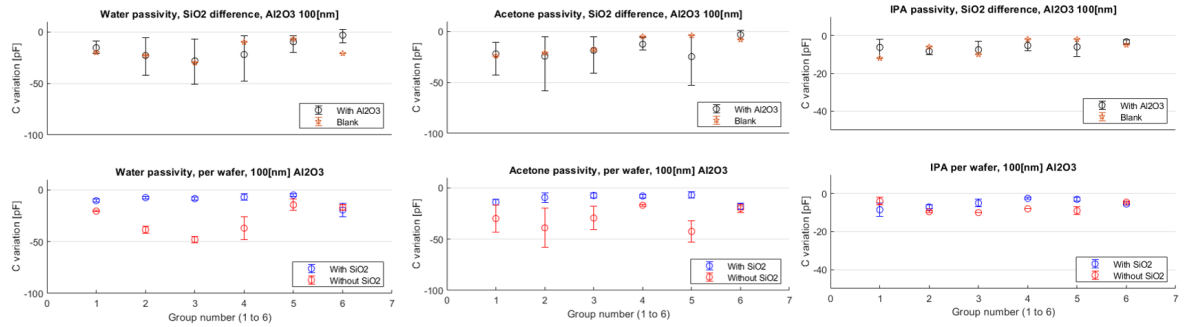

Figure 10: Capacitance variation for 100[nm] Al_2O_3 layer.

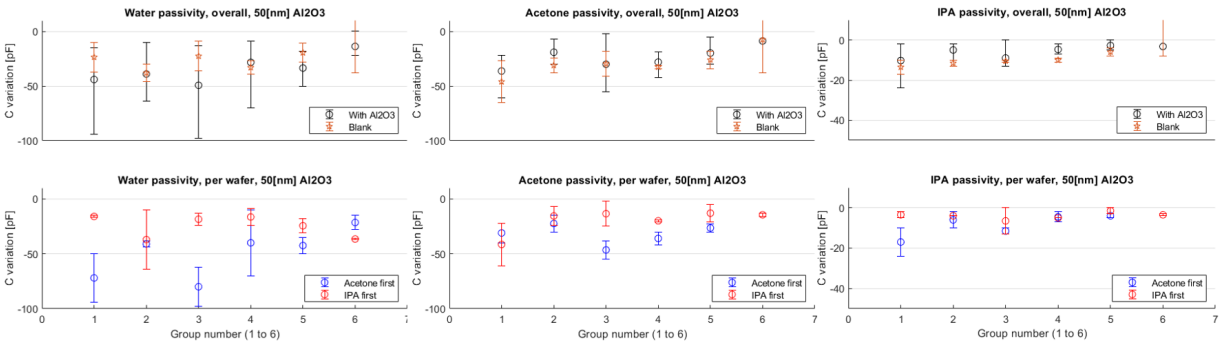

Figure 11: Capacitance variation for 50[nm] Al_2O_3 layer.

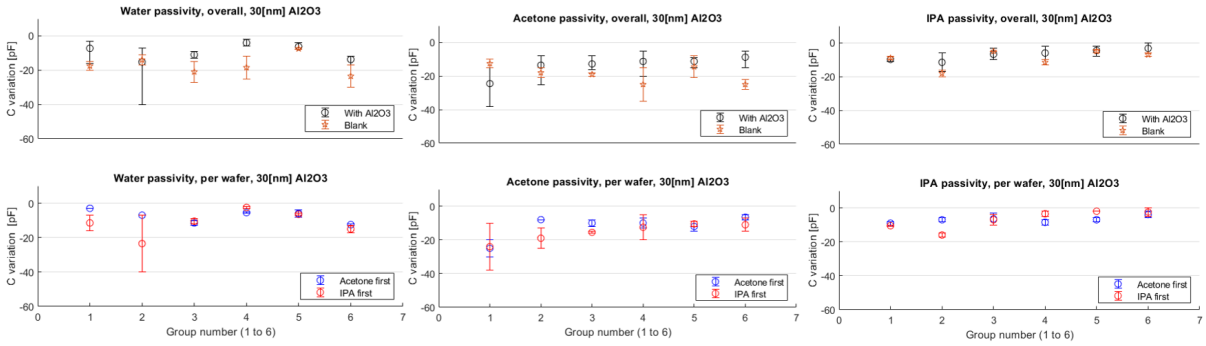

Figure 12: Capacitance variation for 30[nm] Al_2O_3 layer.