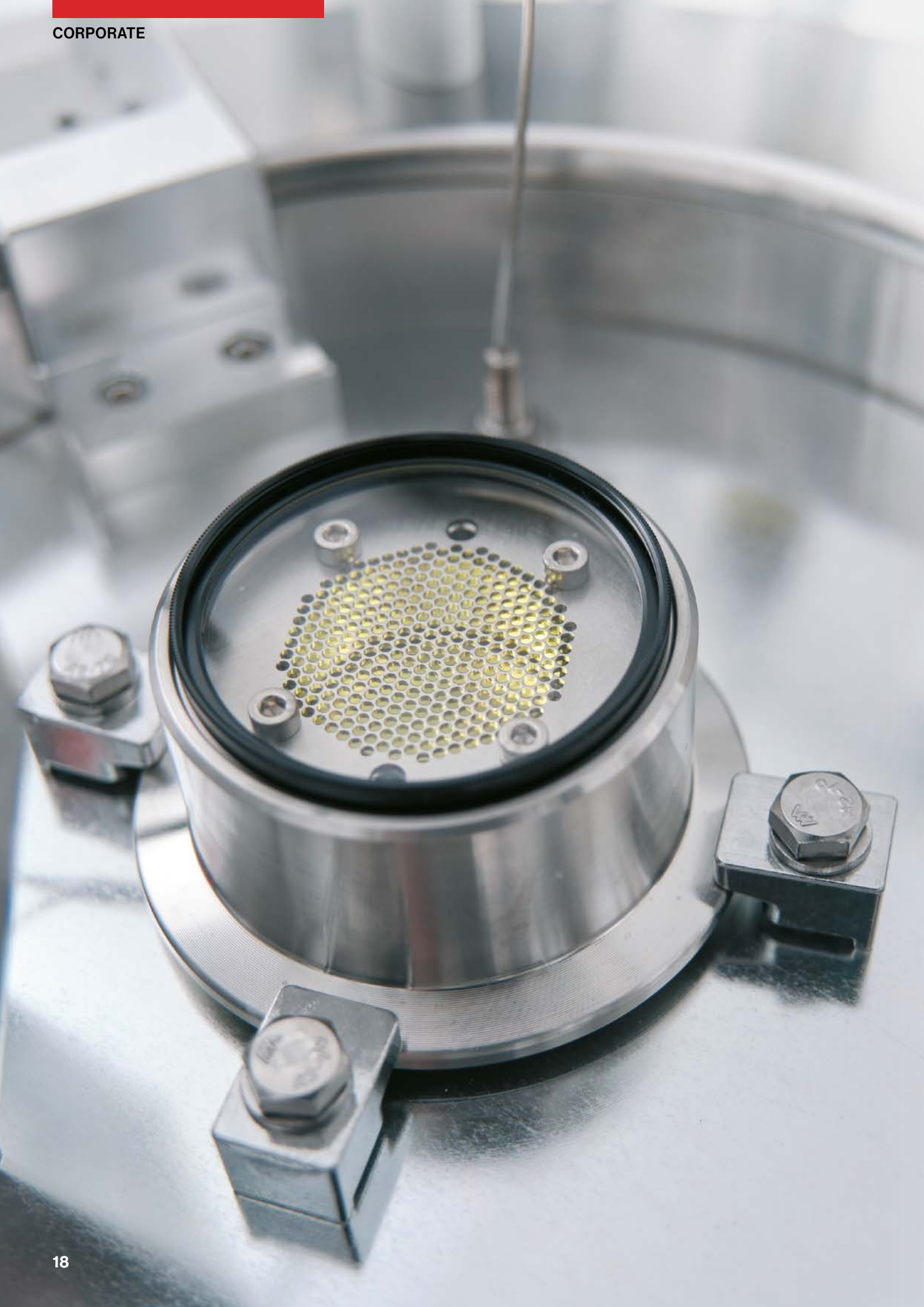

PEALD: The new kid on the CLUSTERLINE® block

Dominik Hartmann, Manager Technology Development & ***Dr. Joerg Patscheider***, Principal Scientist, present a new module for Plasma-Enhanced Atomic Layer Deposition (PEALD). As just one of the modules available on the CLUSTERLINE® 200 family, customers can freely combine it in configurations of up to six modules per cluster together with established techniques like sputter, etch and PECVD.

