FTIR In Situ Depth Monitoring System

1.0 Title

FTIR *In Situ* Depth Monitoring System for STS

2.0 Purpose

The FTIR system at STS is a unique and powerful instrument that is capable of measuring the precise depth of micro features *during* a DRIE process. 2-micron trenches can be measured accurately up to 50 microns deep. The tool is likewise capable of measuring the thicknesses of multiple, thick film stacks that would otherwise be opaque to visible light.

3.0 Scope

When light reflects from a patterned and etched feature, interference occurs between those wavefronts returning from the top and the bottom of the feature. The resulting interference pattern contains information about the etch depth, the masking layer, and any other subsequent buried layers of material (e.g. an SOI wafer). The FTIR system at STS uses an infrared laser to make measurements and subsequently analyze based upon this principle. Results are typically very accurate.

4.0 Applicable Documents

Revision History

4.1 *Real-Time Etch-Depth Measurements of MEMS Devices,* Journal of Microelectromechanical Systems, Vol. 11, No. 2, April 2002. Sylvie Bosch-Charpenay et al.

4.2 *FTIR BSAC IAB poster,* M. Wasilik, N. Chen

5.0 Definitions & Process Terminology

5.1 FTIR: Fourier Transform Infra Red

5.2 Base Plate Swivel: the base that the FTIR system rests upon. The swivel allows the base plate to move out of the way when access to the inside of the chamber is necessary. The default position of the base plate is **ON** the STS chamber lid.

5.3 SOI: silicon on oxide

5.4 SNR: Signal to Noise Ratio

6.0 Safety

7.0 Statistical/Process Data

For SOI and regular silicon wafers, the optimum feature size has been found previously to be 20um line and space arrays. Depths up to 70 microns have been measured accurately. Please see link to FTIR poster for more information concerning the limits of measurable etch depths. For potential measurement applications not discussed in this document, please consult with Matthew Wasilik. Ideas for the development of new recipes are encouraged.

8.0 Available Processes, Gases, and Process Notes

8.1 Scalar Processor

This processor is a full model-based analyzer and performs non-linear least-square fits of parameters in order to match the measured reflectance data. This processor is powerful, yet relatively slow, and is best used with static measurements of complex films (e.g. multiple film stacks, silicon germanium, etc.).

8.2 Freq2thk Processor

Freq2thk is the preferred processor to use when measuring dynamic *in situ* depths during DRIE processes. The “Freq2thk” post-processor converts frequency peaks into film thicknesses for an etched (patterned) multi-layer film stack. It uses the output from the “frequency” post-processor (i.e., the positions of multiple “frequency” peaks in the measured spectrum, which are related to the optical path differences between the layers of a film stack, ultimately related to the thickness of each film). This processor fits the thicknesses of all the defined films such that the modeled frequency peaks match the position of all the experimental peaks. Note that the peaks’ amplitude is not fitted (which would otherwise be equivalent to a full model-based analysis). This processor is *fast*, and can be used when full model-based analysis is difficult (possibly due to scattering effects) or too slow. Recipes that use this processor include **ETCH ON SOI FREQ2THK** and **ETCH ON SI FREQ2THK**.

9.0 Equipment Operation

9.1 Instrument Qualification

9.1.1 Load a bare, clean, silicon p-type test wafer into the STS chamber. It is best to use the same reference wafer over and over, as long as it remains clean! No STS processes should be running during this step.

9.1.2 Ensure that the MEMS software is not running. Double click **TestSuite** to open the qualification software.

9.1.3 Select **Check-Out**, then **AutoRun**. The SNR (Signal to Noise Ratio) should read ~85 or higher. An excellent SNR will be 130. A higher SNR will allow for a deeper and more accurate measurement. If the SNR is not high enough to meet the standards of the process, a beam calibration must be performed. Request that staff perform this procedure, if necessary.

