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

Intellemetrics Global Ltd
www.intellemetrics.com
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:**
  \(\text{TiO}_2 / \text{SiO}_2\)
  Ebeam deposition and IAD

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

- **Band Edge Position Spec:** \(\pm 0.3\text{nm}\)
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 Intellemetrics 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
- e.g. Noise as low as 0.002% T or R,
- Calibration accuracy as low as 0.002% T or R
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
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 (3ms)

Ebeam Chamber
Direct Monitoring on the Rotating Calotte

Direct Monitoring
Transmission or reflection
# Optimised Products for Different Wavelength Ranges

## Standard Product Range
- **IL570-1**: 300 - 800nm
- **IL570-2**: 400 - 1100nm
- **IL570-3**: 550 - 1650nm
- **IL570-4**: 800 - 2200nm

**BW = 2.2 – 6.5nm**
All optical coatings except extreme NBFs (i.e. DWDM)

## Combined Product Range
- **IL570-1-3**: 300 - 1650nm
- **IL570-1-3**: 400 - 1650nm
- **IL570-1-4**: 300 - 2200nm
- **IL570-2-4**: 400 - 2200nm

**BW = 2.2 – 6.5nm**
All optical coatings except extreme NBFs (i.e. DWDM)

## Enhanced Product Range
- **IL570-DUV-ES**: 230 - 800nm
- **IL570-DUV-3-ES**: 230 - 1650nm
- **IL570-1-3-ES**: 300 - 1650nm
- **IL570-3-ES**: 550 - 1650nm
- **IL570-1-4-ES**: 300 – 2200nm

Deep UV capability down to 230nm.
Accessories: Test Glass Changers

- In-house designs. Customised for your chamber geometry.
- Driven from IL570 OMS for true integration and automation.
- Intelligent interface knows which carousel position is being used, which test glasses have been coated, handles error checking, etc.
- Optional Integrated Multiposition Crystal Changer, thermocouples, etc.
- Suitable for front or back face reflection and transmission optical monitoring modes.
- Optical alignment from outside the chamber, i.e. under vacuum.
- Extremely high uniformity from test glass to test glass.
- Up to 16 test glass carousel system dependant upon chamber geometry.
Powerful Software

- Intellemetrics’ 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:
  - **FilmMaker2**
    - FilmBuilder
    - FilmModeller
    - FilmEditor
    - FilmSimulator
    - FilmCharacters
    - FilmReviewer
  - **FilmDirector2**
- Provide a single complete integrated solution.
- Windows 7, 8 and 10, 32bit and 64bit
**Film Stack Design ➔ Optical Monitoring Scheme**

**FilmBuilder**

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
Material Properties

- Unlimited number of custom materials
- Define $n$ and $k$ at unlimited number of wavelengths
- Define deposition rate for each material
- Define tooling factor for each material
- Read in data from CSV files, export to CSV
- Create Public or Private materials databases
FilmModeller

- Automatically reads a FilmBuilder © file
- Calculates and displays the expected Optical Signal as a function of Deposition Time
- Includes effects of wavelength changes and test glass changes
- 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 ©
FilmEditor

- Powerful, graphical intuitive process design & optimisation tool with instant visual feedback
- Inspect the waveform for any layer within the stack, BEFORE and AFTER Processing
- Change the following parameters to optimise waveform for that layer.
  - Wavelength, sample rate, test glass number, HoldOff, Latency, Filtering parameters, cut method, analyser mode.
- Automatically optimises waveform cutpoint depending upon parameters defined.
- Automatically shows sensitivity of each layer

Improves cut point precision & manufacturing process stability / yield
Flip-Chip Coating Schemes

FilmMaker correctly models filmstacks on two sides of a test glass.

