Development of Liquid Phase Deposition of Zirconium Oxide and Comparison to Silicon Dioxide

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Abstract

In a recently-developed liquid phase deposition (LPD) process silicon dioxide thin films are deposited from a solution of hexafluorosilicic acid (H_2SiF_6) supersaturated with SiO_2 by boric acid (H_3BO_3) addition. In this study, an analogous process for zirconium oxide is attempted and compared to the process with SiO_2. The effects of boric acid, H_2ZrF_6 and ammonia concentrations are studied along with differing solution preparation routes. Films of 10–70 nm thickness are achieved, though the determination of their exact composition requires further study.

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1 Introduction

1.1 Silicon dioxide thin films

Silicon dioxide thin films are used in many industrial areas. SiO_2 films are used in some anti-reflection coatings and as an ion barrier in flat panel displays such as liquid crystal displays (LCD) and electroluminescent displays (ELD). It is also the most important insulating material in the fabrication of semiconductor devices. It is used for example as the gate insulator of metal-oxide-semiconductor (MOS) transistors and as masks in very large scale integration (VLSI) circuit processes.

There are many ways to form SiO_2 thin films, *e.g.* thermal oxidation (when the substrate is silicon), chemical vapor deposition (CVD), electron-beam evaporation and sputtering. All those methods require processing temperatures of several hundred degrees centigrade. Many also require expensive vacuum equipment and cannot be applied well to large surface areas.

1.2 Liquid phase deposition

Recently a new process called liquid phase deposition (LPD) has been developed, in which silicon dioxide is deposited while the substrate is immersed in a solution of hexafluorosilicic acid (H_2SiF_6) supersaturated with SiO_2 [1, 2]. It does not require expensive equipment and the oxide can be deposited below 50°C and applied to a large and uneven surface. The oxide is furthermore grown selectively on the substrate and no growth occurs on materials such as photoresist.

The process is achieved by supersaturating a solution of H_2SiF_6 with SiO_2 by boric acid addition according to the following reactions:

$$\mathrm{H_2SiF_6(aq) + 2\ H_2O \rightleftarrows SiO_2(s) + 6\ HF(aq)} \tag{1}$$

$$\mathrm{4\ HF + H_3BO_3 \rightarrow BF_4^- + H_3O^+ + 2\ H_2O} \tag{2}$$

Boric acid reacts with hydrofluoric acid creating a stable complex ion BF_4^-. This reduces the concentration of hydrofluoric acid and causes equilibrium (1) to shift to the right according to Le Chatelier's principle. This can also be accomplished by adding aluminum to the growth solution, where it reacts with HF to produce AlF_3 [3]. This model of growth is, though, over-simplified and does not explain the selective growth. The selective growth is further discussed in section 4.1.

Figure 1 shows a schematic diagram of the process, including two routes as described by Chang *et al.* [2]. The difference in the routes is the order of saturating the H_2SiF_6 solution and diluting it with water. It has been noted that using route I (saturation before dilution) results in a notably higher growth rate [2, 4]. Chang *et al.* proposed that this is due to the role of water as a reagent, not only as a solvent. This means that the addition of water shifts reaction (1) to the right. In route II, the added SiO_2 then functions as a substrate actually depleting the solution of SiO_2 instead of saturating it.