9.1.4 Exit **TestSuite** after measuring the SNR.

9.2 Measure Silicon Reference

A reference spectrum is required before each new run is started. It is also recommended that a new reference scan be taken as often as possible (every hour or so for example). Furthermore, a new silicon reference must be taken if any settings such as sample resolution or wavenumber range is changed in the recipe. Reference scans are always taken with a bare, clean, silicon p-type test wafer.

9.2.1 Load into STS a bare clean silicon wafer (or just use reference wafer already loaded from SNR qualification in previous section). No processes should be running when the reference scan is taken.

9.2.2 Ensure that **TestSuite** has been closed. Double click the **MEMS** software icon to open the FTIR in situ depth monitoring software.

9.2.3 Select REFERENCE. Then select **SCAN** followed by **OK**. The new single beam (bell-shape curve) will show up on the screen.

9.3 Signal Strength

The following items affect signal strength:

9.3.1 Displaced measurement spot (see above).

9.3.2 When wafers pieces or chips are placed on top of a carrier wafer, the signal is a bit lower because of the difference in height. There is ~5% less reflectance for 1 mm difference in height.

9.3.3 Scattering in trenches will reduce signal strength. This is especially important to be aware of for full model-based analysis recipes, where the entire spectrum is fitted.

9.3.4 If trenches (lines and spaces) are located within the incidence plane, the reflected signal will be higher than if the trenches are perpendicular. This is because there is less scattering of the light, and more light can reach the detector.

9.4 Locate Measurement Spot

9.4.1 Load wafer to be measured into STS chamber.

9.4.2 Ensure that the **low light** setting is selected such that features can be made out on the wafer.

9.4.3 The IR measurement spot should show as a faint dot on the wafer (see Figure 2). Ideally, the features to be measured should be located in the region on the wafer shown in Figure 1. The diameter of the laser dot is roughly 1000 um.

9.4.4 Use the **x** and **y** stage micrometers to align the measurement spot such that it falls upon the intended features on the wafer. The spot should cover half of the features being measured and half of the area that will be unetched. The software uses the unetched portion of the wafer as a reference. Note that the SNR will drop off readily as the **y** axis position is changed. The **x** axis position however has a larger range for good SNR. Alternatively, one may also manually adjust the baseplate to position the spot with less effect on the SNR. Ask staff for tips on spot positioning while maintaining good SNR.

9.4.5 For best results, it is recommended that the User reload reference wafer to determine SNR after positioning measurement spot on the actual wafer. Repositioning the spot to procure a better SNR will yield a stronger output signal, and thus a more accurate measurement.

9.5 Measurement Setup Conditions

9.5.1 Ensure that the **MEMS** software is running (if not make sure **TestSuite** is NOT running, and double click **MEMS** software icon).

9.5.2 Select **SETUP** on the main screen.

9.5.3 Select the desired analysis recipe. All parameters extracted with the selected recipe are shown on the parameters list. The resolution selected should typically be *8cm-1 double sided*. The Low Limit of the spectrum should typically be selected as *1200.00 cm-1*, and the High Limit should typically be *5000 cm-1*. If any of these settings are changed, a new reference needs to be taken.

9.6 Making a Measurement with the FTIR Instrument

9.6.1 Before the plasma is struck in the STS ICP chamber, Select START from the main screen. The software will begin taking measurements, and the real time results will be shown in the respective windows and tables on the main screen.

9.6.2 When the plasma ignites, select the **bright light** option such that features on the wafer may be viewed.

9.6.3 Each run is saved in C:\OLT\DATA, and in a directory named "YYYY-MM-DD HHSS *run name*". Each measurement point has its own file (*.lab). An ASCII file contains all the results. A *.dat file contains the results for subsequently retrieving the data within the software.

9.6.4 While measurements are being taken (i.e., a run is in progress), it is possible that the recipe used has starting parameters that are too far away from the actual values, and the model will not be able to converge. The option: **Reset Model Parameters** allows the user to change values that are used in the modeling while a run is in progress. The Reset does not affect the actual recipe, which will remain the same. It only affects the model loaded in memory after the recipe was selected.

