Chapter 6.4

Guide to SiO_x Deposition in Oxfordpecvd4

(oxfordpecvd4) (586)

1.0 Document Summary

1.1 This document provides information on growing SiOx films in Oxfordpecvd4 at 350°C using the 81 MHz generator. It outlines general trends between the deposition rate, uniformity, film stress and refractive index of the film, and the process gas flowrates, pressure and power

1.2 This document also provides ready-to-use recipes for creating SiOx films (*see section 6.0*). The most notable improvements include a 13x deposition rate increase over the previous 13.56MHz standard oxide recipe

1.3 Note that this manual does not provide information for films at other temperatures than 350°C or generator frequencies other than 81 MHz

2.0 Related Documents

2.1 Oxford Thin-Film Deposition Cluster Common Manual: provides information on operation of the tool itself; this manual **must** be read before operating oxfordpecvd4

2.2 Henrie, *et al*. "Electronic color charts for dielectric films on silicon": this provides a quick way to qualitatively assess the thickness of your oxide film

2.3 Adams, *et al*. "Characterization of Plasma-Deposited Silicon Dioxide": a study of plasma deposition of SiOx in reactor conditions that are very similar to the conditions in Oxfordpecvd4

2.4 PECVD Overview for Oxford Instruments: a slideshow provided by Oxford Instruments to give an overview of the PECVD process

2.4.1 Slide 3: process trends for SiOx deposition

2.4.2 Slides 6-7: deposition rate and refractive index dependence on N_2O/SiH_4 ratio

2.4.3 Slides 9-10: BHF and KOH etch rate dependence on deposition temperature

2.4.4 Slide 20: film stress dependence on N_2O/SiH_4 ratio

2.5 *Thin Films for Advanced Electronic Devices* (1991): this book presents information on interpreting FTIR spectra of various thin films, with information for SiOx films starting on page 287. The contents of this book relating to peak assignments in FTIR spectra of SiOx films are repeated in the FTIR analysis section of this document

2.6 Pilskin, "Comparison of Properties of Dielectric Films Deposited by Various Methods": shows empirical trends for film stoichiometry with film properties that are measurable in the lab

2.7 *Infrared Characterization for Microelectronics* (1999): information about FTIR analysis of various thin films. Available for checkout at the Engineering Library

2.8 Wang, *et al*. "Assignment of surface IR absorption spectra observed in the oxidation reactions: 2H + H_2O/Si(1 0 0) and H_2O + H/Si(1 0 0)": a detailed overview of all the possible peaks that one might see in the FTIR spectrum of a SiOx film

3.0 Definitions & Process Terminology

3.1 N_2O/SiH_4 Ratio: the ratio of nitrous oxide flow to silane flow. This is reported as (sccm N_2O)/(sccm pure SiH_4), so for a recipe using 50 sccm 10% SiH_4 in Ar and 200 sccm N_2O, the N_2O/SiH_4 ratio would be (200 sccm)/(0.10*50 sccm) = 40

3.2 Total flowrate: the sum of all individual gas flowrates being pumped into the chamber

3.3 Non-Uniformity: defined as `(max-min)/(max+min)*100%`, where `max` is the position on the wafer with the highest deposition rate and `min` is the position with the lowest deposition rate

4.0 Available Recipes

4.1 The new SiOx recipes that were created from this investigation are listed below. The standard multipurpose SiOx recipe is listed alongside the previous standard recipe to highlight the improvement over the previous standard

4.2 Standard SiOx recipe for general use

4.2.1 CH4 - STD - SiOx Recipe 1010

4.2.1.1 Ar: 650 sccm, N_2O: 150 sccm, N_2: 200 sccm, 10% SiH_4/Ar: 50 sccm

4.2.1.2 Generator: 81 MHz, Power: 200 W

4.2.1.3 Pressure: 1000 mTorr, Temperature: 350C

4.2.1.4 Deposition Rate: 1738 Å/min, Non-Uniformity: 1.8%

4.2.1.5 Refractive Index: 1.468, Film stress: -280 MPa

4.3 Previous standard SiOx deposition recipe for past reference

4.3.1 CH4 - STD - SiOx Recipe 1101

4.3.1.1 N_2O: 750 sccm, N_2: 162 sccm, 10% SiH_4/Ar: 4 sccm

4.3.1.2 Generator: 13.56 MHz, Power: 20 W

4.3.1.3 Pressure: 1000 mTorr, Temperature: 350C

4.3.1.4 Deposition Rate: 132 Å/min, Non-Uniformity: 1.4%

4.3.1.5 Refractive Index: 1.454, Film stress: -380 MPa

4.4 Other SiOx deposition recipes available for general use are listed below, alongside the typical film properties that come from that recipe

SiO_x Deposition Recipes					
	Typical Film Properties				
Recipe Name & Description	Dep. Rate (Å/min)	Dep. Rate non-Uniformity (%)	Refractive Index (at 633 nm)	Stress (MPa)	Density (g/cm^3)
CH4 - STD - SiOx Recipe 1001	858	2.7	1.465	-380.0	1.99
CH4 - STD - SiOx Recipe 1002	876	2.0	1.481	-190.0	2.00
CH4 - STD - SiOx Recipe 1004	1745	1.6	1.468	-300.0	2.13
CH4 - STD - SiOx Recipe 1005	883	2.4	1.466	-360.0	2.05

CH4 - STD - SiOx Recipe 1006	1312	2.3	1.466	-330.0	2.06
CH4 - STD - SiOx Recipe 1007	1688	2.0	1.492	-120.0	2.11
CH4 - STD - SiOx Recipe 1008	1316	2.2	1.466	-360.0	2.08
CH4 - STD - SiOx Recipe 1009	1276	2.0	1.490	-140.0	2.05
CH4 - STD - SiOx Recipe 1010	1738	1.8	1.468	-280.0	2.06

4.5 The process parameters used in the above recipes are listed below. All recipes take place at 350°C, 1000 mTorr and 200 W using the 81 MHz generator, with 200 sccm of N_2 flow

Recipe Properties			
	Recipe Parameters		
Recipe Name & Description	10% SiH_4/Ar flow (sccm)	N_2O flow (sccm)	Ar flow (sccm)
CH4 - STD - SiOx Recipe 1001	25	125	700
CH4 - STD - SiOx Recipe 1002	25	25	800
CH4 - STD - SiOx Recipe 1004	50	250	500
CH4 - STD - SiOx Recipe 1005	25	75	750
CH4 - STD - SiOx Recipe 1006	37.5	112.5	700
CH4 - STD - SiOx Recipe 1007	50	50	750
CH4 - STD - SiOx Recipe 1008	37.5	187.5	625
CH4 - STD - SiOx Recipe 1009	37.5	37.5	775
CH4 - STD - SiOx Recipe 1010	50	150	650

5.0 <u>Design of SiOx Recipes</u>

5.1 Overall trends observed in correlations with process variables:

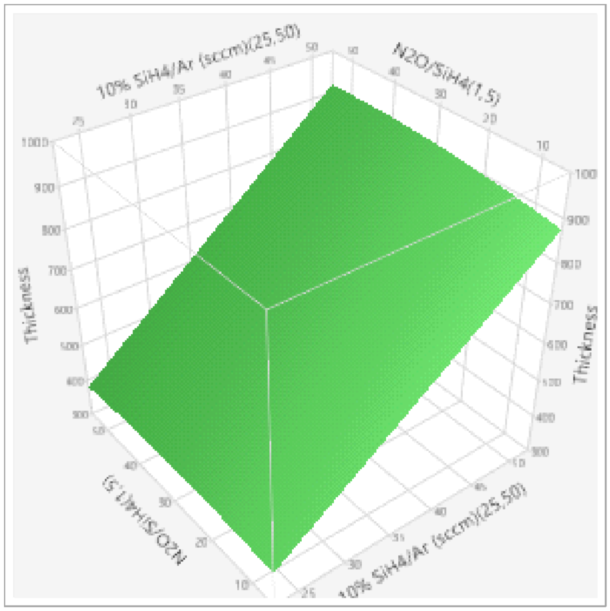
5.1.1 SiH_4 flow affects the deposition rate strongly and has weak effects on the film quality

5.1.2 There are two regimes for SiO_x deposition depending on the N_2O/SiH_4 ratio:

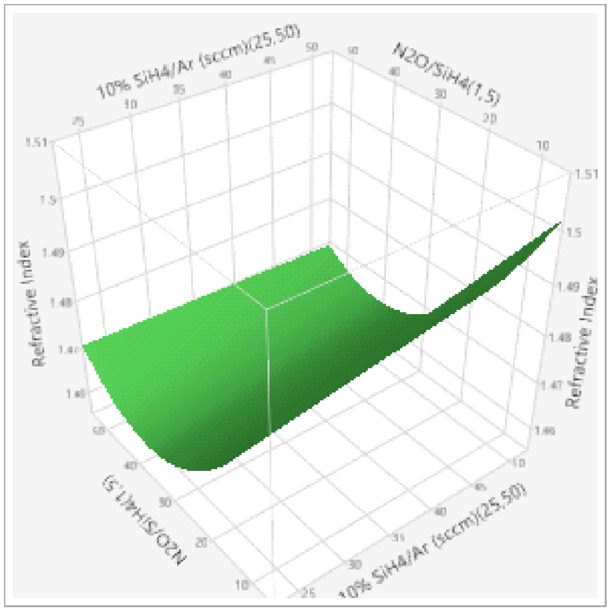
5.1.2.1 For $N_2O/SiH_4 > 30$: the film is nearly stoichiometric, high-stress, and has a refractive index close to thermally-grown SiOx

5.1.2.2 For $N_2O/SiH_4 < 10$: the film is oxygen-deficient, low-stress, and has a higher refractive index

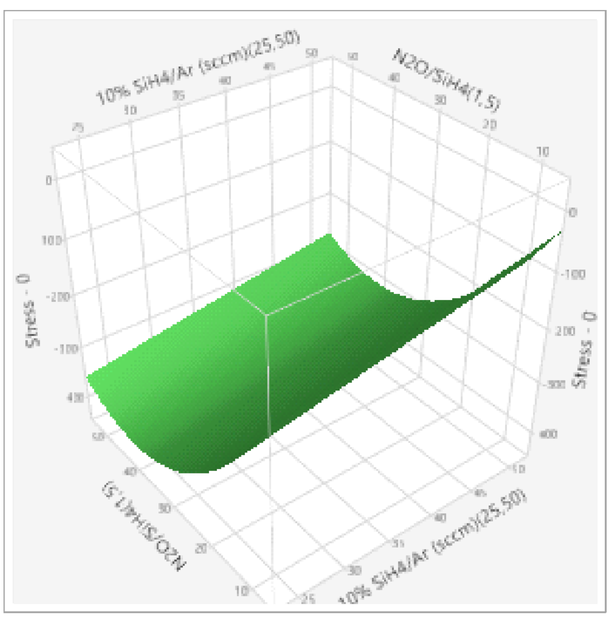
5.2 *Dependence of deposition rate on SiH_4 flow and N_2O/SiH_4 ratio*: deposition rate depends strongly on silane flow while being nearly independent of the N_2O/SiH_4 ratio. As seen in the plot below, the deposition rate (labeled “thickness” in the plot) will increase if the SiH_4 flow is increased, while it will remain nearly constant if the N_2O/SiH_4 ratio is changed

