Optical Monitoring: Delivering High Precision & Yield to the Manufacture of Optical Coatings

Intellevation Ltd
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Why Use Optical Monitoring?

The Challenges:

- Complexity ↑
- Precision ↑
- Volume ↑
- Cost ↓

The Solution:

- Quartz crystal measures the **Deposited Mass**
- Optical Monitoring measures the true **Optical Thickness**
- Inherent error compensation in optical monitoring
  - Film stack errors can decrease as layer thickness and complexity increases
Target Specification

- **Product:**
  High Performance Steep Edge Notch Filter

- **Materials:**
  TiO₂ / SiO₂
  Ebeam deposition and IAD

- **Film Stack Design:**
  Demanding 34 layer film stack with non-QW termination

- **Band Edge Position Spec:** ± 0.3nm
Optical Monitoring Vs Quartz Crystal Example

10 back-to-back growth runs...

Quartz Crystal Monitoring

- Band Edge Spread > 3.3 nm
- Poor Yield

Optical Monitoring with Intellevation IL551

- Band Edge Position ± 0.1 nm
- Very High Yield

In-direct optical monitoring process in back face reflection mode with 2 test glasses. Results shown above are from the coated product.
Advanced Measurement System

Optical & Electrical Noise
- Electron beam guns including sweep controls
- Plasma sources
- Heaters
- Arcing

Solution
- Dual beam system
- Four phase chopper (light / dark / reference / dark)
- Time demultiplexed common optical path
- High speed digitisation and DSP within detector head
- High off axis rejection optics
- Rugged optical mounts
- High EMF / EMC immunity

Result – High Quality, High Precision Data
In-Direct Optical Monitoring – Test Glass

- Process flexibility & complexity
- Dynamic range
- Superior S/N
- Standard test piece – independant of product
- Result – Higher precision, yield, performance

Example: Symphony Series
High Precision Electron Beam Deposition with IAD
Direct Optical Monitoring

- Monitor the actual product or a witness piece at the same location
- No tooling factors
- Sample once per rotation
- Fast acquisition time (2ms)

Example: OptoFab 3000
High Precision Ion Beam Deposition
High quality AR and HR facet coating
Wavelength Ranges

**Source Module:** Quartz halogen 300 – 2400nm
Extension down to 250nm achieved with deuterium source

**Detectors**
- PMT 250 - 800nm
- Silicon 400 - 1100nm
- Peltier Cooled Si plus InGaAs 500 - 1650nm
- Peltier Cooled PbS 800 - 2200nm

**Standard Products**

- Free Space Systems
  - IL551 300 – 800nm
  - IL552 400 – 1100nm
  - IL553 500 – 1650nm
  - IL555 800 – 2200nm

- Fibre Based Systems
  - IL562 400 – 1100nm
  - IL563 500 – 1650nm

*Other wavelength ranges available on request.*
Accessories: Test Glass Changers

- In-house designs. Customised for your chamber geometry.
- Driven from Optical Monitor system for true integration and automation.
- Optional Integrated Multiposition Crystal Changer.
- Suitable for front or back face reflection and transmission optical monitoring modes.
- Optical alignment from outside the chamber, i.e. under vacuum.
- Up to 20 test glass carousel system or 250 glass drop glass system.
- Integrated carousel system for fibre based monitor retrofitted to your crystal changer.
Powerful Software

- Intellevation’s Optical Monitors give thin-film engineers the tools to decrease process development time & manufacturing costs AND increase yield & product performance.

- The system combines advanced optoelectronic hardware with a suite of powerful software packages including
  - **FilmMaker**
    - FilmBuilder
    - FilmModeller
    - FilmPhasor
    - FilmSimulator
    - FilmCharacters
    - FilmReviewer
  - **FilmDirector**

- to provide a single complete integrated solution.
Film Stack Design ➔ Optical Monitoring Scheme

Film Builder

Film Stack Design
Import from FilmStar, TFCalc, Essential MacLeod, Optilayer, etc.

Optical Monitoring Scheme Design

On a layer-by-layer basis, specify
- Monitoring wavelength
- Filter parameters
- Cut algorithms
- Cut on optical monitor, crystal or time
- Calibration scheme
- and many other parameters
FilmModeller ©

- Automatically reads a FilmBuilder © file
- Calculates and displays the expected Optical Signal as a function of Deposition Time
- Snapshot of whole process
- Rapidly see the effect of your model design
- Provides guide to signal compression
- Provides guide to number of films per test glass.
- Suggests optical monitoring scheme options to try in FilmSimulator ©
FilmPhasor©

- Powerful process design & optimisation tool for **NON-QUARTER WAVE TERMINATION**.
- Inspect the waveform for any layer within the stack.
- Change monitoring wavelength to optimise waveform for that layer.
- Automatically shows sensitivity of that layer to small process variations – enabling design of highly robust processes.