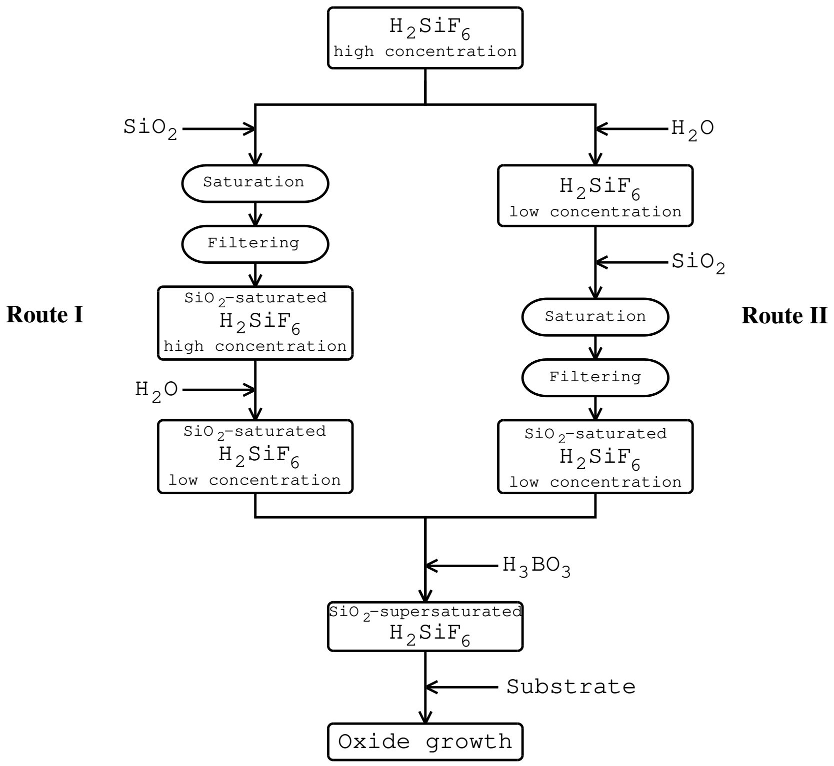

Figure 1: Schematic diagram of LPD-SiO_2

1.3 Other oxides

Liquid phase deposition is not limited to the formation of silicon dioxide layers. For example iron oxide [5] and vanadium oxide [6] can be deposited with a similar liquid phase process, whereas titanium oxide has been grown with an identical process using a H_2TiF_6 solution supersaturated with TiO_2 [7, 8].

Another metal for which similar hexafluoro-complexes exist and are commercially available is zirconium. This suggests that a similar LPD process for ZrO_2 deposition might be possible, which would be an intriguing alternative to current deposition methods, such as atomic layer CVD (ALCVD) and sputtering. Zirconium oxide films are used in optical coatings on account of their high refractive index (2.05 at $\lambda = 500$ nm) and high transparency over a large range of wavelengths (from near-UV at 300 nm to IR at 8 µm) [9].

In this research, I attempted to develop a method for zirconium oxide coating by directly substituting Si with Zr in the LPD process. Only one previous reference of LPD-ZrO_2 was found [10], a Japanese patent of which only the abstract was available in English. In the abstract ZrO_2 layers are claimed to have been deposited on soda-lime glass by adding aluminum chloride ($AlCl_3$) to hexafluorozirconic acid (H_2ZrF_6) and achieving thicknesses of 78 and 20 nm in 16 hours. This could not be tested due to the lack of necessary chemicals and time.

2 Experimental methods

Many experiments were made trying to grow ZrO_2 by means of LPD under varying conditions. The effects of different concentrations of H_2ZrF_6 and boric acid were studied along with different saturation levels, growth temperatures and preparation routes of H_2ZrF_6. Also differing pH levels were tested by replacing boric acid by ammonium borate or ammonium. Source materials were 98 wt-% H_2ZrF_6 (7.6 mol/dm^3, ABCR), boric acid powder (99.5 %, J. T. Baker) and 25 wt-% NH_3 (13.4 mol/dm^3, Merck).

As the delivery of commercial ZrO_2 powder had been delayed, I decided to saturate the H_2ZrF_6 solution in several experiments with the precipitate formed in the reaction between H_2ZrF_6 and ammonia. I made the precipitate from waste H_2ZrF_6 (containing *ca.* 35 wt-% H_2ZrF_6, 60 wt-% water, 3 wt-% ammonia and 2 wt-% boric acid) by adding about half of the volume 25 wt-% ammonia to it. The precipitate was then filtered, washed several times with water and dried in an oven at about 90°C for 15 hours and then at 120°C for 5 hours. It was then ground up to a powder with the largest pieces being about 2 mm in diameter. The precipitate was studied by thermogravimetry with a Seiko Instruments TG/DTA-320 thermobalance with an airflow of 80 ml/min.

Four different saturation types were tested: (*i*) no saturation of the 98 wt-% (7.6 mol/dm^3) H_2ZrF_6 (*ii*) saturating the 7.6 mol/dm^3 H_2ZrF_6 with the precipitate described above (route I) (*iii*) saturating 1.9 mol/dm^3 H_2ZrF_6 (1:3 ratio of H_2ZrF_6 and water) with the precipitate (route II) and (*iv*) saturating 1.9 mol/dm^3 H_2ZrF_6 with commercial ZrO_2 (99.7 %, Alfa Aesar) (route II). It was noted that several times more precipitate was required to

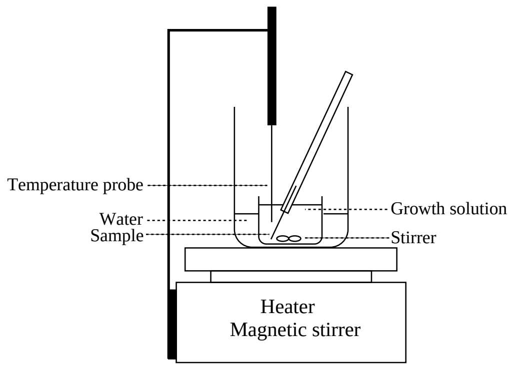

Figure 2: Experimental setup of deposition

saturate the diluted H_2ZrF_6, than 98 wt-% H_2ZrF_6.