FilmDirector correctly calibrates on the bare test glass, and handles recalibrations after in-situ flipping of the test glass, enabling high precision monitoring of complex filmstacks on both sides of a substrate.
FilmSimulator - Pre Coating Run

- Off-Line simulation runs including
  - Optical Model
    - Physical effects of Optical Monitoring hardware (bandwidth, wavelength, noise)
    - Physical effects of Customer’s Coating Tool
      - E-gun noise (material dependent)
      - Gun dep rate control
      - Test glass changes
  - Calculates ‘cut point’ errors on a layer-by-layer basis
  - Builds a new stack each run.
  - Shows compensation effects.
  - Identifies problem layers.
  - Shows effect on resultant spectrum.
**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

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

10 minutes on FilmSimulator © saves many days of process development on the production line.
FilmCharacters - Pre Coating Run

- Determine the Spectral Characteristics of the final film stack
- Compare the THEORETICAL DESIGN spectra with the ‘REAL-LIFE’ spectra from FilmSimulator ©
- 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!

FilmCharacters © shows the designed response and the run-to-run variability – even before a run is done.
FilmDirector2

- Loads a project from FilmMaker2
- Performs the run under automatic or manual control as required
- Autocalibrates on start up
- Automatically changes the wavelength and the test glass
- Detects each cut and controls the deposition through an advanced I/O capability.
FilmDirector2

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 FilmMaker2© design front-end.
- Freely configurable, panelled user-interface.
- Fully touch screen capable if required.
- 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.
FilmDirector2 – Wavelength Scanning

Key Features

- Perform wavelength scan on bare substrate before coating.
- Perform wavelength scan after each layer, or at the end of the coating run.
- Automatic scanning can be preselected in FilmMaker2, or scans be done ‘on the fly’ as required.
- Displays theoretical scan as well as experimental scan for easy comparison.
- Auto saves scans to log files.
**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.

![FilmReviewer screenshot](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
- **Reprocess the data on a layer by layer basis to optimise future runs**
- **Change Acquisition Settings, Turning Point Analysis Settings and Analyser Mode and see the impact on accuracy of cutpoint determination.**
Integration into Your Coating System

Complete seamless integration for fully automated operation. Customer can choose any one of the interfaces above, or use any combination of them. Interfaces are fully specified and documented.
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 ✓
Training & Support Products

Remote Training
- FilmMaker and FilmDirector training
- Setup within 1 minute
- Fully interactive – you interact with the program under instruction
- Full VOIP for intuitive live instruction
- Either run FilmMaker & FilmDirector on your computer or on our computer

Remote Support
- You invite us to log onto your optical monitor from anywhere in the world
  - You have full control of each log on event
- View Only
  - Diagnose problems
  - Provide training support
  - Provide process development support
- View and Interact
  - Diagnose and Fix
  - Install updates
Installation Base

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

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

intellemetrics
Thank You

For further information & support, please contact

Intellemetrics Global Ltd

Tel: +44 (0) 141 889 0700
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www.intellemetrics.com
IL550 & IL560 Series Optical Monitors

Customer Endorsements
“Tecport Optics serve to serve again. We work vigorously and continuously with our customers and world class instrument manufacturers to provide state-of-the-art coating systems with cutting-edge technology processes. That’s why you will find Intellemetrics’ optical monitors integrated into our high precision coating systems.”

- Joseph Kim, General Manager, Tecport Optics Inc.
“Oxford Instruments OptoFab3000 provides high performance optical coatings across a range of applications. We offer our customers high levels of precision and control and Intellemetrics’ optical monitor integrated with our patented holder is an important part of that.”

- Dr Mike Cooke, New Product Introduction Manager, Oxford Instruments Plasma Technology Ltd.
“scia Systems provides surface processing equipment for the MEMS, microelectronics and precision optics industries. For precise deposition of optical multilayers an in-situ optical monitoring is essential. The optical monitoring from Intellemetrics integrated in our scia Coat 200 ensures high quality and repeatable process results.”

- Marcel Demmler, Sales Director, scia Systems GmbH
"In a demanding industry where precision, accuracy and repeatability matters the most, Intellemetrics have come up with a system that provides exactly that. We are very pleased working alongside Intellemetrics as they are always helpful and willing to offer a good service while continually improving their systems."