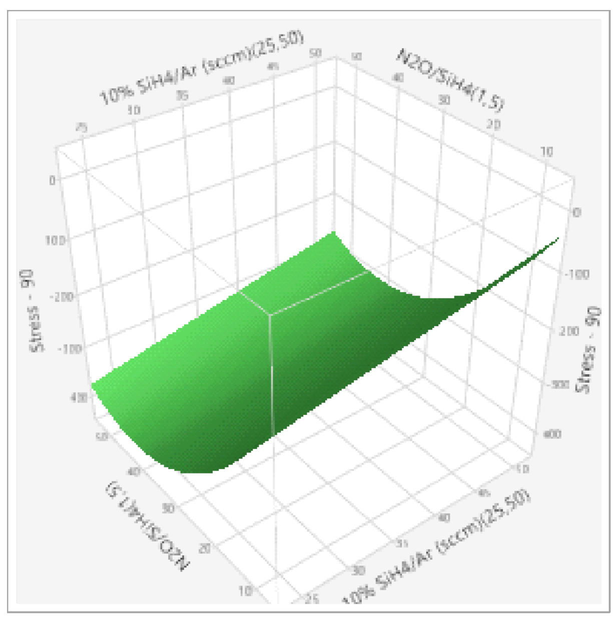

10% SiH4/Ar (sccm)(25,50)
N2O/SiH4(1,5)
Thickness
Thickness
N2O/SiH4(1,5)
10% SiH4/Ar (sccm)(25,50)

5.3 *Dependence of refractive index on SiH_4 flow and N_2O/SiH_4 ratio*: refractive index shows a slight correlation with SiH_4 flow, but a strong dependence on N_2O/SiH_4 ratio. Since refractive index increases with oxygen deficiency, the increase in refractive index with decreasing N_2O/SiH_4 is likely due to the creation of non-stoichiometric SiOx films in the oxygen-starved chamber. FTIR analysis (*see section 9.0*) indicates the same trends of refractive index with stoichiometry

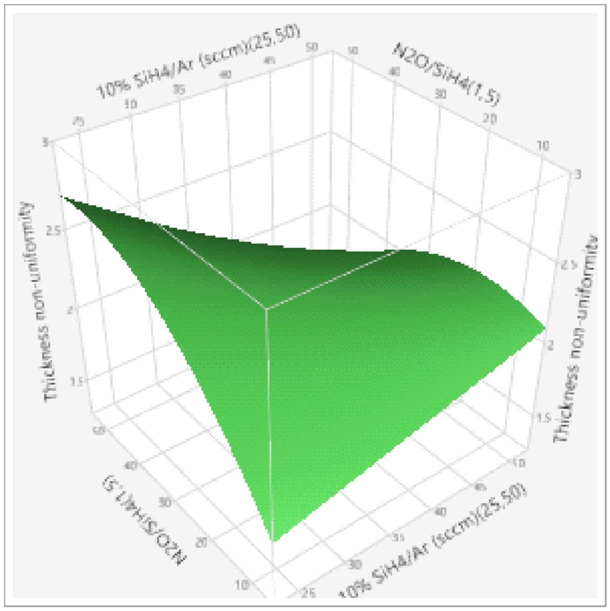


5.4 *Dependence of stress on SiH_4 flow and N_2O/SiH_4 ratio*: all wafers deposited with PECVD oxide show a moderate compressive stress, shown as negative values in the plots for 0°/90° stress below. Stress is weakly dependent on SiH_4 flow and strongly dependent on the N_2O/SiH_4 ratio. To decrease the stress, one should increase the SiH_4 flow and decrease the N_2O/SiH_4 ratio in the deposition recipe, though this will create non-stoichiometric films

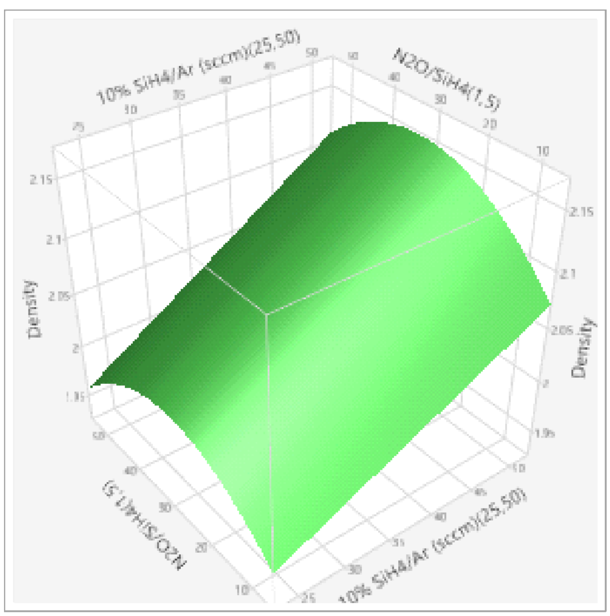




5.5 *Dependence of deposition rate non-uniformity on SiH_4 flow and N_2O/SiH_4 ratio*: at the recommended conditions for pressure, power, temperature and total flowrate (i.e., at 1000 mTorr, 200 W, 350°C and 1050 sccm), the non-uniformity of deposition rate across the wafer is nearly independent of SiH_4 flow and N_2O/SiH_4 flow



5.6 *Dependence of film density on SiH_4 flow and N_2O/SiH_4 ratio*: increasing the SiH_4 flow causes mild densification of the film while changing the N_2O/SiH_4 ratio has a comparatively minor effect on the film density



5.7 Explanation for the choice of CH4 - STD - SiOx Recipe 1010 as the default SiOx recipe:

5.7.1 Recipe 1010 has a high deposition rate, owing to the use of the maximum amount of silane available from oxfordpecvd4's MFC

5.7.2 Recipe 1010 employs a moderate N_2O/SiH_4 ratio of 30, giving it a refractive index that closely approximates that of a thermally-grown oxide

5.7.3 FTIR analysis of films grown using Recipe 1010 indicates a high oxygen content in the films, showing them to be stoichiometric or near-stoichiometric SiOx

6.0 Process Explanation

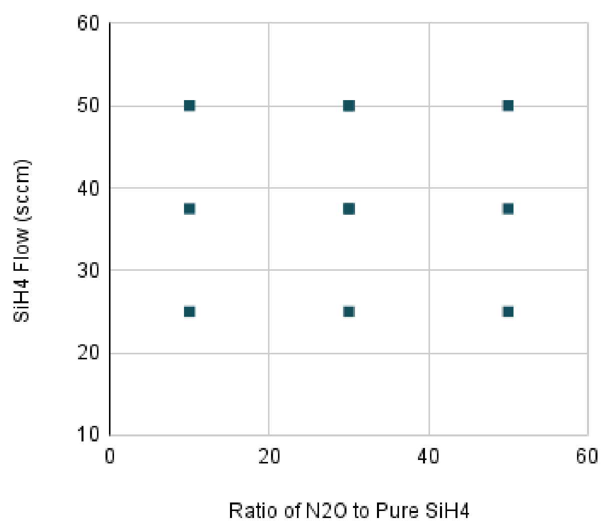
6.1 The SiOx recipes and process trends outlined in this document were obtained by growing films according to a design of experiments methodology:

6.1.1 The process variables that were identified as being the most important for growing the films were varied according to a statistically-determined pattern in the statistical analysis software JMP and used to create new recipes

6.1.2 These recipes were then performed in oxfordpecvd4 and measured for film thickness, refractive index, stress, and density, and evaluated using FTIR

6.2 Experimental design that yielded Recipes 1001-1010:

6.2.1 SiH_4 flow and the N_2O/SiH_4 ratio were determined to be the most important factors for growing SiO_x films, so a set of experiments were generated by varying the SiH_4 flow and N_2O/SiH_4 ratio according to the following pattern:



6.2.2 The DoE parameters for recipes 1001 through 1010 are listed below. Recipe 1006 was used as the centerpoint for the experiments:

Recipe Properties		
	Recipe Parameters	
Recipe Name & Description	10% SiH_4/Ar flow (sccm)	N_2O/SiH_4 Ratio
CH4 - STD - SiOx Recipe 1001	25	50

CH4 - STD - SiOx Recipe 1002	25	10
CH4 - STD - SiOx Recipe 1004	50	50
CH4 - STD - SiOx Recipe 1005	25	30
CH4 - STD - SiOx Recipe 1006	37.5	30
CH4 - STD - SiOx Recipe 1007	50	10
CH4 - STD - SiOx Recipe 1008	37.5	50
CH4 - STD - SiOx Recipe 1009	37.5	10
CH4 - STD - SiOx Recipe 1010	50	30

6.2.3 **NOTE:** N_2O/SiH_4 ratios here are listed as ratios of pure N_2O to pure SiH_4

7.0 <u>FTIR Analysis of SiOx Films</u>

7.1 FTIR is a powerful tool for determining the composition of a SiOx film deposited via a variety of methods, and can hint at the stoichiometry, H-content and stress of the deposited films

7.2 **<u>DISCLAIMER</u>**: The intensities of and shapes FTIR absorption bands and peaks vary widely across deposition technologies, while band and peak positions stay mostly unchanged. To compare multiple films using FTIR spectroscopy, they should have been deposited using the same deposition technology and be of comparable thickness in order to make accurate conclusions regarding film stoichiometry