The experiments were performed on a magnetic hotplate stirrer with external temperature probe. Unfortunately the probe broke at the very beginning and no replacement was available. It had to be wrapped in plastic for most of the experiments, reducing the accuracy of the measurement. The given temperatures are probably within a range of ±2°C.

The saturation was done on a magnetic stirrer overnight (~16 h, the exact saturation times may vary) at room temperature. The solution was then filtered through a 0.2 µm filter prior to deposition. The boric acid (or other HF scavenger) was then added and the solution was heated to 35°C, unless mentioned otherwise. The magnetic stirrer was at approximately 250 rpm. As the substrate pieces of a p-type (100) silicon wafer were used. Figure 2 shows the experimental setup for the deposition.

After deposition, the samples were rinsed in water and dried with nitrogen. The films were examined by means of ellipsometry with a Philips SD 2300 ellipsometer. The ellipsometer can either calculate both thickness and refractive index of the layer or it can be given a fixed refractive index for which it calculates the respective thickness. I tested its accuracy with LPD-SiO_2 samples of a short growth time. The results show that the ellipsometer is quite inaccurate at giving the thickness or refractive index of layers thinner than about 30 Å, but does show the general trend of changing thickness in a series of samples. The test results are given in appendix A. When examining the trend, a fixed refractive index was used as for some of the thinner samples the calculated refractive index fluctuated randomly between 1.5 and 3. It is plausible that the refractive index in a series of samples would stay approximately the same.

To further explain differences between LPD-SiO_2 and LPD-ZrO_2, I made several precipitation tests by titrating H_2SiF_6 and H_2ZrF_6 with ammonia. As several of the substances corrode glass (mainly HF, which is a reaction product), it was not possible to use a digital pH meter for measurements. I therefore had to use traditional pH paper to measure most of the pH values. I estimate that the accuracy is generally about ± 1. Also distinguishing very low pH values (1 and smaller) from each other was impossible.

In addition to the precipitation tests, I grew several samples in 25 wt-% H_2SiF_6 (2.2 mol/dm^3, Acros Organics) saturated with $SiO_2 \cdot xH_2O$ (Mallinckrodt Chemical) with only ammonia and water addition (route I). I have not seen any references to this in existing articles.

3 Results

3.1 Films grown

In most of the solutions, no actual growth was observed. In all cases, though, a constant-thickness layer was formed within one hour. The thickness can not be due to a measurement error, as almost all samples (with the notable exception of samples made by saturation type *iii*) were hydrophobic. Pure silicon is also hydrophobic, but even a native oxide makes it hydrophilic. Etching of the native oxide cannot be the case, because the samples were still hydrophobic even after several days, in which time a native oxide would have certainly been formed.

The presence of a layer is also shown by a gradual change in thickness as some growth parameter was changed, but when testing different lengths of deposition time, the layer thickness stayed approximately the same. It was noted, though, that most 1–2 hour samples were 10–20 Å thick, but almost all samples grown overnight (>16 hours) were approximately 50 Å thick. This might be caused by a gradual change in the growth solution, due to evaporation.

Table 1 presents the discovered trends. The exact results are left ambigious on purpose, because the layers are so thin. All growth solutions had 10 ml of H_2ZrF_6 (7.6 mol/dm^3 for types *i* and *ii*, 1.9 mol/dm^3 for types *iii* and *iv*) and 5 to 10 ml of water. Increased temperature seemed to give a slight rise to the thickness, though no thorough study of this was made.

