SimulyzR & EtchNet: Driving etch process control to the next level with LayTec's latest reflectance simulation, modelling and monitoring tools for plasma-etching

Accurate etching down to sub-nanometer precision has become a gating factor for next generation power devices, LEDs and RF electronics. LayTec's software suite tackles this challenge on two complementary frontiers. **EtchNet** uses live multi wavelength reflectance data for reliable endpoint detection to stop the etching process exactly when the target depth is reached. **SimulyzR** creates a digital twin of the wafer stack, letting engineers predict, fit and optimize those optical traces before a single product wafer is etched. Used together, they close the loop between virtual modelling and real time control, reducing process development effort substantially while boosting production yield.

A brief primer on plasma etching and in- situ optical monitoring

Plasma etching – whether reactive ion (RIE), inductively coupled (ICP) or atomic layer etch (ALE) – removes material from the wafer surface by exposing it to reactive species. Because endpoint detection is needed there with a precision down to less than a nanometer, manufacturers integrate LayTec's TRIton® in-situ metrology system with their etchers. Three LEDs with selected wavelengths are focused on the wafer on a dedicated metrology test pad as small as 200 µm x 200 µm or directly on the open area of the structure; the reflected intensity changes as the layer thickness changes. If that signal is interpreted correctly, the tool can decide when to end the step or process or to switch chemistry to proceed with the next process step.

Traditional 'etch through' trials cost wafers and hours and are only helpful for forecasting process and step durations if the etch-rate remains constant throughout the entire process. LayTec's approach reduces the effort with its data driven control: SimulyzR calculates in advance how the transient should look, whilst EtchNet monitors the etch trace in real time and initiates the hardware stop signal.

EtchNet – real time control of the etching process

Concept

EtchNet runs on the TRIton® control PC displaying the reflectance signals from the three LED traces – the so-called etch traces. Additionally, the plasma-intensity can also be monitored as a potential process control parameter. The interpretation of the curves allows to identify endpoints and to control the process. For this purpose, the software can initiate start and stop signals for the respective etching steps, if fully integrated in the plasma etching tool. EtchNet saves the trace reflectance data, allows an etch trace replay and endpoint recipe development and parameter modification in a recipe editor in order to adjust the recipe based on the learnings of previous runs.

User interface and workflow

When an operator opens the measurement view (**Figure 1**), a dual panel layout appears: reference traces on the top, live traces on the bottom. A toolbar loads reference runs, links the corresponding recipe and clears or stores data. Reference runs can be derived from simulations, etch-through runs or previous processes, such as growth runs.

Figure 1: EtchNet measurement view showing the reference traces with recipe preview (top) and the live processing and predicted endpoint during an etch run (bottom).

Under the hood, each endpoint recipe is a sequence of logical steps – e.g. WaitForStart, Recognize Pattern, Delay etc. with separate parameters, shown in the editor tables underneath the color coded timeline (**Figure 2**). About a dozen step types are available to analyse the curve and react in a defined way on certain features of one or more wavelengths, again with a list of parameters. When, for example, the software sees an endpoint reached, it sets the stop signal on the interface to the etching tool or prompts the operator to stop the process.

The moment the user presses Run, the live window shows how the process follows the recipe. Then EtchNet logs every data point in a database. The current endpoint recipe is loaded into the hardware and executed in an automated way as soon as the endpoint has been forecasted, detected and reached. The recorded data sets are linked to the endpoint recipe data for traceability and repeatability.

For the proper positioning of the measurement spot, the spot can be moved across the wafer area in a special positioning mode either based on scanning the reflectance intensity over a certain area or by employing an optional camera . During the process, the spot remains at one point on the test pad or open area. The software and the TRIton® metrology system as a whole are designed as a toolbox system which can easily handle changes in the etch rate, the etch area or the whole etch method.

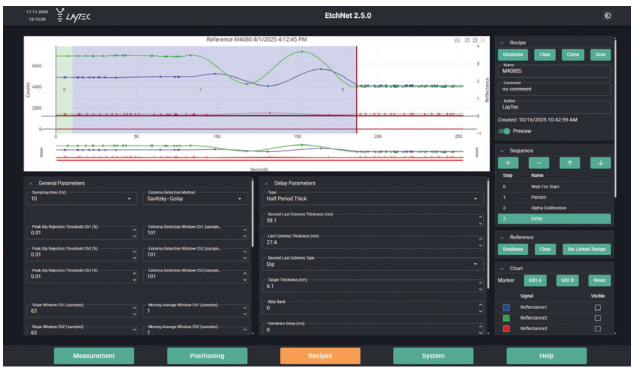

Figure 2: EtchNet recipe editor showing the preview of a recipe on a loaded measurement run.

Why fab engineers value EtchNet

Customers from both academia and industry report three recurring gains:

- **Precision:** endpoint detection down to sub-micron precision (depends on the etching method) is crucial for quality control.
- **Recipe portability:** the recipe can be exported/imported across tools or duplicated for multi chamber platforms.
- **Traceability:** every run – raw data, recipe version, operator comments – remains searchable in the database for audits or statistical process control.