7.3 Notable features of SiOx FTIR spectra that are relevant to analyzing film quality:

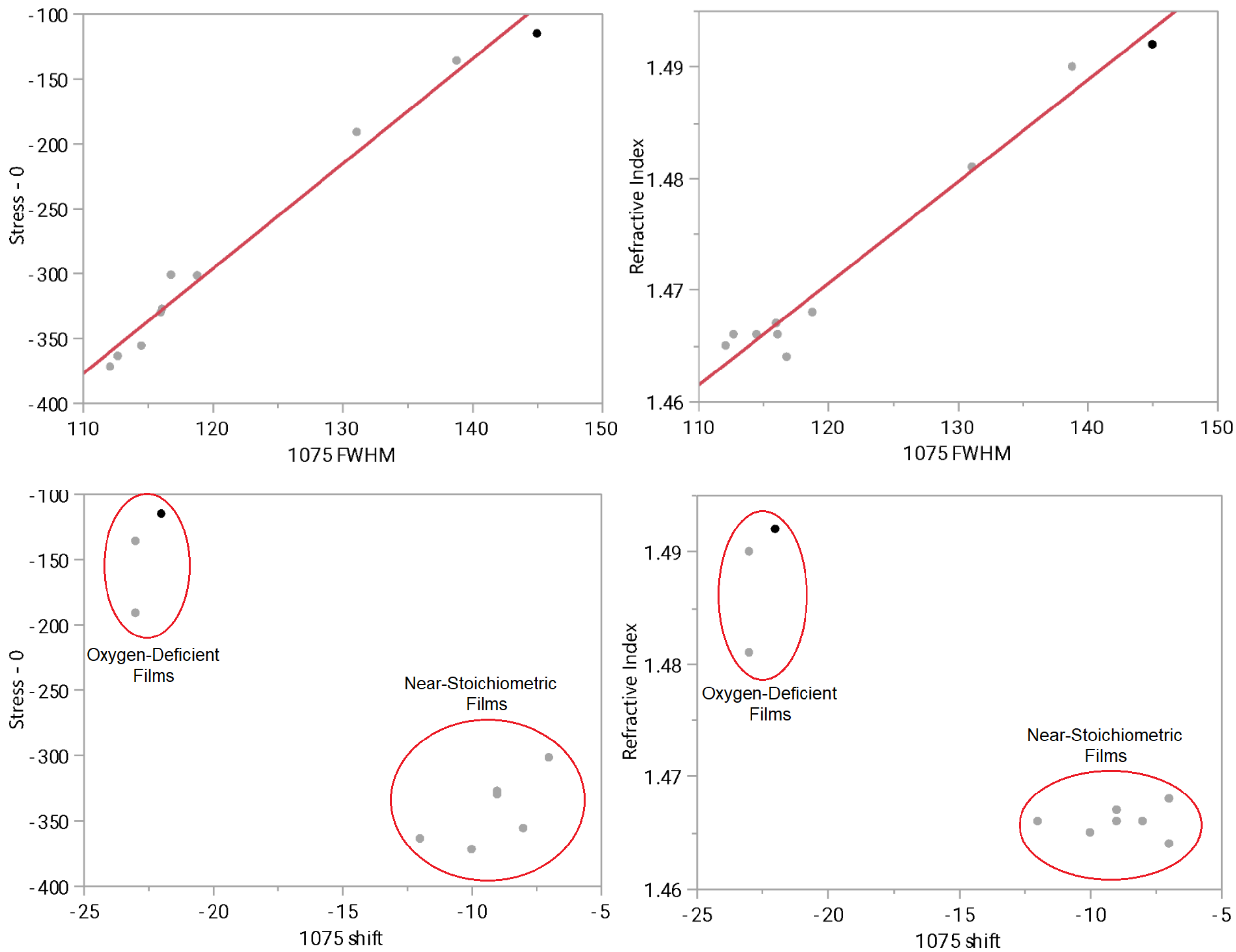
7.3.1 Intense, well-defined peak in the region of 1075-1050 cm^{-1}

7.3.1.1 Origin: stretching of individual Si—O bonds

7.3.1.2 FWHM: higher FWHM indicates more oxygen deficiency and strongly correlates with lower stress and higher refractive index. Fits of stress and refractive index with FWHM are shown in the following plots

7.3.1.3 Position: the peak is located at 1075 cm^{-1} for stoichiometric SiOx films and decreases until reaching 940 cm^{-1} for highly oxygen-doped amorphous Si films, so lower wavenumbers indicate increasingly O-deficient films. The plots below show the distance of the peak position from 1075 cm^{-1} for films grown using each of the recipes in this document, highlighting the two regimes for SiOx deposition that was outlined in section 8.3.2

7.3.1.4 Intensity: higher intensity loosely correlates with a thicker film



7.3.2 A small, less-pronounced shoulder that sometimes appears on the main 1075 cm^{-1} peak at wavenumbers just higher than the peak's position, usually at 1100 cm^{-1}

7.3.2.1 Origin: this shoulder is likely due to various H_2Si—O □ O—SiH_2 complexes

7.3.2.2 Analysis: this peak is usually obscured by the main peak at 1075 cm^{-1}, but if there is a pronounced shoulder it indicates oxygen-deficiency in the film

7.3.3 Presence of a weak absorption band in the region of 890-950 cm^{-1}

7.3.3.1 Origin: vibrational modes of various Si—H and silane-derived structures and complexes

7.3.3.2 When this band is present, it indicates a higher amount of hydrogenation of the film. It is suspected that performing a numerical integration of this band would provide a quantitative way to assess the hydrogenation of the film, but this is not within the scope of this investigation. Contact the oxfordpecvd4 process engineer if you would like to investigate this further

7.3.3.3 When this band is not present, the spectrum in this region appears as a nearly-parabolically shaped trough which approaches a value of 0.000 at around 930 cm^{-1} and indicates a lower amount of hydrogenation in the film

7.3.4 Absorption peaks related to the presence of water in the film and/or deposition gases:

7.3.4.1 3650 and 3400 cm^{-1}: O—H stretching in Si—OH structures

7.3.4.2 2260 cm^{-1}: Si—H in H_2O-contaminated SiOx films

7.3.4.3 3350 cm^{-1}: vibrational modes of H—Si—OH structures and H_2O

7.3.4.4 1620 cm^{-1}: O—H bending mode of H_2O

7.4 Other features of SiOx FTIR spectra that are less useful for analyzing film quality but which can be used with further investigation:

7.4.1 A large, wide shoulder on the main 1075 cm^{-1} peak in the region of 1150-1250 cm^{-1}

7.4.1.1 This peak is a feature of most PECVD oxide films but is weaker on thermal oxides. Its origin is not clear, but its intensity usually correlates with the intensity of the main 1075 cm^{-1} peak

7.4.2 A wide absorption band in the region of 800-870 cm^{-1} with a peak intensity at roughly 820 cm^{-1}

7.4.2.1 Origin: vibrational modes of various Si—H bonds and silane-derived structures and complexes

7.4.2.2 Analysis: unlike the absorption band around 890-950 cm^{-1}, the intensity of this band correlates with the intensity of the main peak at 1075 cm^{-1}, making it a less useful indicator of film hydrogenation. It is suspected that the ratio of the peak intensity of this band to the peak intensity of the 1075 cm^{-1} peak would be a good way to quantitatively assess film hydrogenation, but this is outside the scope of this investigation

7.4.3 A small, unpronounced peak at 820 cm^{-1}

7.4.3.1 Origin: bending modes of O—Si—O bonds in tetrahedrally-bound SiO_4 sites

7.4.3.2 Analysis: a strong 820 cm^{-1} peak indicates a more stoichiometric film, but since this peak is usually obscured by the band at 800-870 cm^{-1}, it is not recommended to base your analyses off this peak

7.4.4 Sharp, pronounced peak at 611 cm^{-1}

7.4.4.1 Origin: the main absorption peak of the Si wafer substrate. This peak will not be present if the spectrum for the Si wafer is subtracted-out from the gathered FTIR spectrum of the film

7.4.5 Small, wide absorption peak with a peak intensity around 452 cm^{-1}:

7.4.5.1 Origin: rocking modes of O—Si—O bonds in tetrahedrally-bound Si—O_4 sites

7.4.5.2 Analysis: this peak usually behaves similarly to the main peak at 1075 cm^{-1} but is flanked by other absorption bands due to various bonds in the film, making it difficult to use this peak in analysis and to assign a definitive position to this peak

7.5 Example FTIR spectra to highlight the relevant peaks:

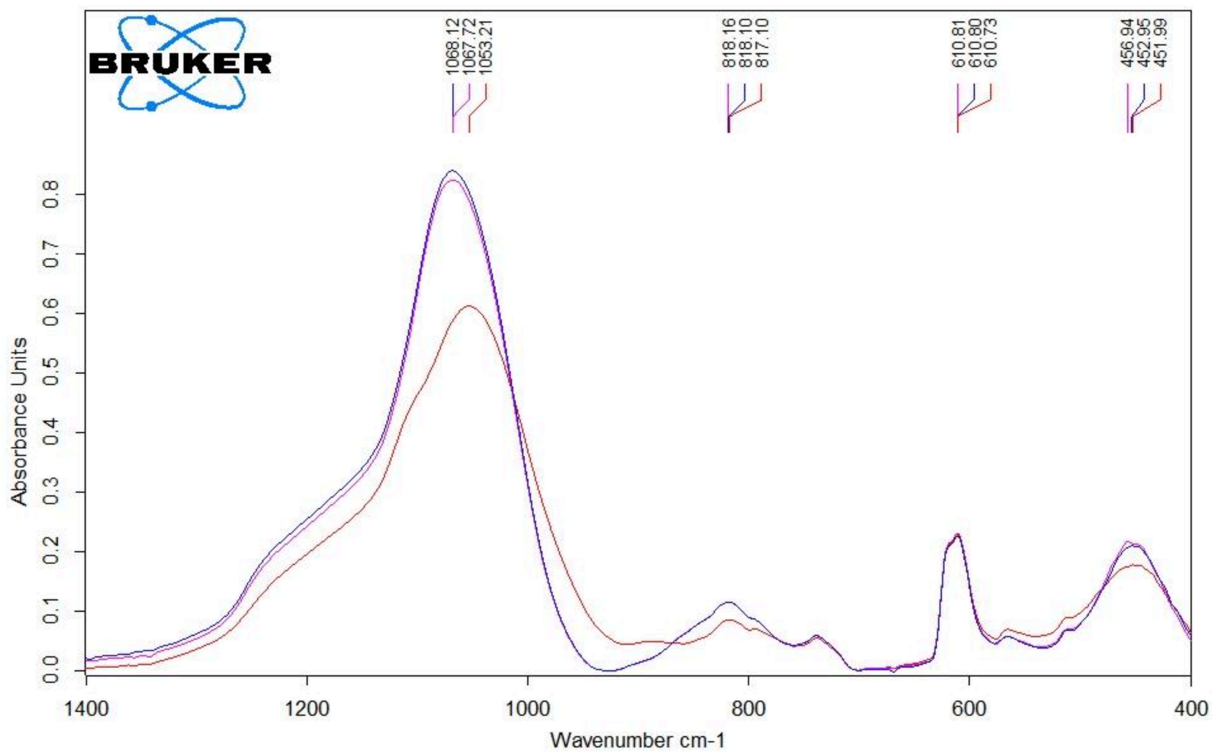
7.5.1 In the spectrum below:

7.5.1.1 Blue = 868 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1010

7.5.1.2 Red = 844 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1007

7.5.1.3 Pink = 873 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1004

7.5.1.4 Yellow = bare Si wafer with no film



7.5.2 The three recipes differ only in the N_2O/SiH_4 ratio with all other variables held constant with 50 sccm of 10% SiH_4/Ar; the pink spectrum represents a film grown with N_2O/SiH_4 = 5, blue represents N_2O/SiH_4 = 3, and red represents N_2O/SiH_4 = 1

7.5.3 Notable observations for the Recipe 1010 and 1004 spectra:

7.5.3.1 Narrow FWHM, a peak intensity at a higher wavenumber and no shoulder at 1100 cm^{-1}, indicating good stoichiometry in the film