The $H_3BO_3 \cdot xNH_3$ solution was made by adding 25 wt-% (13.4 mol/dm^3) ammonia to 0.5 mol/dm^3 boric acid until the pH was 7 (measured with a digital pH meter). The boric acid – ammonia ratio was about 150:1. This is a bit surprising, because stoichiometrically the required amount of ammonia should be three times the amount of boric acid, giving a ratio of 9:1. This

Sat. type	Variable parameter	Number of samples	Thickness Å	Trend*
i	c(H_3BO_3) = 0.25. . . 0.40 mol/dm^3	4	16. . . 23	Down
ii	c(H_3BO_3) = 0.00. . . 0.10 mol/dm^3	5	13. . . 20	Down
ii	Time = 1. . . 6 h	5	9. . . 16	None
ii	water amount = 50%. . . 80%	4	9. . . 16	Down
ii	c($H_3BO_3 \cdot x NH_3$) = 0.00. . . 0.17 mol/dm^3	3	13. . . 18	Down
iii	c(H_3BO_3) = 0.00. . . 0.09 mol/dm^3	4	∼30. . . ∼50	None
iv	Time = 1. . . 3 h	3	8. . . 12	None

* as effect on thickness with increasing value of parameter.

Saturation types:
i Non-saturated 7.6 mol/dm^3 H_2ZrF_6
ii Precipitate saturated 7.6 mol/dm^3 H_2ZrF_6
iii Precipitate saturated 1.9 mol/dm^3 H_2ZrF_6
iv Commercial SiO_2 saturated 1.9 mol/dm^3 H_2ZrF_6

Table 1: Results of LPD-ZrO_2 with changing parameters. Only series with at least 3 samples are shown. The thicknesses are measured with a fixed refractive index of 2.00 and results are not expected to be totally reliable.

might be due to the extremely low acidity constant of boric acid, $5.4 \cdot 10^{-10}$ for the first step and under 10^{-14} for the second [11, p. 8-43]. Therefore boric acid might not ionize completely even in a basic solution.

The only samples that grew over 25 Å (measured with refractive index of 2.00) in one hour, were the ones made with saturation type *iii*. Unfortunately, I did not have time to study them extensively. They were also the only samples that were hydrophilic after deposition. This is reasonable, as silicon dioxide is also hydrophilic (whereas HF-stripped silicon is hydrophobic). It is also the only solution to show some kind of growth pattern, though the samples were often too uneven to calculate a growth rate. Table 2 lists the obtained results for saturation type *iii* in full.

3.2 Precipitation experiments

I titrated H_2SiF_6 and H_2ZrF_6 with 25 wt-% ammonia several times and obtained seemingly contradictory results. Figure 3 shows the titration curves. The filled bullets show the point were precipitation occurred.

Curves (a) and (b) are totally contradictory, though both were done with same amounts of H_2SiF_6 and in a similar environment. Curve (a) is more

$c(H_2ZrF_6)$ mol/dm^3	$c(H_3BO_3)$ mol/dm^3	Time h	Refractive index	Thickness Å	Fixed n=2.00 thickness / Å
1.3	0	1	2.38	30...32	30...32
1.2	0.0063	1	1.33	37...65	26...46
1.0	0.021	1	1.63	53...69	26...62
0.86	0.086	1	1.23	55...68	33...37
0.95	0	1	1.40	52...125	45...85
0.95	0	2	1.45	103...110	86...89
0.90	0.0048	1	1.32	89...194	66...122
0.90	0.0048	18	1.18	710...839	283...301

The first four samples have 10 ml of H_2ZrF_6 and 5 ml of water and demonstrate the effect of boric acid addition.
The last four samples have 10 ml of H_2ZrF_6 and 10 ml of water and demonstrate the effect of deposition time.

Table 2: Results of LPD-ZrO_2 using 1.9 mol/dm^3 H_2ZrF_6 saturated with precipitate (saturation type *iii*).

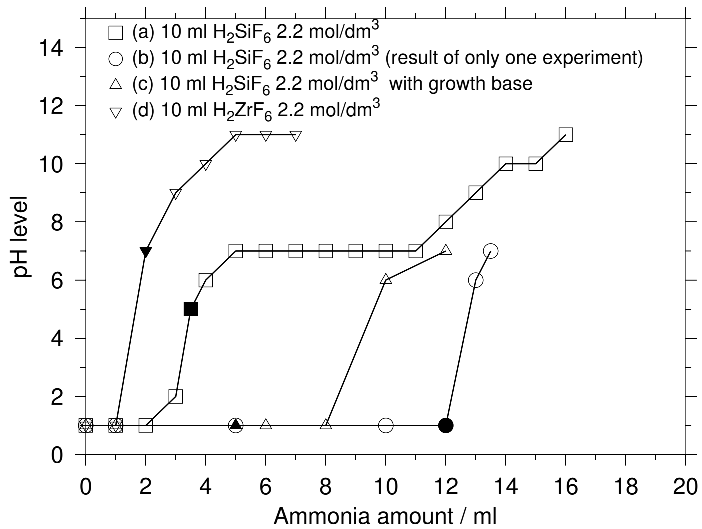

Figure 3: Titration curves of H_2SiF_6 and H_2ZrF_6. Filled bullets mark the point where a non-soluble precipitate was formed. All pH values below 2 are treated as pH 1.