9.7 Check Model Fit During Run

It is important to check the fit during the run, as the model may not always converge.

When using a recipe that uses full model-based analysis (i.e., where a film stack has been defined and parameters are fitted), the frequency of the modeled fringes must match that of the experimental fringes. The amplitude of the fringes can be off without having an effect of the parameters, because scattering in the trenches is usually not very well predicted. See Figure 3.

When using a recipe with the “freq2thk” model, the report window must show that the position of the predicted and experimental peaks are as close as possible, and that there is no extra peak that is not matched. Refer to Figure 4.

10.0 Troubleshooting

11.0 Figures & Schematics

Recipe Name	Information
Bare silicon scalar	► Bare, doped silicon wafer. Extracts doping level. Wafer needs to have a rough backside.
Bare SOI scalar	► Measures bare SOI wafer (no resist).
Etch on Si combined	► Analysis time ~10 s ► The results will be reliable only if the fitted fringes follow well the measured fringes (even if the fringe height is not, as this is affected by scattering), and the peaks in the Freq2thk window are well matched.
Etch on Si freq2thk	► Analysis time < 1 s ► The results will be reliable only if the peaks in the Freq2thk window are well matched.
Resist on SOI combined	► Analysis time ~10 s (full model-based analysis) ► Resist thickness = fixed (recommended) = 1.3 mic ► Oxide thickness = fixed (recommended) = 1 mic ► Silicon range = 52 mic ± 10 mic (see optimizer settings) ► The results will be reliable only if the fitted fringes follow well the measured fringes (even if the fringe height is not).
Resist on Si scalar	► Analysis time few seconds ► The results will be reliable only if the fitted fringes follow well the measured fringes.
Resist on SOI scalar	► Analysis time few seconds ► The results will be reliable only if the fitted fringes follow well the measured fringes.
Etch on SOI freq2thk	► Analysis time <1s ► Approximate silicon thickness = 52 mic ► Approximate etch depth to be entered by user using RESET MODEL PARAMETERS
Epi p on p+ scalar	► Analysis time few sec (uses model based analysis) ► Small fringes (noise will appear comparatively larger)