7.5.3.2 Weak absorption in the region of 890-950 cm^{-1}, indicating low film hydrogenation

7.5.3.3 Relatively stronger peaks at 820 and 452 cm^{-1}, indicating more tetrahedrally-bound SiOx sites and hinting at good stoichiometry

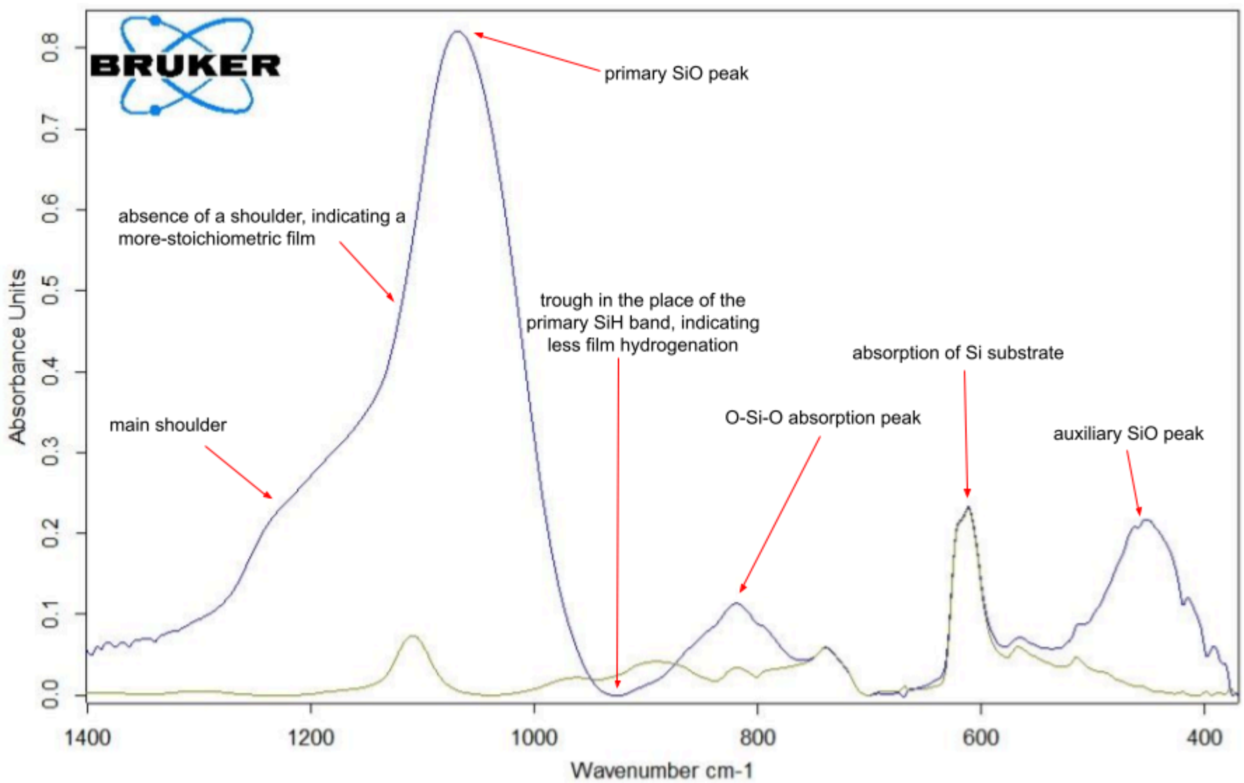
7.5.4 Notable observations for the Recipe 1007 spectrum:

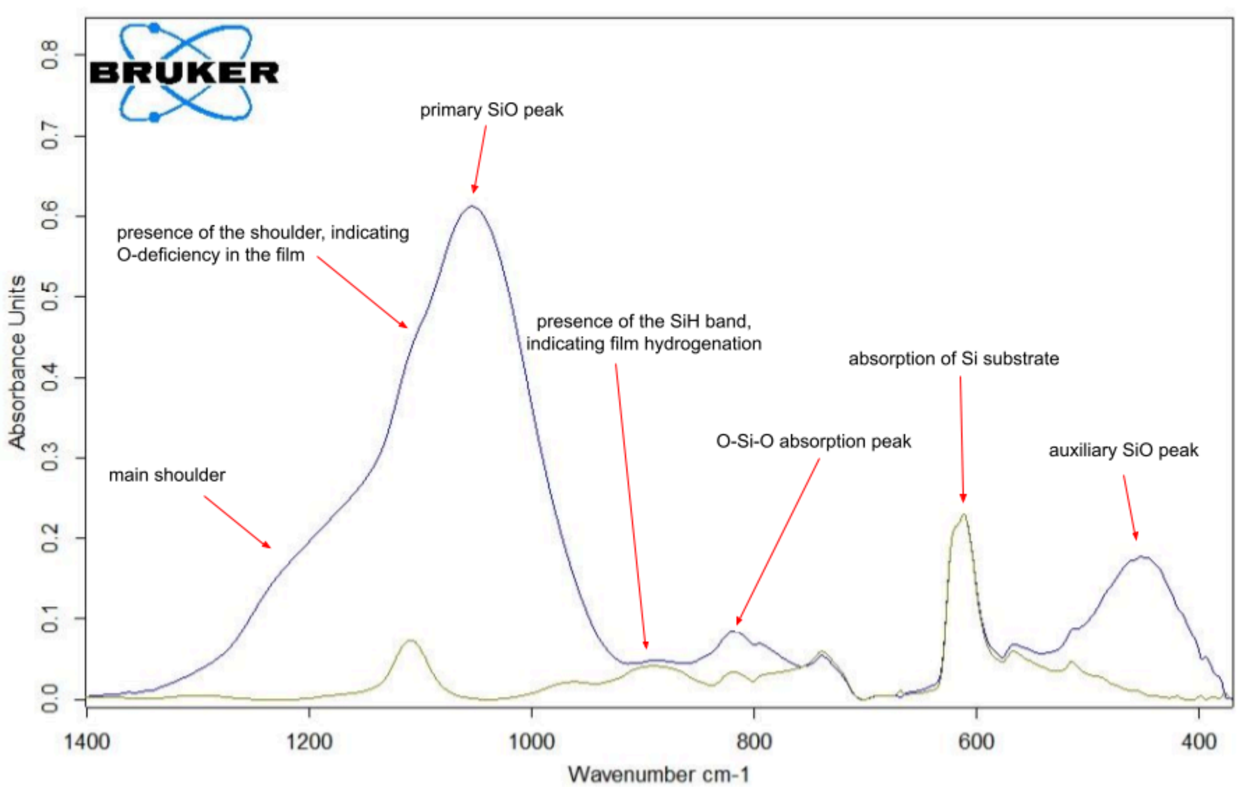
7.5.4.1 Broad FWHM, a peak intensity at a lower wavenumber and a pronounced shoulder at 1100 cm^{-1}, indicating oxygen deficiency

7.5.4.2 Strong absorption in the region of 890-950 cm^{-1}, indicating hydrogenation

7.5.4.3 Relatively weaker peaks at 820 and 452 cm^{-1}, indicating fewer tetrahedrally-bound SiOx sites and hinting at poor stoichiometry

7.6 FTIR spectra of films grown using Recipe 1007 and 1010, annotated to highlight the peaks mentioned in this report:





7.7 Summary of features in SiOx FTIR spectra: most relevant peaks show up in the range of 400-1400 cm^{-1}

Position	Type	Origin	Indicates
1075 cm^{-1}	Peak	Si—O stretch	Overall film quality
1100 cm^{-1}	Shoulder	H_2Si—O vibrational modes	Oxygen deficiency
1100-1200 cm^{-1}	Shoulder	—	—
890-950 cm^{-1}	Band	Si—H vibrational modes	Film hydrogenation
800-870 cm^{-1}	Band	Si—H vibrational modes	—
820 cm^{-1}	Peak	O—Si—O bending modes	Film stoichiometry
611 cm^{-1}	Peak	Si substrate absorption	—
450 cm^{-1}	Band	O—Si—O rocking modes	—
3650 & 3400 cm^{-1}	Peak	SiO—H stretch	Water contamination
2260 cm-1:	Peak	Si—H stretch in H_2O-contaminated films	Water contamination
3350 cm-1:	Peak	H—Si—OH and H_2O vibrational modes	Water contamination
1620 cm^{-1}	Peak	O—H bending mode of H_2O	Water contamination

8.0 ***Troubleshooting Guidelines***

8.1 Always make sure that you are using the correct N_2O/SiH_4 ratio: the N_2O/SiH_4 values we give in this manual represent the ratio of flow of N_2O to the flow of *pure* SiH_4, NOT the ratio of N_2O to the total flow of 10% SiH_4 in Ar

8.2 Combinations of low pressure and low power at high SiH_4 flowrates can result in high non-uniformities and failures in deposition

8.3 See the oxfordpecvd4 equipment manual for more troubleshooting guidelines

9.0 Appendices

9.1 Photos of a selection of SiO_x wafers, selected to highlight how non-uniformity appears to the unaided eye

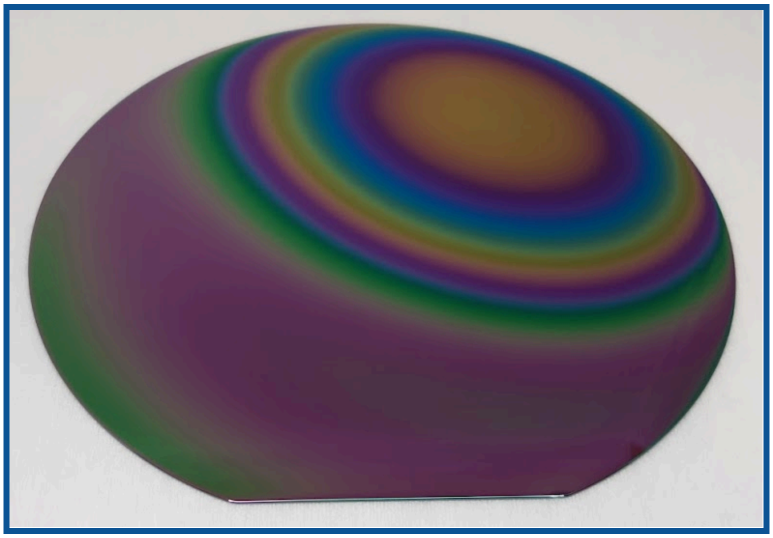


Figure 1: a wafer with a high amount of non-uniformity (39%)