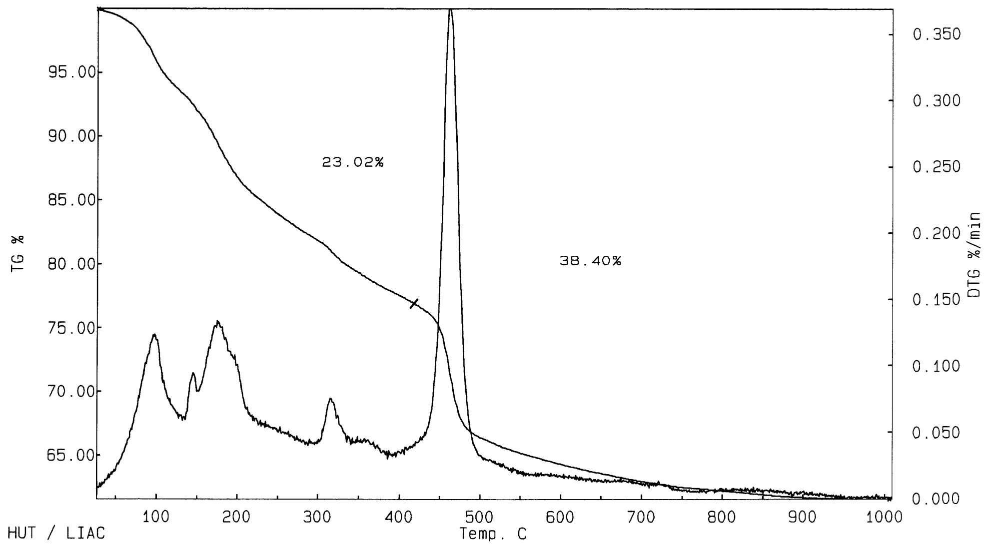

Figure 4: The thermogram of the precipitate

common and easily reproducible. Curve (b) was obtained from only one experiment and I was not able to reproduce it. Curve (c) demonstrates the effect of adding a small amount of precipitate as a growth base after each ammonia addition. Curve (d) is the titration curve of H_2ZrF_6.

The concentration of H_2SiF_6 and H_2ZrF_6 were both 2.2 mol/dm^3. Addition of boric acid to H_2SiF_6 prior to titration caused the precipitate to form earlier, but otherwise the titration curve was like curve (a). When using 98 wt-% (7.6 mol/dm^3) H_2ZrF_6 or SiO_2-saturated H_2SiF_6, a precipitate formed with under 0.5 ml NH_3 addition.

It was also noted that the precipitate of H_2SiF_6 was insoluble in hydrochloric acid (HCl) when washed, but dissolved when HCl was added to the solution containing the precipitate. The precipitate from H_2ZrF_6 was soluble in high quantities (100–200 g/l) in HCl even when washed.

Figure 4 presents the thermogram of the precipitate.

4 Discussion

The results show that direct substitution of Si with Zr is not totally sufficient in developing a process for zirconium oxide coating. Even though both have hexafluoro-complexes, they have subtle differences in other compounds. To understand the process better, it is necessary to further analyze the reactions in the LPD process.

Substance	Exists only in solutions	Soluble in water	Soluble in acid	Soluble in HF
SiO_2	No	No	No	Yes
ZrO_2	No	No	Slightly	Yes
H_4SiO_4	Yes	–	–	–
$Zr(OH)_4$	No	No	Yes	–

Table 3: Solubility of silicon and zirconium compounds [11, pp. 4-83, 4-98].

