FFT and Thickness Measurement of Thin Interface Layers

Introduction.

Spectroscopic reflectance of the thick films is a periodic function of the wavelength due to constructive/destructive interference, that are frequently called “fringes”. This makes FFT an effective method to determine the thickness of the films. However, the accuracy of the measurement depends on the film thickness and the wavelength range. Typically, one needs few fringes within the measurement range to have a good accuracy. It is theoretically possible to measure the thickness of the thin film (as low as 200nm in visible range) but the accuracy will be quite bad...

At the same time, there are many cases when measurement sample has a thick layer and a thin layer. For example, Glass/ 400nm ITO / 5000nm PR (photoresist). When FFT is used in this case, one can see 3 peaks: Layer 1 peak, Layer 2 peak and a L1+L2 (total thickness) peak. This gives a way to determine L1 (thin film) thickness as a difference between a total thickness and L2 layer thickness (Fig. 1). This indirect method of a “differential thickness” gives a much more accurate result than a direct measurement.

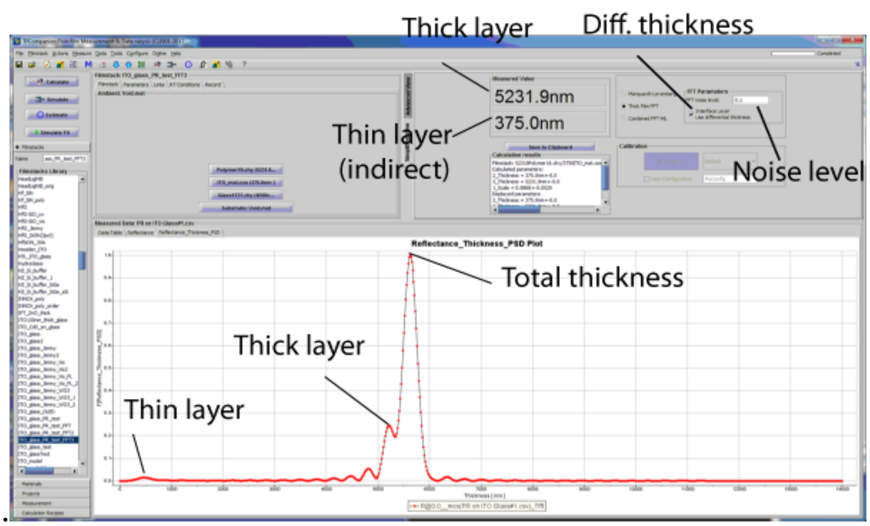

Fig. 1 Measurement using differential thickness

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Using differential measurement is quite simple, but requires basic understanding of the process to setup conditions correctly:

1. “Use differential thickness” check box should be enabled
2. “FFT Noise level” should be setup to reject aliases/noise and weak peak. In our example (Fig. 1), we want to allow only peak 2 (Thick layer) and peak 3 (total thickness). Other features should be below noise level i.e. ignored. In this example, noise level is set to 0.1 (default is 0.04)
3. Measured thicknesses should be properly constrained i.e. min/max thickness is set (Fig. 2).
   Constraints are used for two important purposes:
   a). Software uses constraints to assign measured thickness to a correct layer.
   b). Max constraint is used to determine estimated thickest layer. The dispersion of this layer is automatically used for initial FFT basis.

4. For differential measurement to work - only two layer thicknesses should be selected.

Filmstack Details

!	Layer	Material	Thickness	Min	Max	Solve
	3	Polymer16.chy	5231.9	1000.0	7000.0	☑
	2	ITO_mat.cos	375.0	0.0	500.0	☑
IC 500.0	1	Glass1737.chy	4E08	0.0	3.162E06	☐
	Substrate	Void.mat				

Fig. 2 Thicknesses of measured layers have constraints

I. How accurate is differential measurement

One can expect that the accuracy of the thickness determined using differential method is much higher as compared to direct measurement. Simply because the accuracy should increase with the thickness; and in differential method we are measuring thicker values. But how much better? Direct measurement of the thin film (Fig. 4) shows that the peak is very weak (we had to decrease noise level to 0.01) and broad. The measured thickness is 18nm (5%) higher as compared to differential measurement.