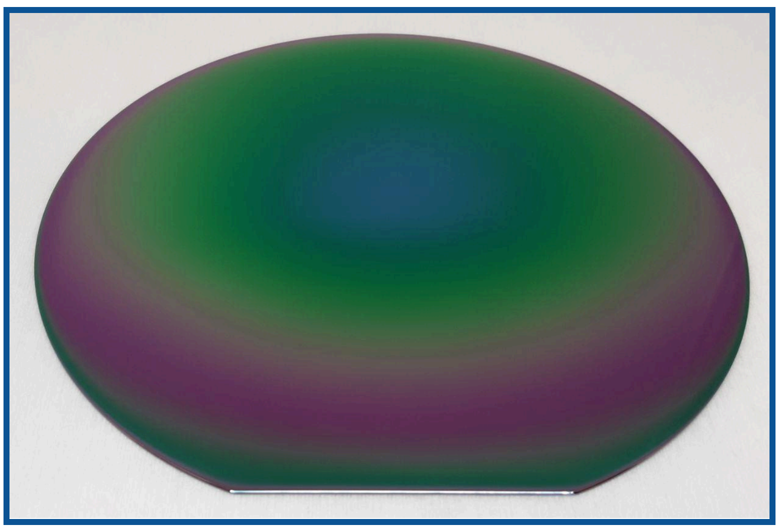


Figure 2: a wafer with a moderate amount of non-uniformity (5.4%)

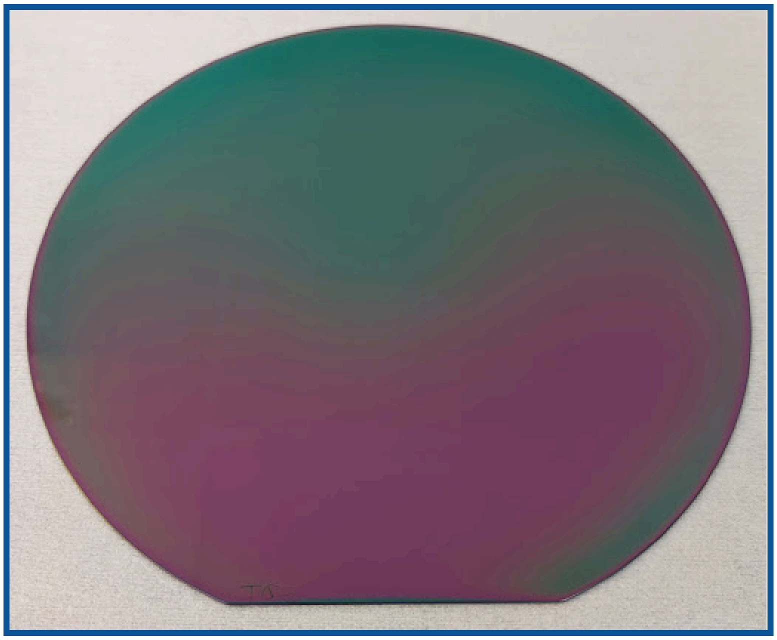


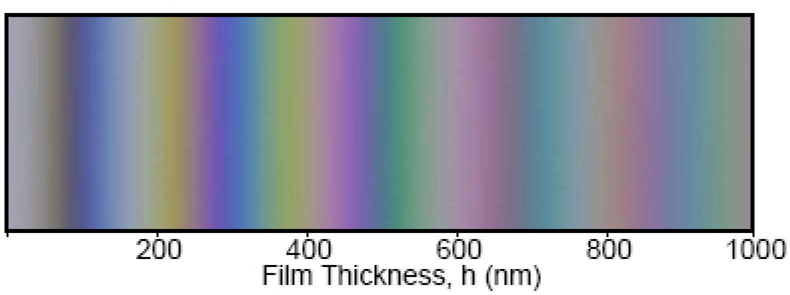
Figure 3: a wafer created using CH4 - STD - SiOx Recipe 1010. This wafer has a low non-uniformity (2.5%). While the wafer might appear to have a thickness gradient between the top and the bottom, this is simply due to the high angle of incidence of the camera taking the photo

9.2 Figures 2 through 11 show FTIR spectra for a SiOx film generated with each standard recipe for 5 minutes

9.2.1 The blue line shows the absorbance of the SiOx film on the Si wafer; the gold line shows the absorbance of a bare Si wafer from the same lot as the given wafer

9.2.2 The region above 1400 cm^{-1} showed no significant absorption peaks for any of the SiOx films and is therefore not shown on these spectra

9.3 Oxide film thickness chart for assessing film thickness with the unaided eye, from: https://opg.optica.org/oe/fulltext.cfm?uri=oe-12-7-1464&id=79472



9.4 Photos of FTIR spectra for SiOx films:

9.4.1 Blue = SiOx film on the Si wafer. Yellow = bare Si wafer

9.4.2 Each spectrum was generated by using the concave rubber band baseline correction with 10 iterations on each spectrum.

9.4.3 Each PECVD spectrum is listed with the FWHM of its main peak and the integrated area of the 890-950 cm^{-1} band using integration method “A” in the Bruker FTIR software

9.4.4 Also note that each FTIR spectrum (with the exception of figure 15 for the 1000 nm thermal oxide) has the same axes scaling so that the reader may readily compare them

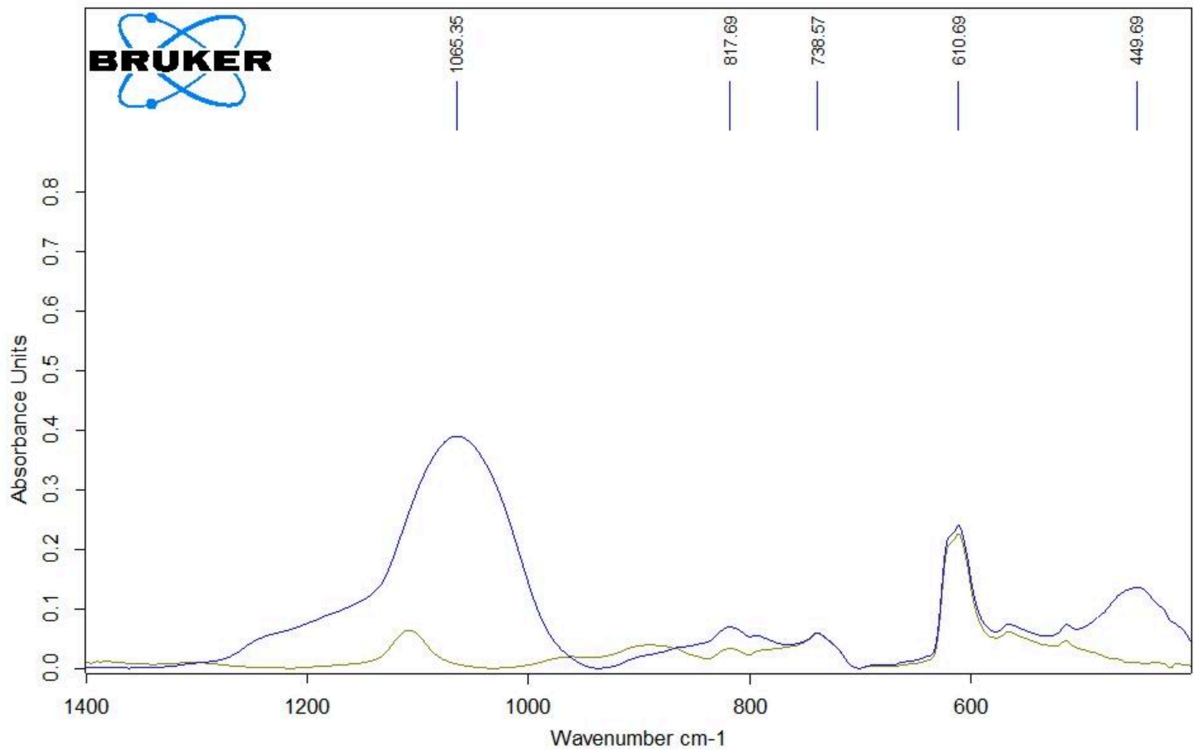


Figure 4: 429 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1001.
Peak FWHM = 112.1, peak intensity = 0.390 A.U.

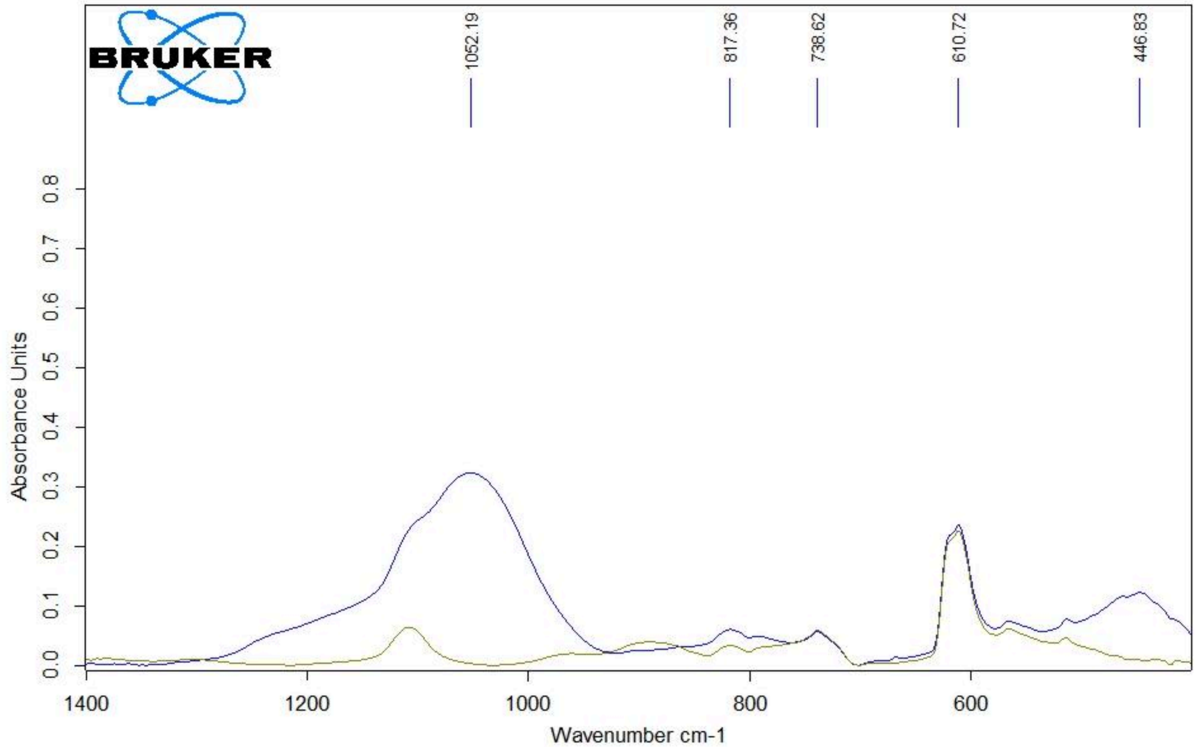


Figure 5: 438 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1002.
Peak FWHM = 131.1, peak intensity = 0.323 A.U.