4.1 Closer inspection of the LPD process

Chou and Lee [4] have proposed that an intermediate species $SiF_m(OH)_{4-m}$ ($m < 4$) is formed in the reactions

$$H_2SiF_6 + (4-m)\ H_2O \rightleftarrows SiF_m(OH)_{4-m} + (6-m)\ HF \tag{3}$$

$$SiO_2 \cdot x\ H_2O + m\ HF \rightleftarrows SiF_m(OH)_{4-m} + (x+m-2)\ H_2O \tag{4}$$

with the first reaction occuring in the growth solution and the second one while saturating H_2SiF_6. This intermediate species then reacts with the Si–OH bonds on the substrate surface forming a SiO_2 coating. This will not be further presented here, as it is not relevant in this study. For clarity, I present reaction (3) simplified with $m = 0$:

$$H_2SiF_6 + 4\ H_2O \rightleftarrows Si(OH)_4 + 6\ HF \tag{5}$$

The solubilities of some of the substances involved are gathered in Table 3. It is notable that $Si(OH)_4$ (often written as H_4SiO_4, orthosilicic acid) exists only in solutions, while $Zr(OH)_4$ is an amorphous powder, insoluble in water. This casts doubt on whether the same reactions can take place with H_2ZrF_6.

Furthermore, SiO_2 is insoluble in acid (other than HF), but ZrO_2 is slightly soluble. This creates doubt whether zirconium oxide can be grown in an acidic environment, and at least limits the pH range and composition of the solution.

The growth with saturation type *iii* can be explained by $Zr(OH)_4$ dissolving into the acidic solution and then depositing either as $Zr(OH)_4$ or ZrO_2 onto the substrate. The exact composition of the layer deposited is unclear at the present time, though it is notable that the refractive index is much lower than that of a dense zirconium oxide layer (approximately 1.9 to 2.1). The reason why route I didn't function even with $Zr(OH)_4$ saturation might be the amount of $Zr(OH)_4$ that dissolved into the solution. The 98 wt-% solution might contain too much zirconium-compounds that not very much

$Zr(OH)_4$ could dissolve. Diluting the solution reduces the concentration of these zirconium-compounds and enables more $Zr(OH)_4$ to dissolve. An important question for further studies is, does the solution have to contain any H_2ZrF_6 for deposition to occur.

4.2 Precipitation analysis

Reaction (3) can also be seen in some of the precipitation tests. The seemingly contradictory results can be explained by the high variety of reactions. The most common case, curve (a), precipitates at about 4 ml ammonia addition and thereafter the pH stays neutral until a bit over 10 ml. This is probably caused by the following reactions [12]:

$$H_2SiF_6 + 2\ NH_3 \rightarrow (NH_4)_2SiF_6 \tag{6}$$

$$(NH_4)_2SiF_6 + 4\ NH_3 + 2\ H_2O \rightarrow SiO_2 + 6\ NH_4F \tag{7}$$

First the ammonia reacts with H_2SiF_6 to form ammonium hexafluorosilicate ($(NH_4)_2SiF_6$). This consumes ammonia twice the amount of H_2SiF_6, stoichiometrically 3.3 ml. This solution is neutral, as both NH_4^+ and SiF_6^{2-} have very low acidic constants. Then $(NH_4)_2SiF_6$ begins to react with the ammonia, creating a SiO_2 precipitate and ammonium fluoride. This consumes ammonia four times the amount of H_2SiF_6 or 6.6 ml. After this, all H_2SiF_6 has been consumed and the pH begins to rise slowly.

Curve (b) can be explained by reaction (5) proceeding to the right and ammonia consuming the resulting hydrofluoric acid. Thus the pH stays low until all H_2SiF_6 has been consumed. This is six times the amount of H_2SiF_6 or 9.9 ml. At some point some $Si(OH)_4$ (which can also be seen as $SiO_2 \cdot 2\ H_2O$) dehydrates into forming SiO_2, giving a growth base for the rest of the $Si(OH)_4$ to deposit to. This would also explain the trouble in reproducing the experiment, as there must not be any SiO_2 particles in the solution.

Curve (c) can be explained with the same reactions as (b), only the dehydration happening earlier, due to the growth base.

Curve (d) differs greatly from the other results. Precipitation occurs already at about 2 ml with a significant rise in pH. Addition of boric acid to the solution also changes the titration curve dramatically with precipitation and pH rise taking place at higher ammonia concentrations. Further study is needed to fully understand the exact reactions that happen in the solution, but this shows that the reactions of H_2ZrF_6 differ significantly from those of H_2SiF_6. Addition of boric acid only increases the amount of possible reactions as it can either consume hydrofluoric acid or neutralize ammonia, both of which decrease the acidity but to a different degree.