**Non Quarter Wave Design**

**Improves cut point precision & manufacturing process stability / yield**
FilmSimulator © - Pre Coating Run

- UNIQUE and POWERFUL feature not found in other packages

- Off-Line simulation runs including
  - Optical Model
  - Physical effects of Optical Monitoring hardware
  - Physical effects of Customer’s Coating Tool
    - E-gun noise (material dependent)
    - Gun dep rate control
    - Test glass variations

- Calculates ‘cut point’ errors on a layer-by-layer basis

- See inside the process and identify where errors will occur

- Helps the coating engineer design a ROBUST process off-line
FilmSimulator© in Action

- Complex 26 layer film stack
- Multiple Non Quarter Wave design
- FilmSimulator© indicates cutpoint errors > 50%
- Proof that the product will be extremely unlikely to meet specification

**Action:** Modify growth scheme and analyse impact with FilmSimulator©

Same film stack – different scheme

- Change monitor wavelengths
- Change Test Glass scheme
- Change filter settings
- Change QW factors
- Change number of samples per QW

**Result:** massive decrease in cutpoint errors (< 1%) – the film stack performance is now achievable!

1 hour on FilmSimulator© saves many days of process development on the production line.
Film **Characters** © - Pre Coating Run

- Determine the Spectral Characteristics of the final film stack
- Compare the **THEORETICAL DESIGN** spectra with the ‘**REAL-LIFE**’ spectra from **Film Simulator** ©
- See the impact of ‘cut point’ errors on the performance of your final product!
- Powerful production process design tool
- Plot many simulated runs on the same graph
  - gain real information on process **YIELD – OFFLINE**!

Complex non-quarter wave design. **FilmCharacters**© shows the designed response and the run-to-run variability – even before a run is done.
A fast and easy-to-use front-end that enables you to drive your process.

Loads a process from **FilmMaker®**

- Performs the run under automatic or manual control as required
- **FilmDirector®** autocalibrates on start up
  - automatically changes the wavelength and the test glass
- Detects each cut and controls the material sources and shutters through an advanced I/O capability.
Key Features

- Incorporates advanced model fitting algorithms for cutpoint determination
- State machine based controller can recover/continue a process context even after a shutdown.
- Integrates seamlessly with FilmMaker© design front-end.
- Freely configurable, panelled user-interface.
- Now includes two operating modes.
  - **ADVANCED** mode for process developers allows access to all of the parameter space.
  - **BASIC** mode enables an ADVANCED user to lock and hide many of the advanced parameters thereby providing a clear front-end for a previously optimised process, ideal for use by operators in a manufacturing environment.
- After a run is completed, the data is logged for later analysis. Files can be exported in CSV format for analysis in your favourite program.
**FilmReviewer © - Post Coating Run**

- **FilmReviewer ©** is used to view, analyse and reprocess previous runs – for **OFF-LINE OPTIMISATION**.

- Take **REAL RAW DATA** from your coating system, and observe the effects of reprocessing it, changing the filtering parameters, the sampling rate, the latency and hold-off parameters and the termination algorithms.

![Diagram of FilmReviewer software](image)

**Load RAW DATA from previous runs on a layer by layer basis**

**View the raw data for the whole stack or analyse a layer at a time**

**Change Acquisition Settings, Turning Point Analysis Settings and Analyser Mode and see the impact on accuracy of cutpoint determination.**

**Reprocess the data on a layer by layer basis to optimise future runs**
Installation

Our skilled engineers will install and commission our monitor systems directly onto your coating system ✔

at your facility ✔

and provide initial on-site operational training ✔
Trainig & Support Products

Intellevation’s growth and optical monitoring experts provide:

- **Post Installation Training Packages**
  - Face-to-face training at the customer’s facility…
  - On the customer’s coating machine…
  - Tailored to the customer’s specific experience & process…
  - Duration determined by customer’s needs…
  - Aims to provide customer with the necessary practical experience in coating machine set-up, optical monitoring, and optical process design to rapidly achieve their precision coating goals.

- **In-House Training Packages**
  - As above but at our coating facility using our equipment…

- **Process Development Packages**
  - Theoretical thin film design, and growth scheme design consultancy…
  - On the customer’s coating machine…
  - Tailored to the customer’s specific experience & process.
Installation Base

We have successfully integrated our Optical Monitor Systems onto coating systems made by the following manufacturers;

and many more............

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Thank You

For further information or support, please contact

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