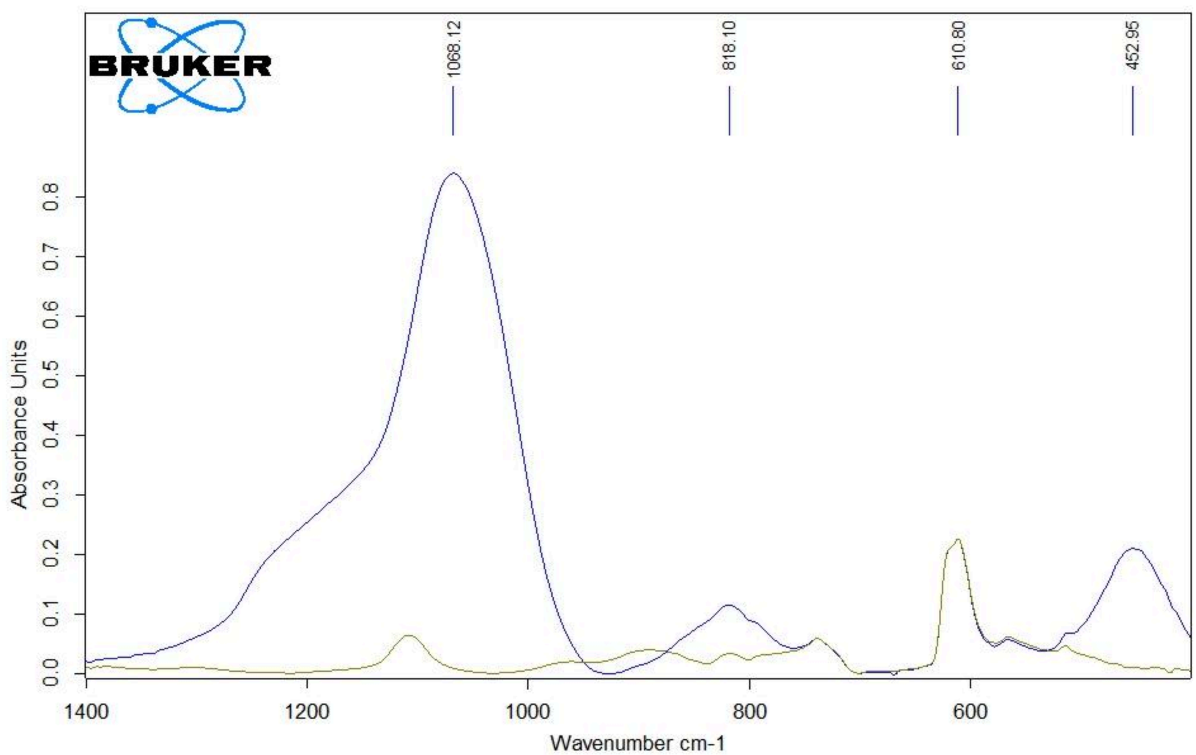


Figure 6: 873 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1004.
Peak FWHM = 118.8, peak intensity = 0.840 A.U.

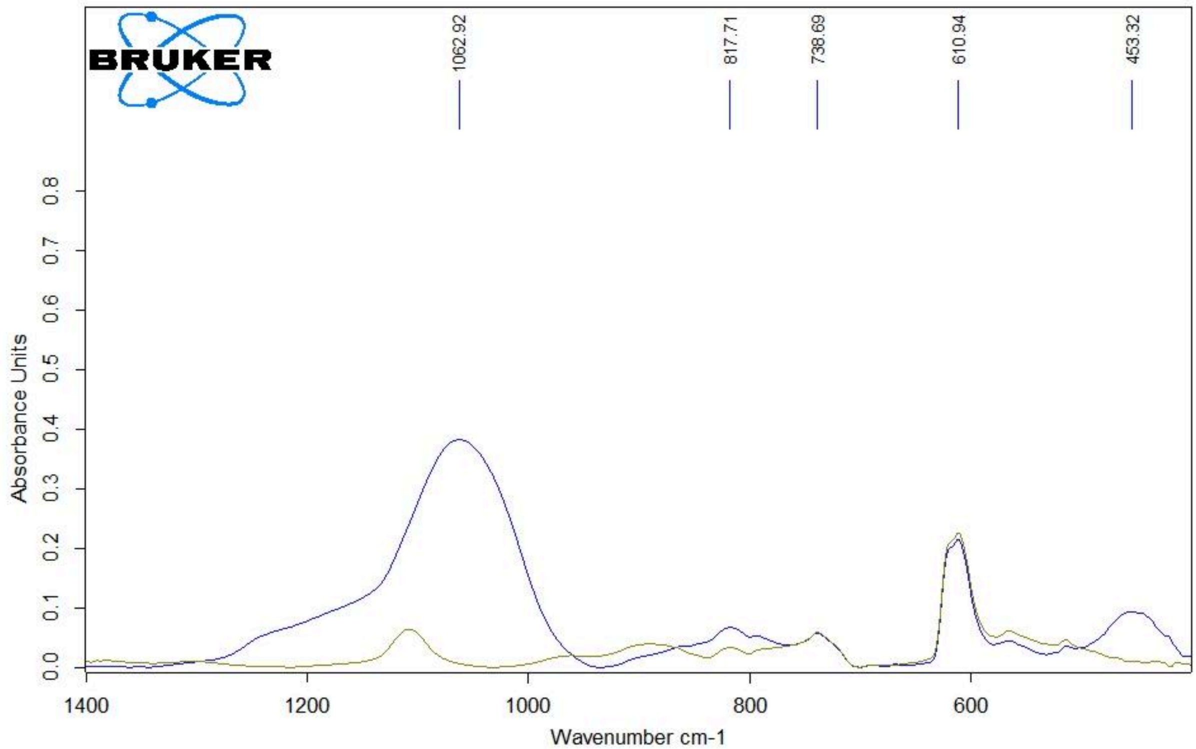


Figure 7: 441 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1005.
Peak FWHM = 112.7, peak intensity = 0.382

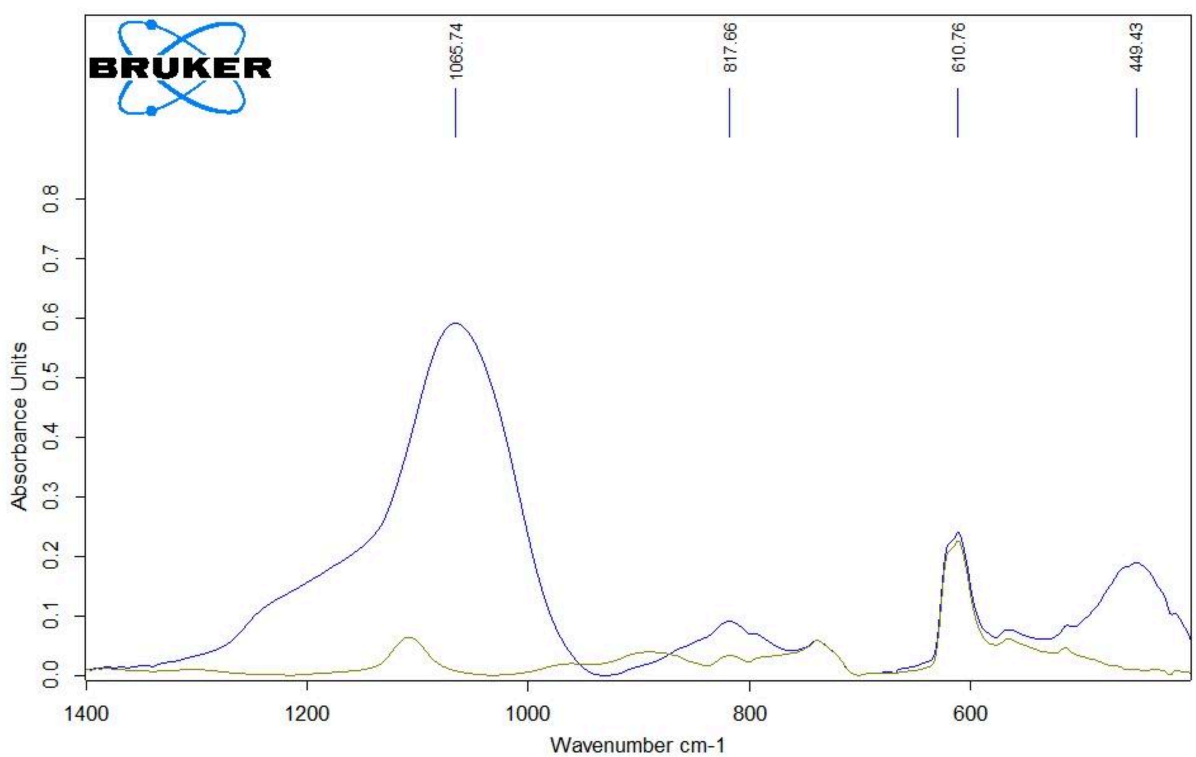


Figure 8: 656 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1006.
Peak FWHM = 116.1, peak intensity = 0.592

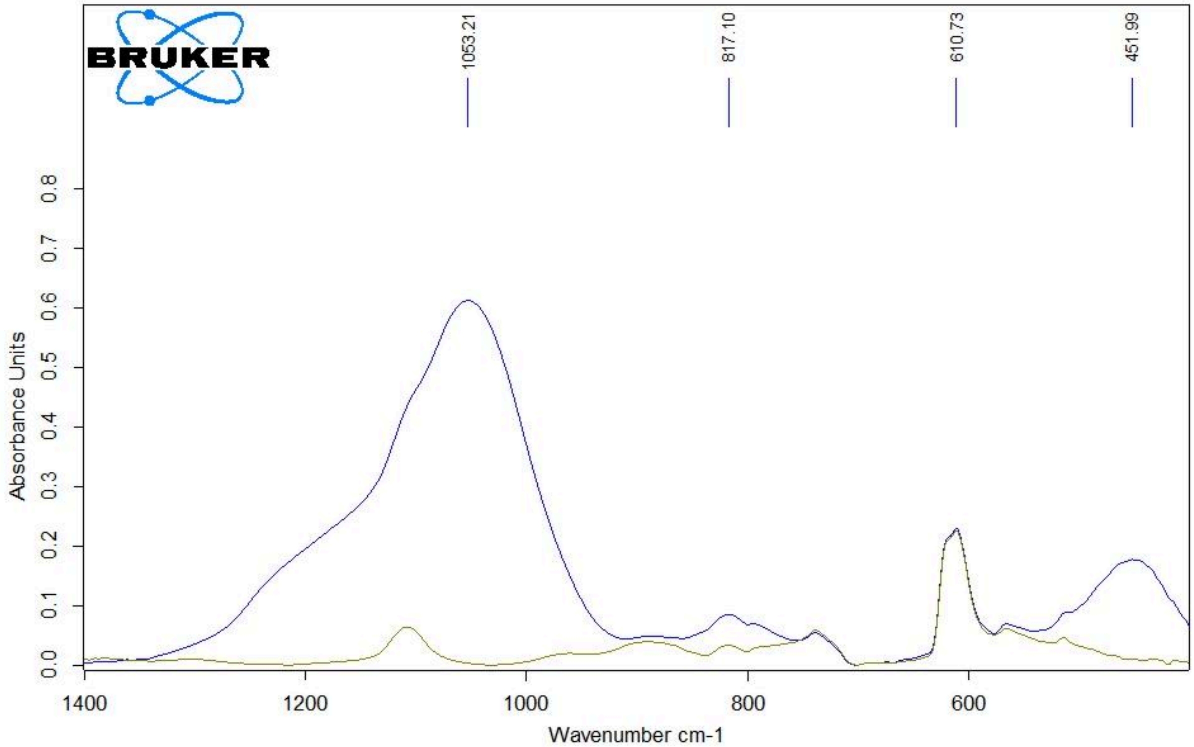


Figure 9: 844 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1007.
Peak FWHM = 145.0, peak intensity = 0.612