SimulyzR – turning data into predictive insight

Concept

Just as EtchNet, SimulyzR is a browser based application that allows offline analysis of etch processes. It either predicts how a given stack will reflect light (based on data which the user defines) or fits unknown parameters – thickness, n,k values, etch rate – to the measured data. It helps to understand what happens during a process and in particular, it helps to define which reflectivity feature from which wavelengths trace should be used for process control for a particular process step.

SimulyzR workflow explained

The user employs preconfigured scripts which simulate the reflectance during an etch process based on the user's input parameters for a specific process. That could, e.g., start with data from a recent etch run. A desired stack of materials can be built according to the original recipe and its simulated expected reflectivity trace during an etch run can be compared to measured data. Simulations can start with best guesses for the parameters such as refraction index n and extinction coefficient k and deliver real values for n and k after fitting the simulation to the measured data. These values for n and k can be used for subsequent simulations of new processes or different layer stacks. Beyond material data, fits can be made for process parameters such as layer thickness or etch rate, too. The user can change data and watch signals change. Once the simulated results are satisfactory, the recipe can be exported to EtchNet for use in a real etch run.

A particularly handy construct is the virtual interface approach: instead of modelling dozens of buried layers, engineers collapse everything below the region of interest into two parameters – amplitude of the reflectance virtual interface and phase of the Fabry-Pérot oscillation speeding fits without hurting accuracy.

Benefits summarized

SimulyzR enables a model-based analysis and simulation of etching transients. It cuts development time by identifying which wavelengths and time windows contain the cleanest markers, lets teams decouple rate errors from optical constant errors, and even inverts epi growth data (coupled with LayTec's EpiNet® software) to approximate an etch through trial.

Figure 3: SimulyzR showing an etch forecast for the set of TRIton® wavelengths based on a modeled material stack.

Using both tools in one workflow

1. **Virtual design:** Engineers sketch a first guess stack in SimulyzR and run a forward calculation. Distinct peaks or dips appear at forecasted times. The data is exported as CSV file.

2. **Recipe prototyping:** The simulated data is imported as a "reference run" in EtchNet. The recipe editor enables operators to develop an endpoint recipe using this reference run. The process is simplified by forecasting the recipes behavior on the reference run as visual feedback on every recipe parameter change.

3. **Recipe refinement:** The robustness of the endpoint recipe can benefit from every new recoded data set if its parameters are refined accordingly.

4. **Simulation refinement:** The recorded data can be imported into SimulyzR to fit any discrepancies leading to n,k values with higher accuracy. Updated parameters flow back into the simulation, the recipe timeline shifts by a few seconds, and the process repeats until the endpoint error falls below the spec.

5. **Release to production:** If the endpoint recipe is considered as stable it can be copied to further machines for volume production.

In day to day use this loop reduces the need for test wafers and runs and shrinks mean time to process transfer

Conclusion

LayTec's EtchNet and SimulyzR embody the shift from time-based etching to model based process control. EtchNet allows for real time process control, based on actual material and machine parameters. SimulyzR gives engineers the opportunity to derive optical constants and process parameters from measured data. This data can be used to improve existing recipes or to create a new recipe. As part of LayTec's Connected Metrology® strategy, the software tools deliver a virtuous cycle of prediction, observation and optimization that drives tighter specs, higher yields and faster time to market. It can even include layer growth data from related EpiNet® software.

For more information, reach out to **info@laytec.de** or visit **www.laytec.de**.

The “Connected Metrology” approach

The LayTec Connected Metrology® ecosystem enables improved process control characterizing complex layer stacks along the manufacturing chain. In a typical frontend production line, wafers are typically measured multiple times. Using LayTec systems in all of these process steps bears the potential to forward and share the respective analysis data from each step to the subsequent ones, thereby unfolding the full potential of the Connected Metrology® approach. During epitaxy, EpiCurve® TT can determine the thicknesses and composition of many individual layers as well as their in-situ. In the ex-situ wafer mapping with EpiX® C2C by white light reflectance and photoluminescence, full 2D wafer maps are acquired characterizing the 2D uniformity of critical layer thickness, layer composition and other sample properties. During sub-sequent plasma-etching processes, the thickness monitoring and endpoint detection is again performed in-situ by LayTec's TRIton®. As the wafer is advancing through the frontend production line, the amount of information on the particular wafer increases and is combined for improved analysis in downstream processes. By connecting in-situ and ex-situ metrology, we can determine the critical layer parameters of increasingly complex layer structures at die-level.

Connected Metrology®

About us

LayTec, founded 1999 in Berlin, is a major provider of in-situ and in-line optical metrology for thin-film processes.

These metrology tools are used in a broad range of thin-film applications such as LED & laser production, power devices and transistors, thin-film photovoltaics, oxide and organic deposition as well as other large area deposition processes. LayTec’s integrated metrology provides access to all key thin-film parameters in real-time – either in-situ, during the deposition process, or in-line. Also, in-situ metrology tools for dry etching have been added expanding LayTec’s portfolio along the production chain.

Beyond these integrated methods, LayTec also offers mapping solutions which ideally complement in-situ measurements by providing uniformity analysis of the deposited layers. The implementation of LayTec metrology systems in production processes significantly shortens development cycles and enables an efficient quality control that helps to considerably reduce production and development costs.