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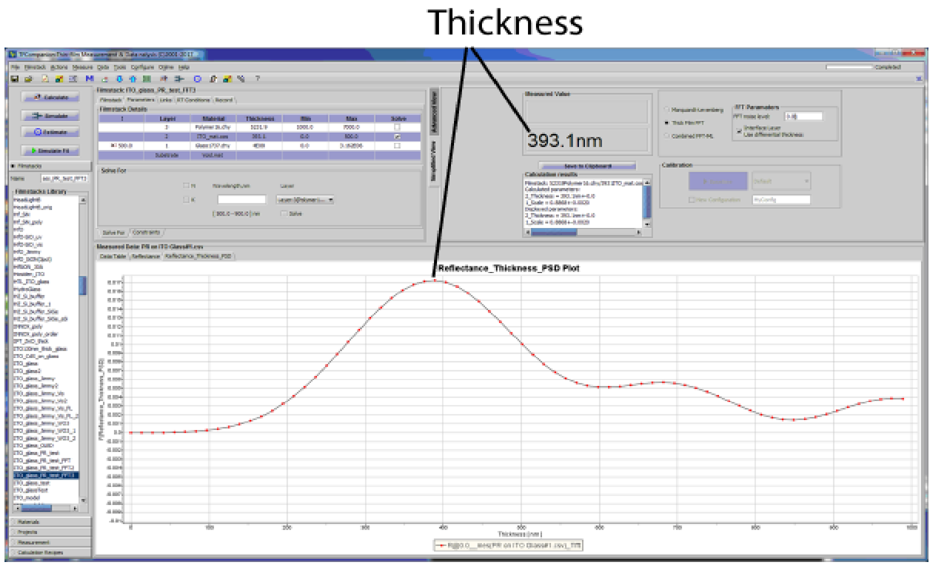

Fig. 3 Direct measurement of the “thin” film with FFT

To verify our measurement result, we can compare it with the result of direct curve fitting (Fig. 4) of this data. The results are closely matched (difference< 1%).

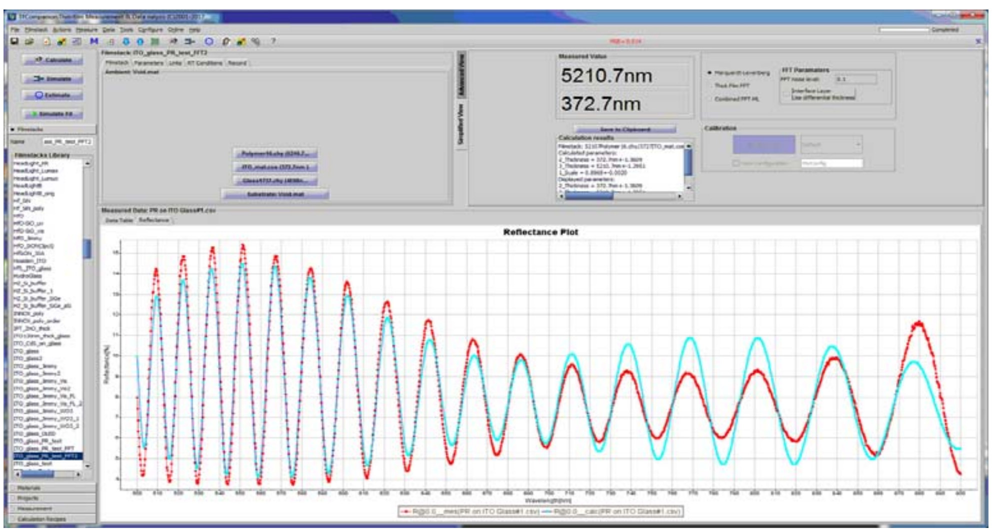

Fig. 4 Measurement results using direct curve fit.

The results are summarized in the Table 1, below.

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Measurement type	Curve fit	Differential	Direct
Thin layer thickness	372.7 nm	375 nm	393.1 nm

Table 1. Comparison of measurement results using different methods

II. Thickness constraints and how they work

We discussed earlier two main purposes of constraints:

1. *Help software to assign correct thickness to correct layer*
   This is demonstrated on Fig. 5 below. Left screenshot shows results when constraint is high (in this case 1000nm -7000nm). The result is that total thickness is assigned to the thick layer. The right screenshot shows the correct assignment due to constraint (1000-5600 nm). The software sort peaks by the strength and tries to assign the tallest peak first. This also shows the limitation of measuring thick film in the presence of the thin film- the constraint may need to be tight. It is better to use differential option in this case, even if thin film thickness is of no interest.