Table 1

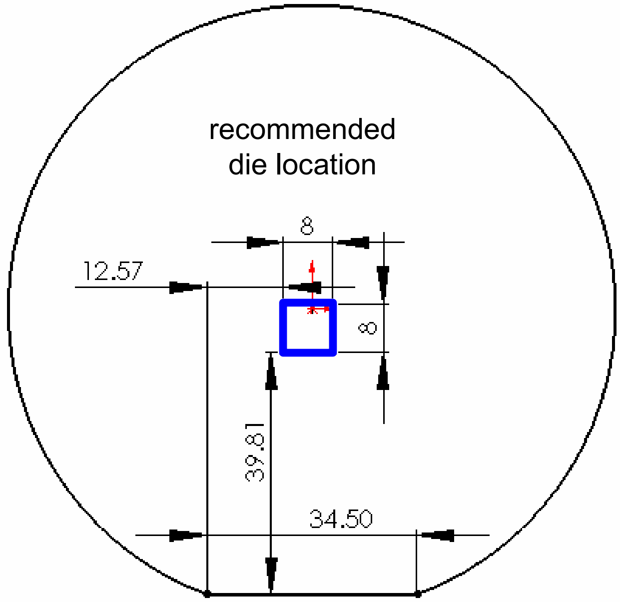


Figure 1

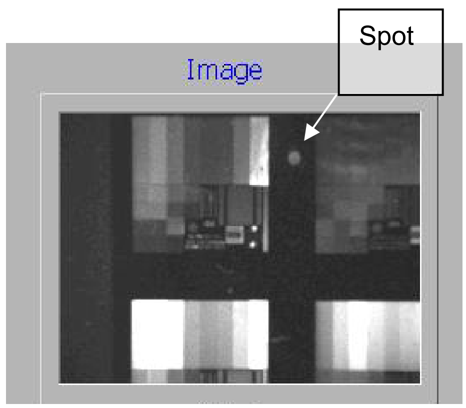


Figure 2

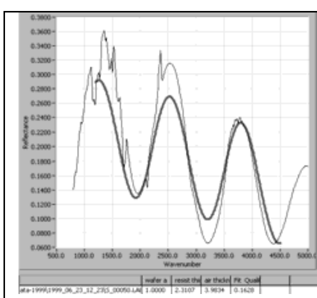
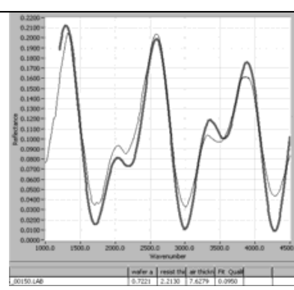
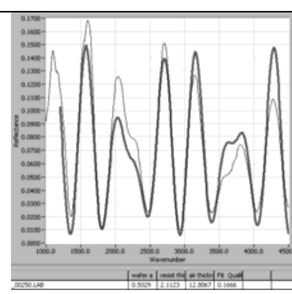
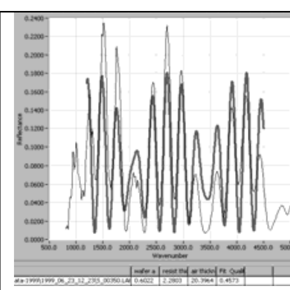
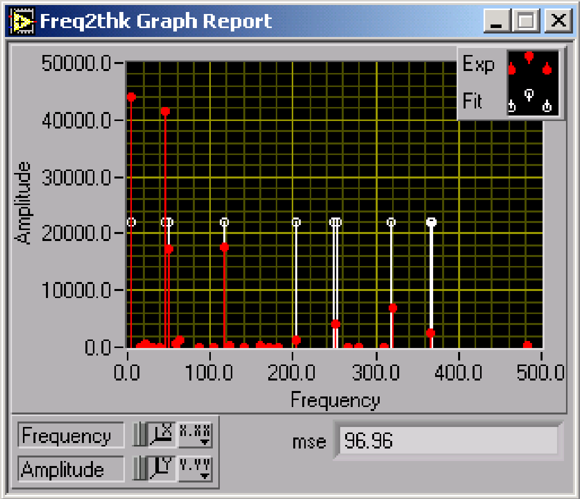
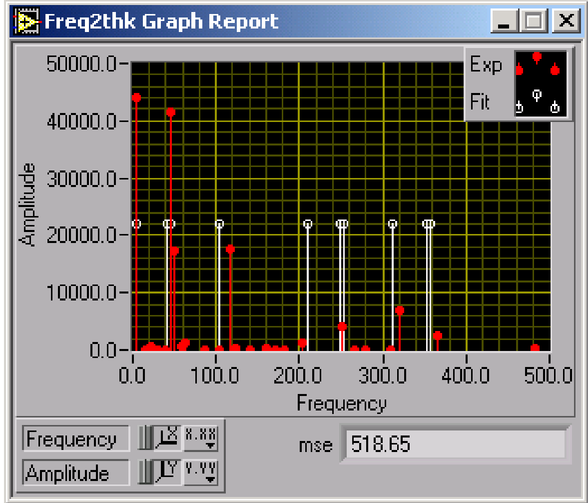
			
Resist ~2.3 mic Etch ~4 mic	Resist ~2.2 mic Etch ~7.6 mic	Resist ~2.1 mic Etch ~12.8 mic	Resist ~2.3 mic Etch ~20.4 mic

Figure 3



Good fit, reliable results for a 24 mic etch on SOI.



Poor fit, not fully reliable results for a 24 mic etch on SOI.

Figure 4