- Loukas Zampelis, Design Engineer, Northumbria Optical Coatings
Meyer Burger is a leading global technology company specialising in innovative systems and processes based on semiconductor technologies and is employing around 1,600 people across three continents. Meyer Burger has integrated the Intellemetrics Optical Monitor into our range of coating systems for the production of precision optical coatings.

IonSys 800 IBS Coater
For high precision optical filmstacks

Intellemetrics IL552+IL553 Optical Monitor for monitoring from 400 to 1650nm in transmission and reflection on rotating substrate.
“Elettrorava has delivered several optical coating systems using ion beam sources and electron beam source specifically designed to meet needs of major worldwide Institutions. The success of these systems has been enabled by the control of the process by the Intellemetrics Optical Thickness Monitor. Besides an outstanding user friendly software with associated hardware Intellemetrics offers on site assistance and round the clock remote assistance for the lifetime of the system”

Dr Paolo Rava, Managing Director, Elettrorava S.p.A
“Kenosistec is a dynamic Italian company with more than two decades of experience in designing, developing and manufacturing High Vacuum Systems and components for Thin Film Deposition and Research Applications. Kenosistec are pleased to integrate Intellemetrics optical monitors into our coating systems.”

- Paola Santilli, Senior System Engineer, Kenosistec.
Plassys – France

Plassys designs and manufactures equipment for thin film deposition and etching. For over 20 years many prestigious public and private research centers have relied on PLASSYS expertise in vacuum technology and application know-how.

Ion beam deposition chamber with IAD installed at prestigious French research lab.

Intellemetrics optical monitor integrated for monitoring and control of a wide range of precision optical coatings.

Monitoring from 220nm to 2,200nm

IL555 Detector Module
800 to 2,200nm

IL551 Detector Module
220 to 800nm

IL550 Source Module with Deuterium UV Extension

Mirror Block and chamber mounting accessories
Intellemetrics IL555 (800 to 2400 nm) in front face reflection mode on a Leybold LABplus 900 chamber.

System full integrated into the Leybold LabPC control system for complete automated operation.

Application: 3 – 5µm and 8 - 15µm
- Bandpass Filters
- Narrow Bandpass Filters
- Edge Filters

Source and Detector Modules
Korea Vac Tec Co Ltd's VTC-1000 PO Coater is designed for precise optical coatings on optical parts and similar products using electron-beam and thermal evaporation (with ion gun pre-cleaning and assistance) to create multilayer optical coating on the surface of substrates. VTC-1000 PO Coater runs in fully automatic mode.
“HHV is a leader in the field of vacuum technology including the manufacture of vacuum coating systems for the production of high precision optical coatings. We are pleased to integrate the Intellemetrics Optical Monitor into our systems thereby offering our customers enhanced precision and control.”

….. Prasanth Sakhamuri,
Managing Director

Images show:

Incorporating Intellemetrics IL56SX Optical Monitor from 400 to 1650nm in transmission and reflection.
Intellemetrics Test Glass Changer
Compact launch and receive optical assemblies mounted ontop and beneath the chamber.
A selection of our End-Users.....
Installation Base

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

- TECPORT OPTICS, INC.
- OXFORD INSTRUMENTS
- MEYER BURGER
- SCIA SYSTEMS
- Solayer
- MeIVAC
- VTC\n- GRAND MINN\n- Cello
- VTD
- KENOSITEC
- Kurt J. Lesker Company
- Awave
- LEYBOLD OPTICS
- ROTH & RAU
- Plassys
- BOC EDWARDS
- PROTECH KOREA CO., LTD
- Advanced Vacuum
- PROVACO
- PFEIFFER VACUUM
- Veeco
- balzers
- DSI
- elettrorava
- satisloh
- OCLI
- Intellemetrics

and many more........
Thank You

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