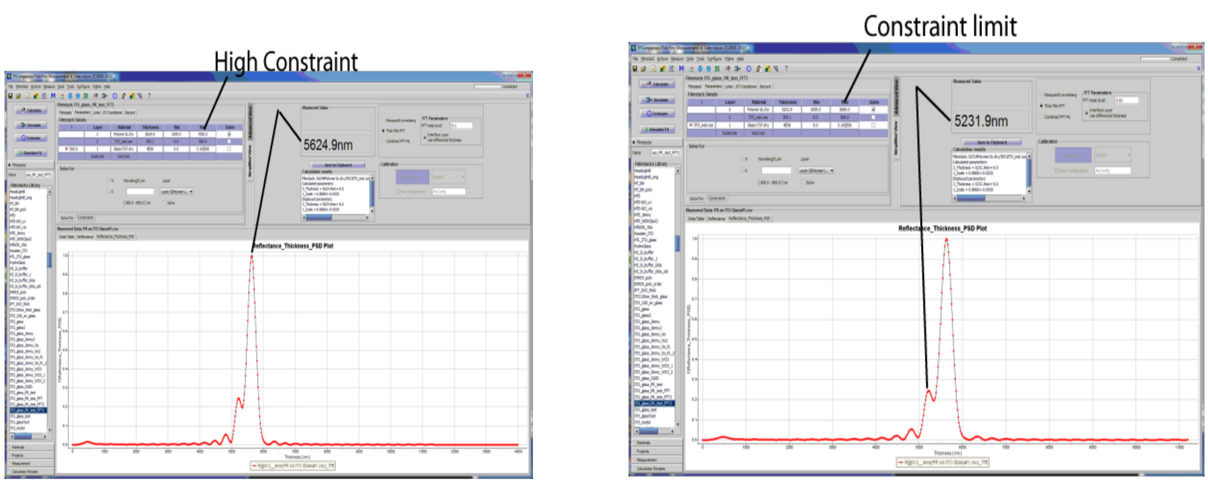

Fig. 5 The effect of constraint on thickness assignment

In this case, we measured one layer, so it demonstrated only correct thickness assignment. What about "correct layer" assignment? We see the example of this on Fig. 1. Software starts thickness assignment from the bottom of the filmstack. If there were no constraints – the bottom film would be assigned thicker value in this case. But it has constraint (0-500nm) and this leads to a correct assignment.

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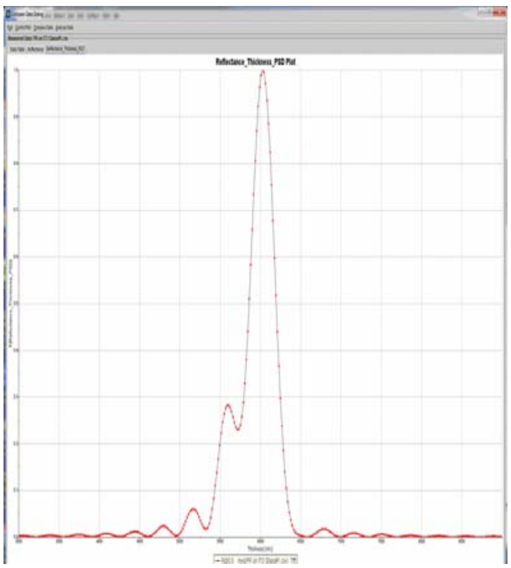
2. Max constraint is used to determine estimated thickest layer. The dispersion of this layer is automatically used for initial FFT basis

In order to determine thickness, measured data is re-scaled using dispersion of one of the layers. It is important to use the dispersion of the thicker layer for best results. Software selects the thickest layer best on maximum constraint value of the thickness. If constraints are not set or equal – the top layer is selected, on a theory that in most cases thick layer is on the top and interface is below. This is not always the case, as if the dispersion of layer is significantly different, as in our case, it maybe a problem(see Fig.5).



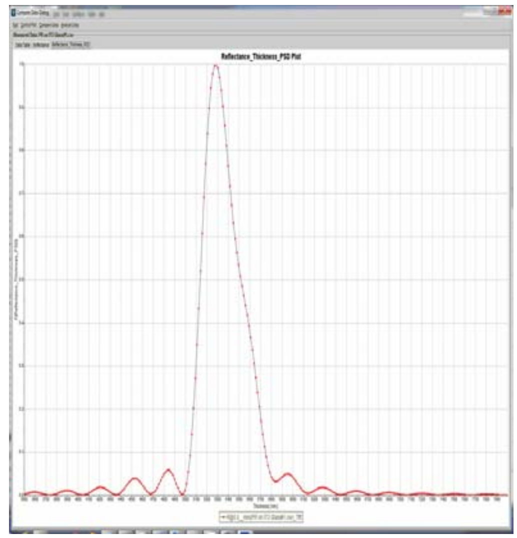


Fig. 6 FFT analysis of the same data using thick film dispersion (left) and thin film dispersion (right) as a basis. The results on Fig. 6 shows that using thin film dispersion (right) gives only one discernable peak.

Using FFT with differential thickness option expands application of FFT to many important applications (hardcoating, adhesives, LCD, etc.) there a thin interface and a thick coating layer need to be measured. It is a simple method; however, it is not well always understood. TFCompanion software includes robust implementation of differential option. It is most commonly used in MProbe Vis, MProbe VisHR and MProbeNIR systems measurement.