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
Optical Monitoring Vs Quartz Crystal Example

Target Specification

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

- **Materials:**
  TiO$_2$ / SiO$_2$
  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 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
In-Direct Optical Monitoring – Test Glass

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

![Diagram showing Front Face Reflection, Back Face Reflection, and Transmission with Test Glass Changer]
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)
Wavelength Ranges

**Source Module:** Quartz halogen 300 – 2400nm
Extension down to 220nm achieved with deuterium source

**Detectors**
- PMT
- Peltier Cooled Silicon
- Peltier Cooled Si plus InGaAs
- Peltier Cooled PbS

220 - 800nm
400 - 1100nm
500 - 1650nm
800 - 2200nm

**Standard Products**

**Free Space Systems**
- IL551UV 220 – 800nm
- IL551 300 – 800nm
- IL552 400 – 1100nm
- IL553 500 – 1650nm
- IL555 800 – 2200nm

**Fibre Based Systems**
- IL561/UV 250 – 800nm
- 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.
- Intelligent interface knows which carousel position is being used, which test glasses have been coated, handles error checking, etc.
- 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.
- Extremely high uniformity from test glass to test glass.
- Up to 16 test glass carousel system or 250 glass drop glass system.
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 ©**
  - **FilmDirector ©**

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

**FilmBuilder**

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

- 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
- 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

Implements cut point precision & manufacturing process stability / yield
FilmSimulator - Pre Coating Run

- 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.
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.
FilmDirector

- 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
- Autocalibrates on start up
- **FilmDirector ©** automatically changes the wavelength and the test glass
- Detects each cut and controls the material sources and shutters through an advanced I/O capability.
**FilmDirector**

**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.

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.
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:

- TECPORT OPTICS, INC.
- OXFORD INSTRUMENTS
- VTD
- VIC KOREA VAC-TEC CO., LTD
- cello (cello technology)
- AWAVE
- LEYBOLD OPTICS
- PLASSYS
- HINDHVAC
- KENOSISTEC
- VordenTec
- PROVACO
- Nordiko
- BOC EDWARDS
- Edwards
- SCT
- INTEC
- Pfeiffer VACUUM
- DSI
- elettroraya
- Veeco
- balzers
- satishoh
- OCLI
- ElectroTech
- MILL LANE ENGINEERING
- intellemetrics

and many more............
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.
Intellemetrics recently successfully installed a new design of optical monitor onto a Tecport Optics 2m chamber used in the manufacture of high performance night vision systems. Optical designs with greater than 250 layers are being deposited in a production environment with over 500 elements being coated in each run.

The customer specification handed to Intellemetrics was extremely demanding with a single shot measurement once per revolution to be taken directly on a test piece mounted at a large radius on a calotte. A high calotte rotation speed, combined with a small test piece size, and a large radial distance resulted in there only being a 3ms window for each measurement. On top of this, the system was required to take measurements from 450nm out to 1080nm, work in a completely automated manner, and be capable of monitoring up to 70 layers on each test glass.

The system was installed and commissioned at the customer’s facility and met all of the customer requirements. Optical noise measurements in the field agreed with the design results and confirmed that the optical signal levels had been increased by a factor of >100. Based on the system performance, the end customer is now thinking about the possibility of even larger filmstacks.
Load Locked Ion Beam Sputtering System

Load-locked Test Glass Changer within Vacuum Bellows

Intellemetrics IL553 Detector Module

Intellemetrics Test Glass Changer on a vacuum bellows assembly for use with the load-lock.

Intellemetrics Optical Monitor Display

Intellemetrics Control Module
Symphony - 1.8m Precision Optical Coating System

Intellemetrics IL551 (300 to 800nm) Optical Monitor in Back Face Reflection Mode on a Test Glass Changer
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

IL551 Detector Module
220 to 800nm

IL550 Source Module with Deuterium UV Extension

IL555 Detector Module
800 to 2,200nm

Mirror Block and chamber mounting accessories
OptoFab 3000: High Precision Ion Beam Coating System

IL563 Fibre Based Optical Monitor System

Ion beam coating system for high quality AR and HR facet coating.

Direct optical monitoring in transmission mode with 3ms sample times.

“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.
Leybold Optics - Germany

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 – 5\(\mu\)m and 8 - 15\(\mu\)m
- Bandpass Filters
- Narrow Bandpass Filters
- Edge Filters

Source and Detector Modules
Korea Vac Tec'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.
“Wordentec is a global supplier of systems to the thin film coating industry. Performance and flexibility of integration are key features for us and that’s why we use Intellemetrics’ optical monitoring systems.”

- Phil Mingay, Managing Director, Wordentec Ltd.
Kenosistec - Italy

Ion Beam Sputtering System with four targets for High Precision Optical Coatings in Swiss R&D lab

IL551 for 300nm to 800nm monitoring

IL553 for 550nm to 1650nm monitoring

“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.
Kenosistec - Italy

Production Plasma Assisted Ebeam Coater
1m³ chamber for High Precision Optical Coatings

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- Paola Santilli, Senior System Engineer, Kenosistec.
Elettrorava - Italy

Ion Beam Assisted Ebeam Coater for Precision Optics

IL552 Detector Module in Transmission Mode

6 Position Crystal Changer

Callot Drive
Intec – South Korea

Source & Detector mounted in back face reflection mode (behind screening)

Intec MARS i 120 Coating System

“LVS & Intec are pleased to integrate Intellemetrics Optical Monitors into our range of high precision optical coating systems.”
- Onno Lootsma, Managing Director, Lootsma Vacuum Solutions
Taurion 800 Precision Optics Coater System

IL552 Detector & Source Modules mounted on the underside of chamber in front face reflection mode.
Installation Base

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

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

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