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Bringing Novel Applications to Large Area with Advanced Sputtering Solutions

Kenny Vernieuwe, Felix Mattelaer, Ignacio Caretti, Wilmert De Bosscher
Soleras Advanced Coatings, Deinze, Belgium

Sputtered oxide thin films hold enormous potential in a wide range of both mature and growing new applications, from energy-efficient glazing and advanced displays to next-generation energy generation and storage solutions. Their unique ability of tunable morphology, providing a desired combination of optical performance and electrical properties, makes them a key component for emerging technologies. Among the various deposition methods, sputtering of ceramic targets has proven to be a versatile and efficient technique for producing high-quality oxide thin films with tailored properties. This study investigates the role of recently developed ceramic target materials in achieving high deposition rates, enhanced material utilization and improved film properties compared to traditional sputtering of metallic targets. Ceramic targets offer superior thin film stoichiometric control, ensuring precise composition of the deposited thin films. Furthermore, combining these targets with advanced sputtering and inline metrology equipment provide enhanced process stability, allowing to maintain film uniformity and composition in large area and industrial production environments. The introduction of easy-to-use process control tools as part of an advanced system software platform enables achieving and sustaining the desired performance of these thin films. Our presented findings will highlight the immense potential of ceramic targets in advancing technologies for use in electrochromic devices, photovoltaic systems, and thin-film batteries. By enabling high-performance solutions, ceramic target-based sputtering addresses the growing demand for functional coatings in large-area applications. These innovations unlock new possibilities for scalable and sustainable technologies, making sputtered oxide thin films from ceramic targets and in combination with advanced magnetron and process capabilities a cornerstone for future advancements in materials science and engineering.

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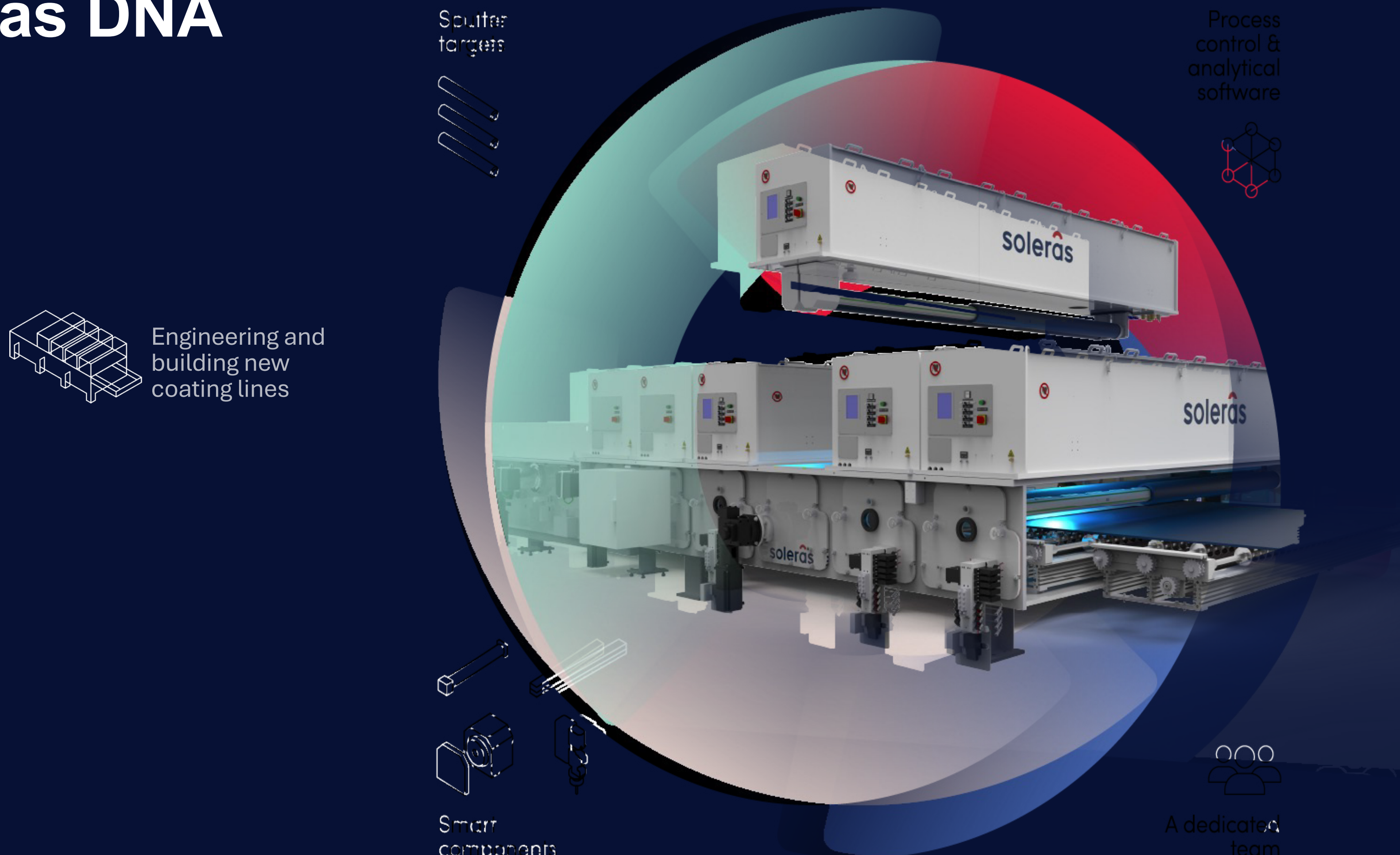
Soleras DNA