H_2SiF_6 ml	Saturated	H_2O ml	NH_3 ml	Time h	Refractive index	Thickness Å	Rate Å/h
10	No	0	2	1.0	2.52	15	15
–	–	–	–	–	1.12 †	45	**45**
10	No	0	3	1.5	1.12	308	**205**
10	Yes	9	1	1.5	1.12	371	**247**
10	Yes	10	0	1.5	1.44	99	**66**

† Results given also with fixed refractive index as floating refractive index differs so much from the other results. Both are considered unreliable, but trendsetting results.

Table 4: Experimental parameters and results of LPD-SiO_2 with ammonia addition. The first two experiments were done at 25°C and the last two at room temperature.

The solubility tests support these findings. When hydrochloric acid is added to the solution, it consumes the ammonia, releasing hydrofluoric acid in which the SiO_2 precipitate dissolves. When the precipitate is washed, the ammonium fluoride is removed and the pure SiO_2 doesn't dissolve in the acid. The precipitate forming in the reaction between H_2ZrF_6 and ammonia is probably $Zr(OH)_4$ or ZrO_2, both of which dissolve in acid. The amount of precipitate that dissolves might suggest a high content of $Zr(OH)_4$ as it dissolves more readily.

The thermogram (Figure 4) also suggests that the precipitate is $Zr(OH)_4$. Assuming the beginning product is $Zr(OH)_4$, the drop in weight for $Zr(OH)_4 \rightarrow ZrO_2 + 2\ H_2O$ is 22.6 %, corresponding the drop from the beginning to the tick. The steep drop after the tick could be the reduction from zirconium (IV) oxide to zirconium (II) oxide. $ZrO_2 \rightarrow ZrO + O$ would result in a drop of 10.1 %, approximately the height of the drop. The rest is probably due to impurities from the production process. It is therefore probable that the precipitate is mostly (~90 wt-%) $Zr(OH)_4$.

4.3 LPD-SiO_2 with ammonia addition

I made four experiments of LPD-SiO_2 with only ammonia addition. Table 4 shows the experimental parameters and results of these tests. One can see that the growth rates with higher concentrations of ammonia are drastically higher than the ones with less ammonia. This indicates a higher concentration of $SiF_m(OH)_{4-m}$ through reaction (3) with ammonia consuming the hydrofluoric acid, stressing the importance of the intermediate species. Ammonia addition also seems to radically lower the refractive index of the film.

This might be due to water incorporating in the film. Further investigation of this effect is, however, beyond the scope of this study.

5 Conclusion

A process for deposition of zirconium oxide, analogous to the liquid phase deposition of silicon dioxide, was attempted. No continuous growth was observed when the growth solution had been saturated at 98 wt-% concentration or when saturated with commercial ZrO_2. A notable film was only deposited when pre-diluted H_2ZrF_6 was saturated with $Zr(OH)_4$, though the exact composition of the film requires further study. This could be done by means of IR-spectroscopy, etch-rate testing and X-ray diffraction (XRD).

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Appendices

A Test results of ellipsometer accuracy

To test the ellipsometer's accuracy, I made four short LPD-SiO_2 samples. First two longer depositions were made in a growth solution consisting of 60 ml of SiO_2-saturated H_2SiF_6 (35 wt-% , Lancaster Synthesis), 90 ml of H_2O and 8 ml of H_3BO_3 (0.5 mol/dm^3). After that four short dips were done and finally one one-hour deposition was performed. From the longer depositions it is possible to calculate the growth rate quite accurately. As LPD on native-oxide coated silicon is not known to have any delay of deposition after immersion in the growth solution [2] and the growth rates of the long depositions are approximately equal, we can calculate the approximate thickness of the short LPD layers. Table 5 lists the results of the one hour depositions and Figure 5 shows the results for the short dips graphically.

The ellipsometer is evidently not very accurate at measuring such thin films, but the results show a definite rise in thickness with growing deposition time. Thus, even for very thin samples the trend of thickness is shown.