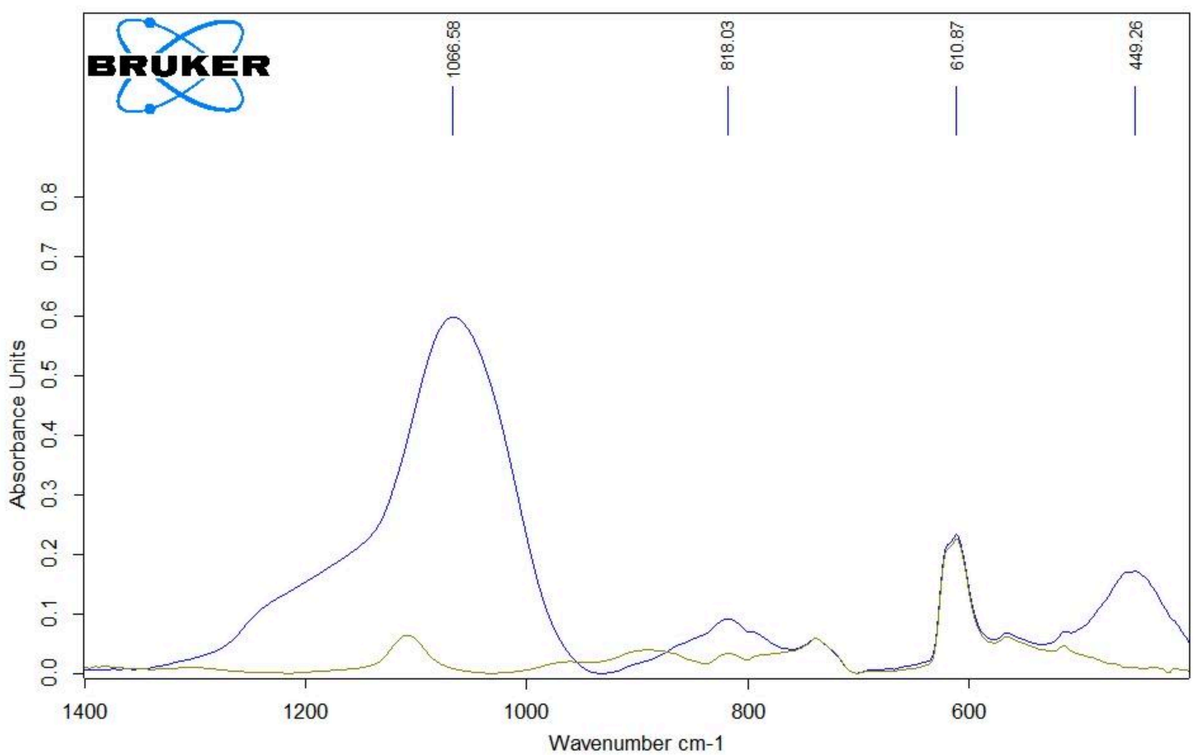


Figure 10: 658 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1008.
Peak FWHM = 114.5, peak intensity = 0.598

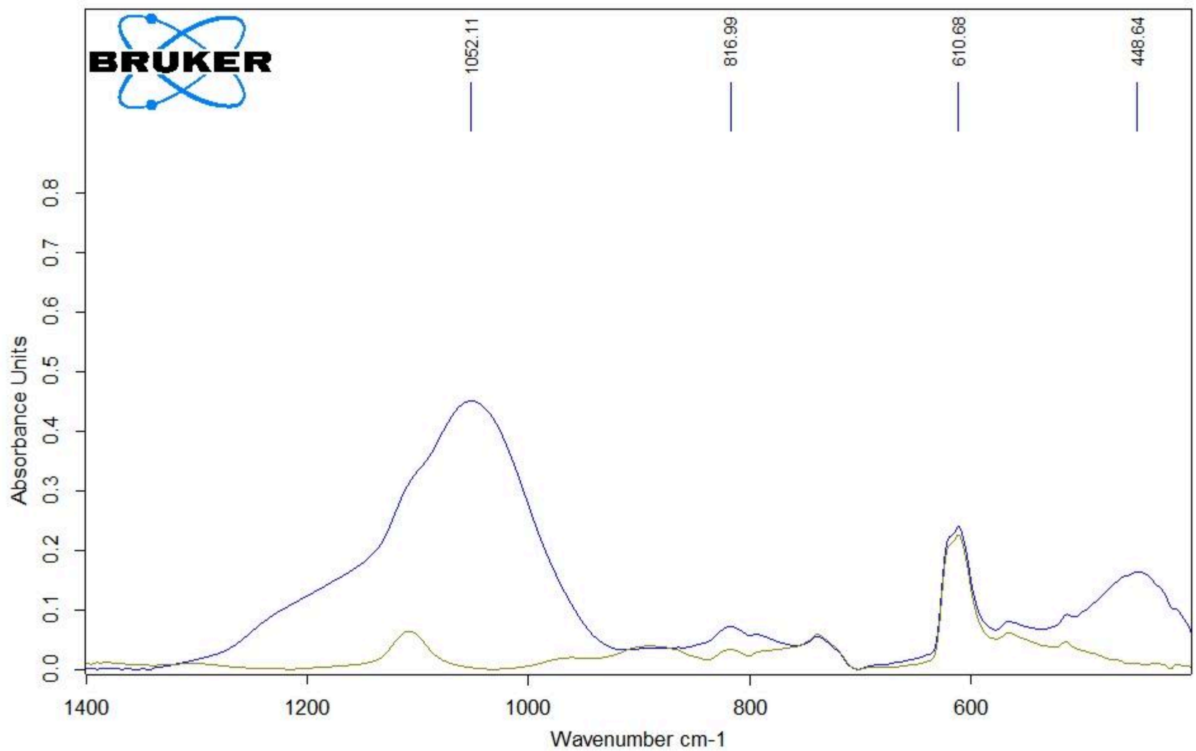


Figure 11: 638 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1009.
Peak FWHM = 138.8, peak intensity = 0.451

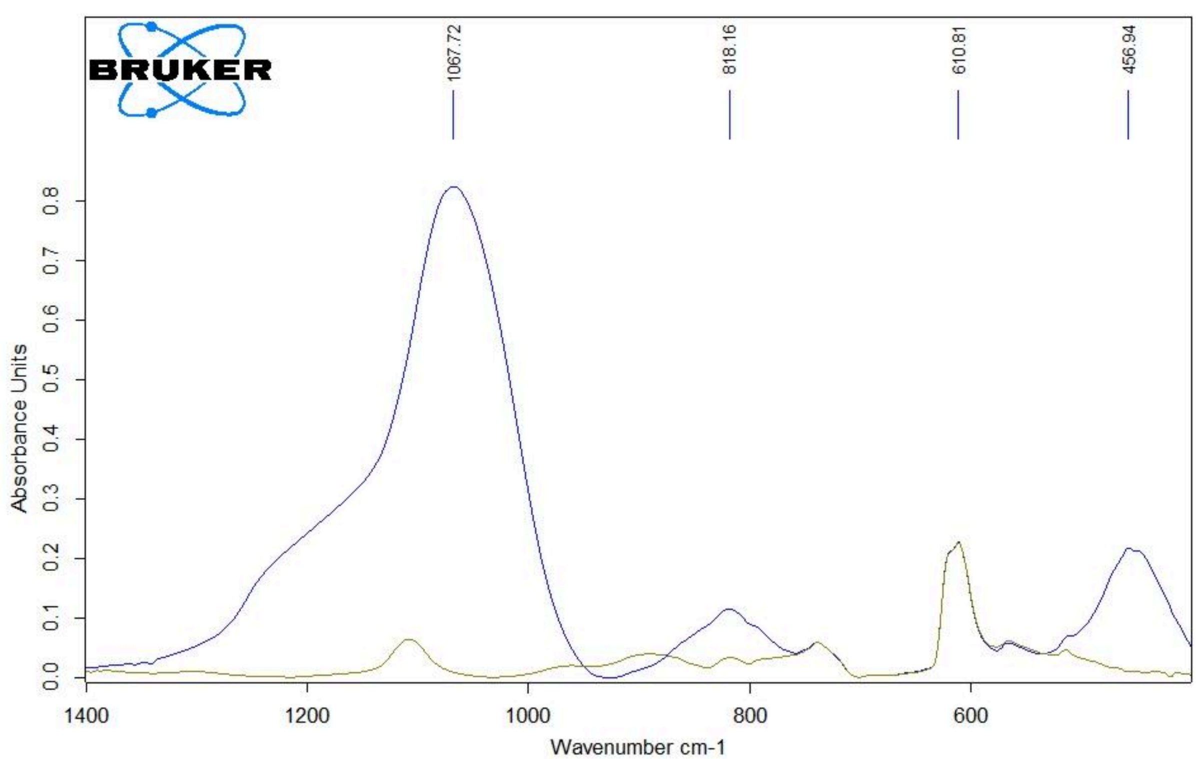


Figure 12: 868 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1010.
Peak FWHM = 118.7, peak intensity = 0.825