Sputter targets
Engineering and building new coating lines
Process control & analytical software
soleras
Smart components
A dedicated team

Functional Metal Oxide Thin Films

Scalable solutions for the deposition of high-quality oxide thin films may be desired for next-gen energy applications:

- Photovoltaics
- H_2 generation
- H_2 utilization
- Thin film batteries

New Generation Ceramics
Benefits Enabled by Soleras

Benefits of ceramic targets

Reduced requirement of reactive gas
- Reducing cross talk

No hysteresis
- Improved process stability

Tailored composition
- Wide range of suboxidic oxides

Higher dep rates than metals in reactive mode

Manufacturing challenges solved by Soleras

Enhanced mechanical toughness
- No more fracturing or cracking

Improved thermal conductivity
- Reduced thermal load to substrate

Modified electrical conductivity
- Long-term process stability

Case Studies
Justification

Case study I: Sputtering of NiO_x thin films via Ni and NiO_x targets

- Low-e
- Electron blocker layer in photovoltaics
- Counter electrode in electrochromic devices
- Photo-catalyst

Case study II: Sputtering of $LiCoO_x$ thin films via $LiCoO_x$ targets

- Thin film batteries
  - Consumer electronics
  - Medical devices

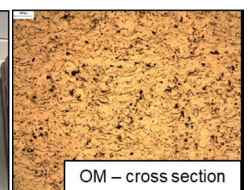
Case study III: Integrated coater solutions

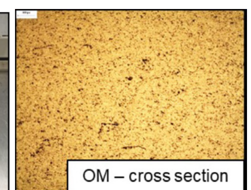
I) Sputtering of Ni and NiO_x Targets

Sputtering of NiO_x Films via Ni and NiO_x Targets

	Ni	NiO_x
Thickness	6 mm	6 mm
Purity	≥ 99.9 %	≥ 99.9 %
Density	≥ 85 %	≥ 95 %
Oxygen	≤ 500 ppm	x on request: e.g. 0.75
Maximum DC power	18 kW/m	15 kW/m*
Maximum AC power	36 kW/m	30 kW/m*
Available target length	3.9 m	3.9 m