Thin films produced by sputter deposition can be used to address various functionalities such as high optical transparency, defined values of electrical conductivity, specific electromechanical properties such as piezoelectric performance and others. Since sputter deposition is a directional process, it is commonly straight forward to achieve such properties on flat and planar substrates. However, as soon as homogeneous films are required on non-planar surfaces, such as structured wafers and surfaces with radii of curvature much smaller than the wafer dimensions, chemistry-based techniques are well-known for providing solutions to such requirements. Plasma-Enhanced Chemical Vapor Deposition (PECVD) is already well-established in a multitude of applications for films in the thickness range from several hundreds of nanometers up to more than ten micrometers. However, if films thinner than about a hundred nanometers and down to the nanometer range are needed, Atomic Layer Deposition (ALD) and its plasma-supported extension, Plasma-Enhanced Atomic Layer Deposition (PEALD) provides solutions that combine excellent conformality (uniform thickness irrespective of substrate curvature) with atomic precision in thickness.

Evatec's new PEALD module is a novel single-wafer processing station within the CLUSTERLINE® 200 family thats ideal for deposition of thin dielectric films. To reduce deposition temperatures with respect to thermal ALD, a microwave plasma source is used enabling for instance, the preparation of Al_2O_3 films at near room temperature. In contrast to other forms of plasma excitation like RF or even pulsed DC, microwave plasmas have very low sheath voltages. Consequently, the energy of ions impinging from the plasma onto the growing film is only a few eV. This is an important feature if thin film materials sensitive to ion radiation damage need to be deposited. While most materials will not suffer radiation damage at energies below ca. 20 eV, some crucial compounds already show deterioration at lower energies. Examples of ion irradiation-sensitive materials are many group III nitrides such as GaN, InN etc., but also sputter-sensitive oxides, e.g. ITO, MoO_3 and other transition metal oxides, as well as sulfides like MoS_2 and other 2D materials. Only microwave-excited plasmas can provide the favorable conditions required. Figure 1 illustrates a typical PEALD process flow.

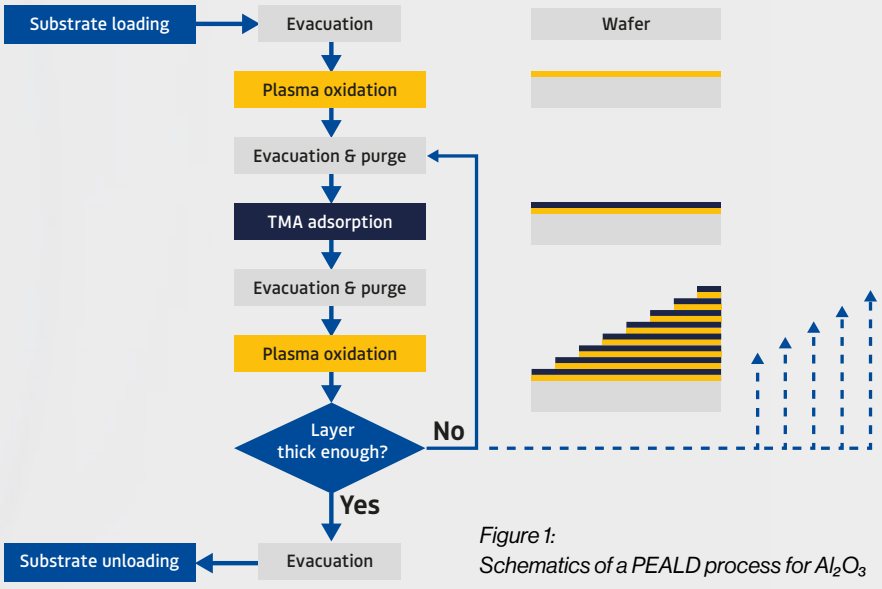

Figure 1:
Schematics of a PEALD process for Al_2O_3

Where ion radiation damage is not of concern for the user, the new PEALD module can be operated with a radio frequency bias on the chuck, allowing full control over the energy of impinging ions in a wide range from a few eV to more than 200 eV. This option allows tuning of various materials parameters of the grown films such as density, refractive index and microstructure.

The use of an arrangement of high-strength permanent magnets outside the process chamber enables this new module to reach Electron Cyclotron Resonance (ECR) conditions. This leads to very high plasma densities which allow almost complete reactions during the plasma step (i.e. during oxidation and nitridation processes) at low temperatures.

In addition to the substrate biasing possibility, the PEALD module is equipped with a heatable substrate holder for temperatures of up to 500°C. While this is 200°C too high for almost all PEALD processes, post-deposition annealing *in-situ* is possible with this device. This opens up new ways to tailor selected properties of the previously prepared films without compromising the PEALD deposition process.

The system is set up to use two different metal precursors, which enables deposition of ternary films such as $SrTiO_3$, Ta-C-N etc. with varying elemental ratios. Ternary oxides, e.g., ITO as well as multilayer structures of the type ABX (X being a non-metal) can also be prepared. The design of the module and processes have been rigorously optimized to achieve minimal precursor consumption and reduced cost of ownership. A special carrier configuration allows for two-side deposition of substrates in a single run, while maintaining the same layer thickness on both sides.