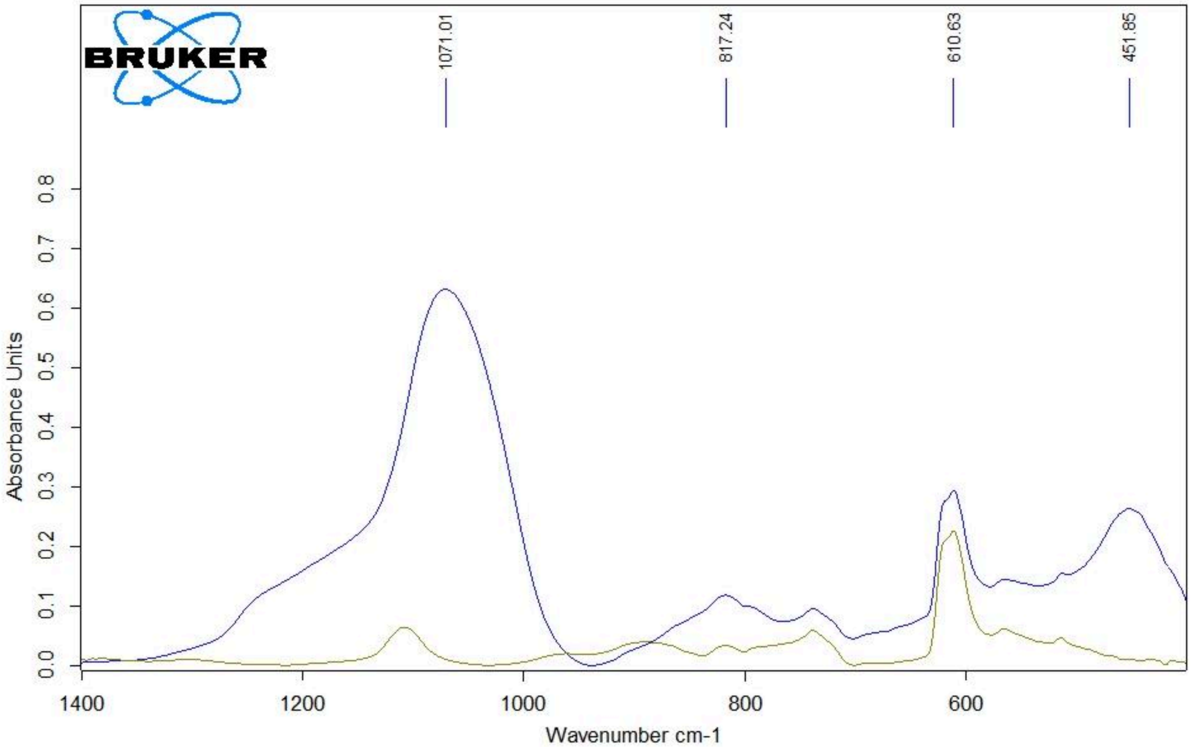


Figure 13: 658 nm-thick SiOx film grown using CH4 - STD - SiOx Recipe 1101.
Peak FWHM = 109.0, peak intensity = 0.632

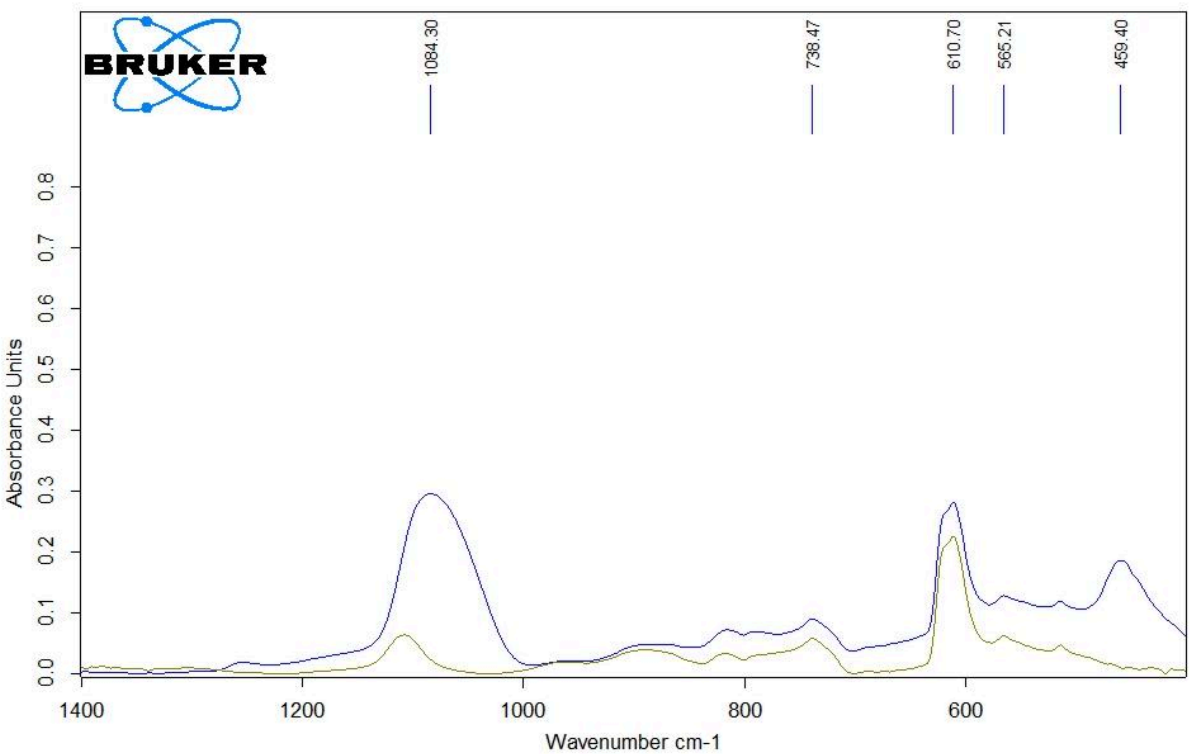


Figure 14: 100 nm-thick thermal SiOx film grown in Tystar 5.
Peak FWHM = 75.5, peak intensity = 0.296

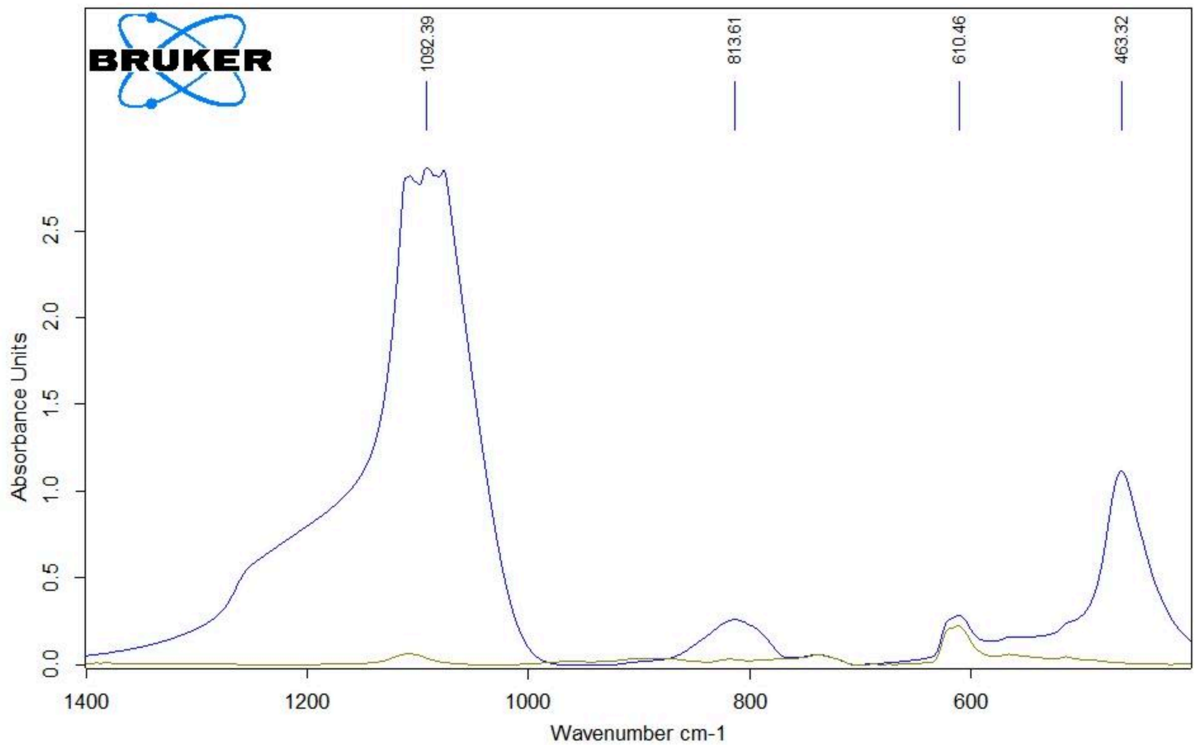


Figure 15: 1000 nm-thick thermal SiOx film grown in Tystar 5.
Peak FWHM = 87.5, peak intensity = 2.864 (saturated detector)

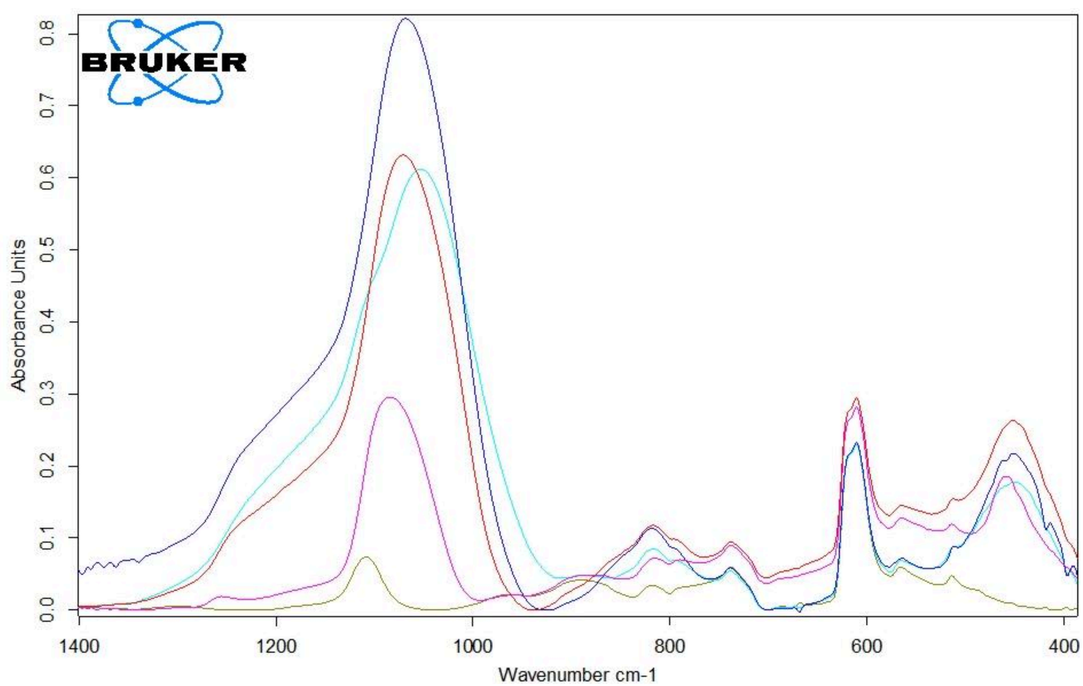


Figure 16: FTIR spectra of various SiOx films shown on the same plot. Blue = 876 nm oxfordpecvd4 recipe 1010, red = 658 nm oxfordpecvd4 recipe 1101, cyan = 844 nm oxfordpecvd4 recipe 1007, pink = 100 nm Tystar5 wet oxide, yellow = bare Si wafer