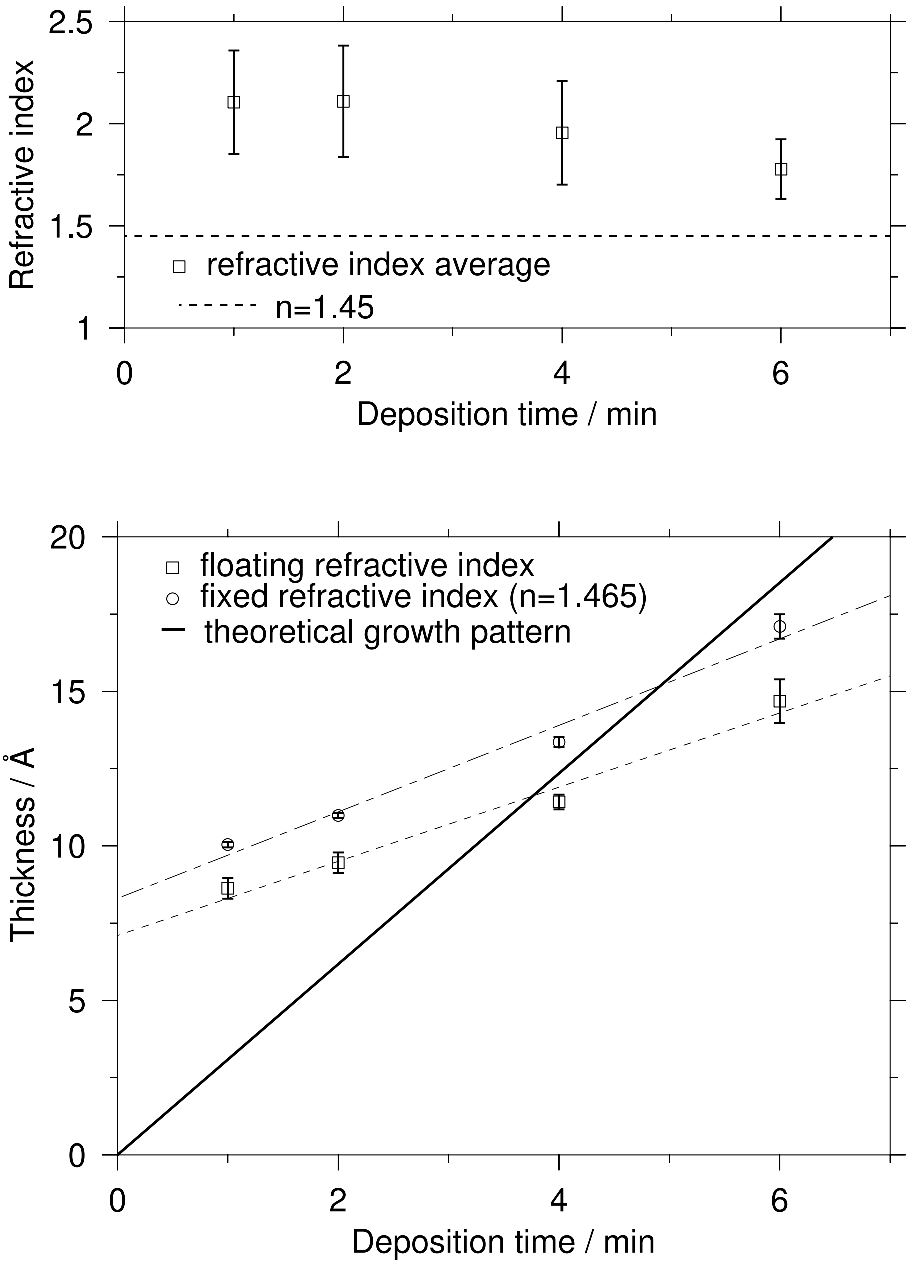

Figure 5: Thin LPD-SiO_2 results for test of ellipsometer's accuracy

Stage	Deposition time	Refractive index	Thickness Å	Deposition rate Å/h
Before	1 h	1.44	184	184
Before	1 h	1.46	181	181
After	1 h 12 min	1.44	227	189
Average		1.45		185

Table 5: Longer LPD-SiO_2 results for test of ellipsometer's accuracy

As expected, the measured growth rate between adjacent points also grows with time, approaching that of the theoretical growth rate. The results may therefore be quite unreliable below 30 Å, but already quite accurate over 50 Å.

B Molarity and percentage correspondence

Substance	Percentage	Molarity	Source
H_2SiF_6	25 wt-%	2.2 mol/dm^3	Given density (1.27 g/cm^3)
	35 wt-%	3.3 mol/dm^3	From 25% correlance
H_2ZrF_6	98 wt-%	7.6 mol/dm^3	Measured density (1.6 g/cm^3)
	35 wt-%	1.9 mol/dm^3	From 98% correlance
NH_3	25 wt-%	13.4 mol/dm^3	Interpolated from [13]

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