To counteract potential issues with particles formation due to deposits on the reactor's inner walls, the module can perform different cleaning processes like plasma-enhanced chemical *in-situ* cleaning procedures.

To illustrate the perfromance of the module, alumina films with thickness up to 100 nm were prepared at 200°C. Figure 2 illustrates the attained homogeneity of refractive index (@633 nm) of a 45 nm thin layer.

The mean refractive index value is 1.65 at 633 nm with a uniformity of better than ±0.5%, with a layer thickness uniformity of <1%. These layers show carbon contents below 1 atomic percent.

Being a member of the single process module family of the CLUSTERLINE 200®, the new PEALD module can be combined with other modules, e.g. metal layers by sputtering to realize any desired combination of layers on one cluster tool without breaking vacuum. Tools configured in that way can be used to achieve layer stacks of various thin film materials, e.g. piezo-active systems with an oxide capping layer.

Get in touch!

Are such combinations of various techniques on one single platform missing in your tool portfolio?

Does this versatile module fit into your existing CLUSTERLINE® 200 units, or are you considering a cluster just with PEALD modules? We will be happy to discuss the various options with you!

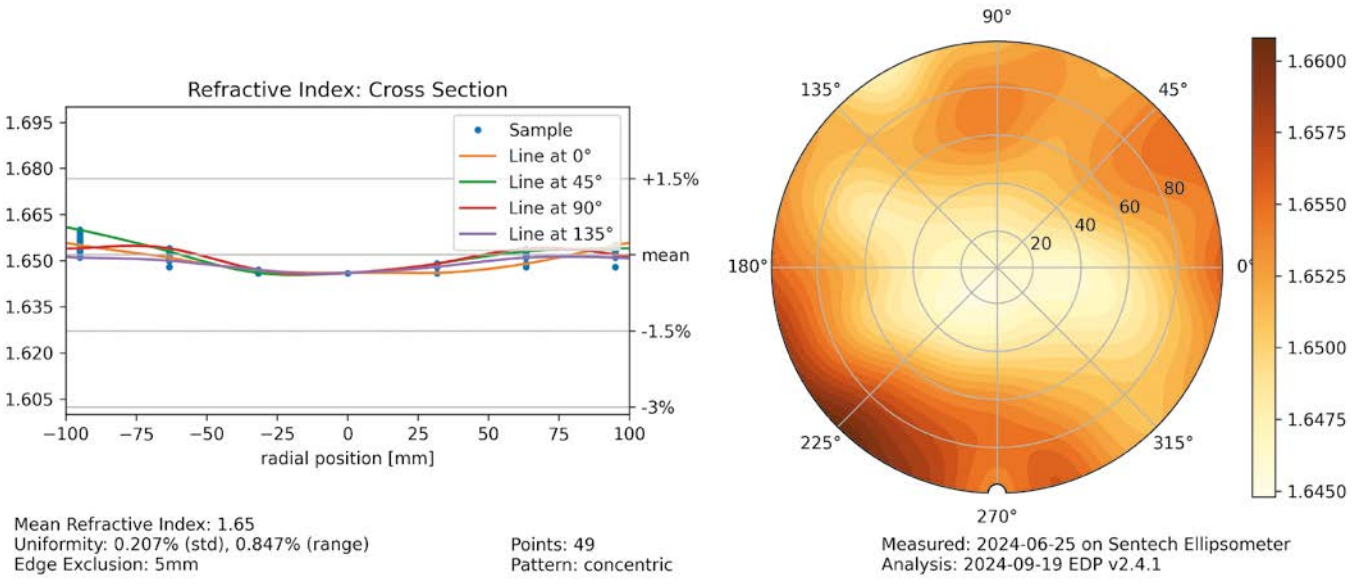

Figure 2: Refractive index uniformity of a 45 nm thin layer of Al_2O_3 prepared by PEALD

Why Evatec PEALD?

Excellent conformality:
Homogeneous film thickness, even on complex geometries.

Precise thickness control:
Ideal for very thin films.

Consistent film properties:
Ensuring optimal material quality.

Flexibility:
Integration of PEALD module alongside PVD, PECVD & etch on CLUSTERLINE® 200.

Process characteristics and module features

Process temperature:
RT – 500°

Deposition pressure:
$2 \cdot 10^{-3}$ – 0.2 mbar

Plasma excitation:
ECR @ 2.45 GHz

Gas lines:
Up to 9

Precursor vessels:
2 or more

Want to know more?

Not familiar with the CLUSTERLINE® platform? Then why not watch the short CLUSTERLINE® family video to learn about Evatec's range of solutions on 200, 300 and 600mm.

To learn more about PEALD contact your local Evatec office