The Thin Film Evolution Revolution – Live Determination of the Physical Properties of a Thin Film During Deposition.

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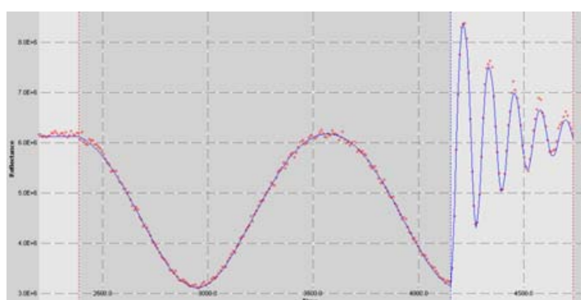
Introduction:

The ability to quantify the physical characteristics of a thin film such as a semiconductor layer during its evolution in an MOCVD, MBE or CVD chamber has been a long standing goal and has proved to be elusive. Various products exist that will allow some of the important properties such as temperature and wafer bow to be determined, but until now it has not been possible to quantify all of the key properties of temperature, growth rate, thickness, surface roughness and wafer bow. We have been working over the last three years to develop a new and highly advanced software package that enables these parameters to be determined on a second by second basis as the thin film is being deposited. The software, called R-Fit LIVE is now complete; it is capable of simultaneously quantifying data from up to 16 different wafers on a multi – wafer reactor, providing values for the growth rates, film thicknesses and surface roughness for each individual wafer. When used in conjunction with an emissivity corrected pyrometer and a wafer bow instrument, the full compliment of physical parameters is produced. It has already enabled pseudo – closed loop control on some reactor designs and has the potential to facilitate full closed – loop control on most makes or models of deposition plant.

Experimental:

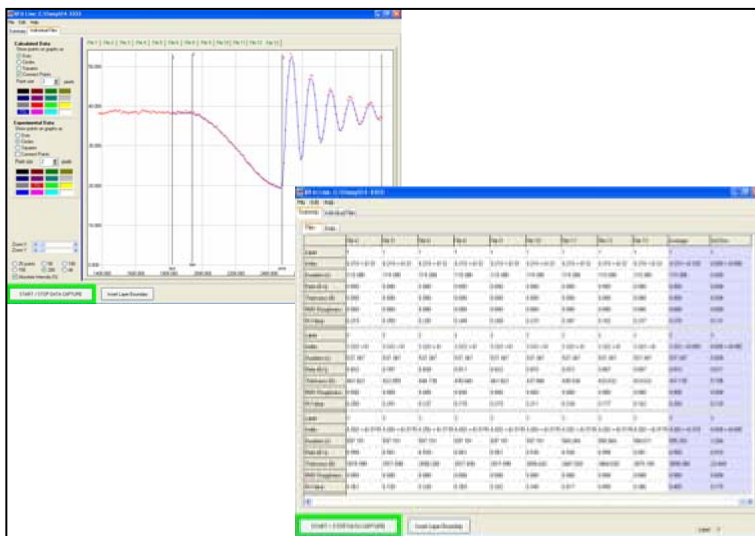
R-Fit LIVE relies on having access to good quality reflectance data during the thin film deposition process. The data must be smooth, of sufficient density (data points per second) and must be properly background corrected. We have used our own reflectometer for this work, the ***MiniEYE Standard***©. This monitor provides reflectivity data at 650nm and 980nm, it also provides emissivity corrected pyrometry at 980nm. The monitor is designed to record up to 16 times per rotation; the angles at which data is recorded are chosen by the operator. The structure we have analysed is a 845nm VCSEL grown on an AIXTRON 2600 G3 reactor at a production facility in the UK. The typical wafer configuration consists of 12 x 3" wafers and the growth temperature was 720ºC. The angles chosen for reflectance and temperature measurements we at the centre of each of the 12 wafers; one angular position was between two wafers and used as the background reading for reflectance. The remaining three angular positions were used to profile across one of the wafers thereby facilitating a real – time uniformity measurement. The susceptor rotation rate was typically seven r.p.m. A template for ***R-Fit LIVE*** is first generated by our post – growth analysis software; ***R-Fit v4.0***. This determines approximate parameters and ranges for ***R-Fit LIVE***; in this case we have chosen to keep the refractive index of the layers fixed at those determined in ***R-Fit v4.0***. ***R-Fit LIVE*** operates by receiving a TTL pulse from the reactor's CACE software to indicate the start / stop of the growth run and a separate TTL pulse at each layer boundary; this triggers to software to change fitting parameters. ***R-Fit LIVE*** curve fits each interferogram as a new data point is received and then it updates the fit and reports on the growth rate, film thickness and r.m.s. roughness. These data are further analysed to provide a statistical breakdown of the whole batch.

Results and Discussion:



Layer	Start t (s)	End t (s)	Index N	Index k	R (Å/s)	T (Å)	Fit
1	0	187.6	4.210	0.330	0.000	0	0.270
2	187.6	1953	3.321	0.000	0.788	1390	0.248
3	1953	2533	4.222	0.333	6.351	3683	0.673

1. *R-Fit v4.0 analysis.*



2. *R-Fit LIVE Output.*

1. An interferogram recorded at 650nm from GaAs on AlAs on a GaAs (100) substrate grown at 720ºC. The data have been analysed in R-Fit v.4.0. From the analysis we see that the AlAs layer is 1,390Å thick and the subsequent GaAs layer is 3,683Å. The thicknesses measured with a Biorad rpm 4000 were 1400Å and 3705Å in excellent agreement with the R-Fit v4.0 analysis. The determined refractive index values for the AlAs layer was 3.321+0i and for the GaAs layer 4.222+0.333i in excellent agreement with the literature values[1]. These values are used as the input search space parameters for subsequent real time analysis using R-Fit LIVE.

2. The output from R-Fit LIVE which is constantly updated as each new data points arrives (at 7rpm with 12 wafers this means a re-fit is performed just over every 0.7s). In this growth, the engineer had made the decision to reduce the thickness of the AlAs layer to save time and materials. The thickness of the AlAs and subsequent GaAs layers of the **batch** are 437±6Å and 3899 ±23Å respectively showing a very good level of uniformity from wafer to wafer. Now the template for this structure has been set up, every time its grown in the future it is automatically analyzed in real time. This provides the engineers with the opportunity to adjust the reactor to optimize yield and provides invaluable **information** for SPC. The next step it to integrate the numerical output directly into the reactor's control software for true closed loop control.

Conclusions:

- R-Fit LIVE is able to quantify the deposited layer in real time with no user intervention.
- R-Fit LIVE in conjunction with R-it v4.0 facilitates closed loop control.
- R-Fit LIVE and R-Fit v4.0 is are important tools to enable increased productivity, reduced scrap and profitability.

References:

1. http://www.ioffe.rssi.ru/SVA/NSM/nk/index.html