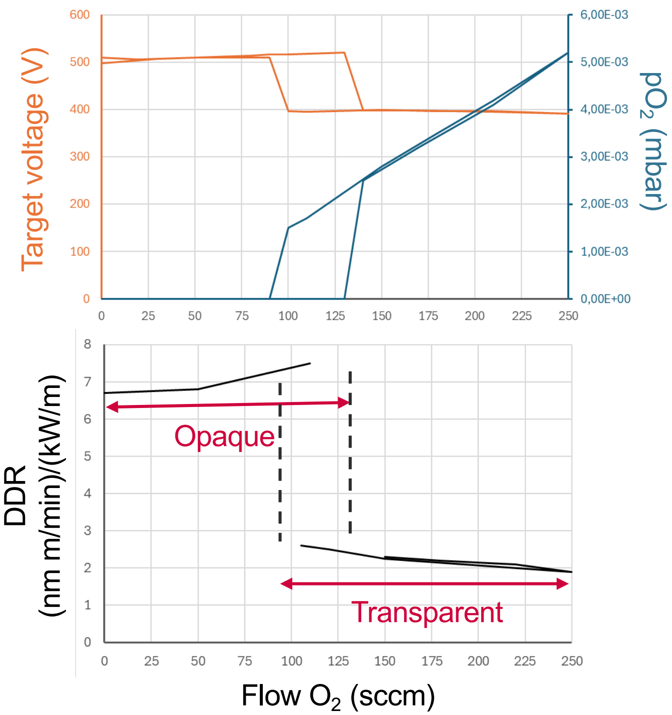
*Maximum has not been determined yet



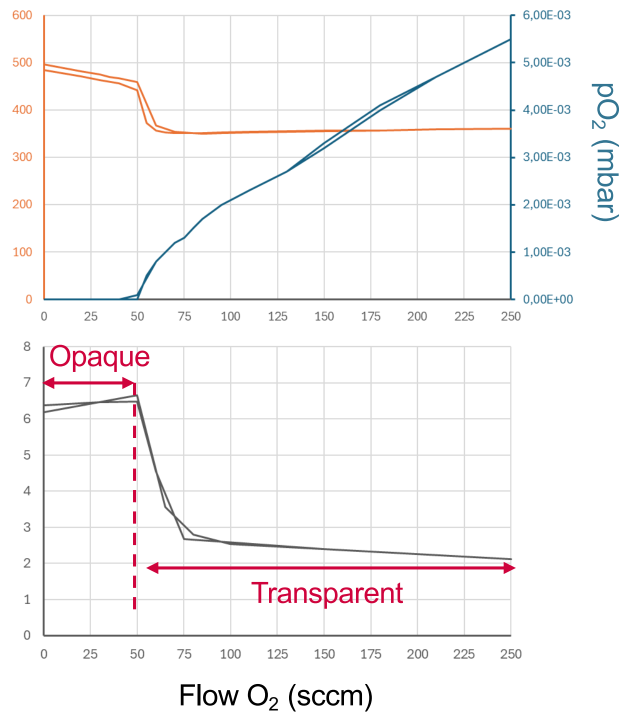


Sputtering of NiO_x Films via Ni and NiO_x Targets

Sputtering of Ni target



Sputtering of NiO_x target



Sputtering of Ni target:

- Typical hysteresis behavior
- DDRs in the range of 2 – 2.6 for poisoned sputtering

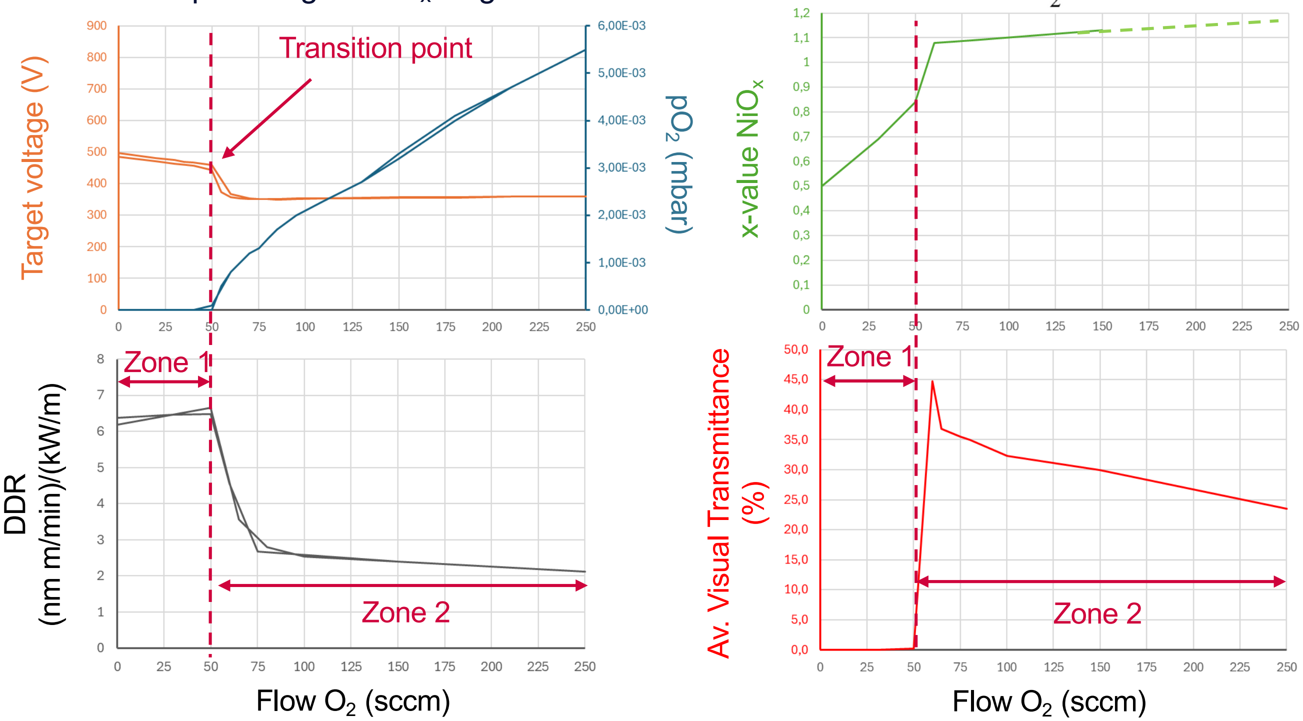
Sputtering of NiO_x target:

- No hysteresis
- Sharp transition point at lower pO_2
- DDR of 4.5 for fully oxidic films feasible

➢ ***2 x faster*** with ceramic NiO_x target

Sputtering of NiO_x Films via NiO_x Targets

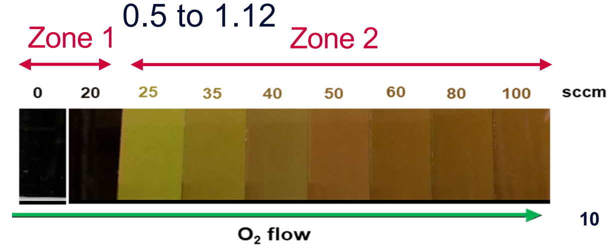
$$2Ni^{2+} + \frac{1}{2}O^{2} \rightarrow O^{2-} + V_c + 2Ni^{3+}\ *$$



Control chemical composition and optical properties :

- Zone 1: ‘metallic mode’
  - Opaque coatings with a suboxidic nature.
- Zone 2: ‘poisoned mode’
  - Transparent coatings nearly stoichiometric composition

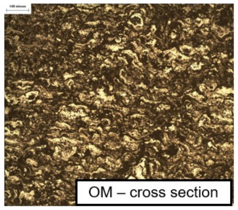
➢ **Optical properties** can be controlled
➢ **x-value** can be controlled from 0.5 to 1.12



II) Sputtering of $LiCoO_x$ Films via $LiCoO_x$ Ceramic Targets

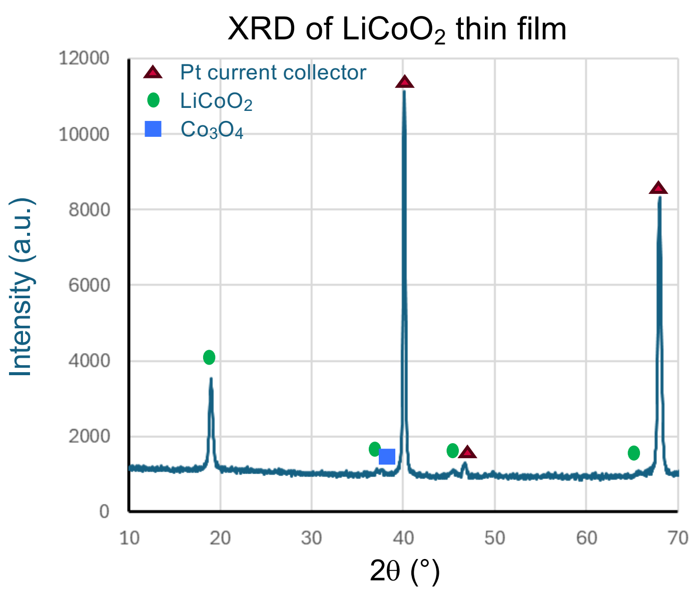
Sputtering of $LiCoO_x$ Films via $LiCoO_x$ Ceramic Targets

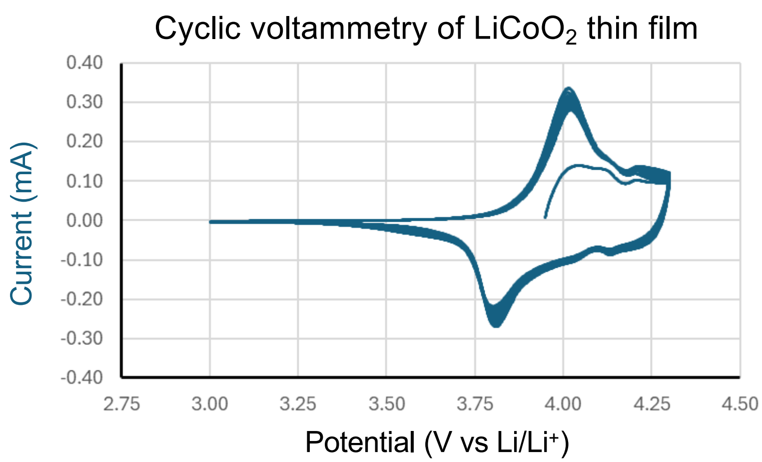
	$LiCoO_x$
Thickness	6 mm
Purity	≥ 99.9 %
Density	>4 g/cm³
Oxygen	x = 1.71 ± 0.05
Maximum DC power	20 kW/m
Maximum AC power	40 kW/m
Available target length	2 m



Sputtering of $LiCoO_x$ Films via $LiCoO_x$ Ceramic Targets

200 nm thick $LiCoO_2$ film deposited via 35-inch $LiCoO_x$ targets.
$LiCoO_2$ film received post annealing at high temperature





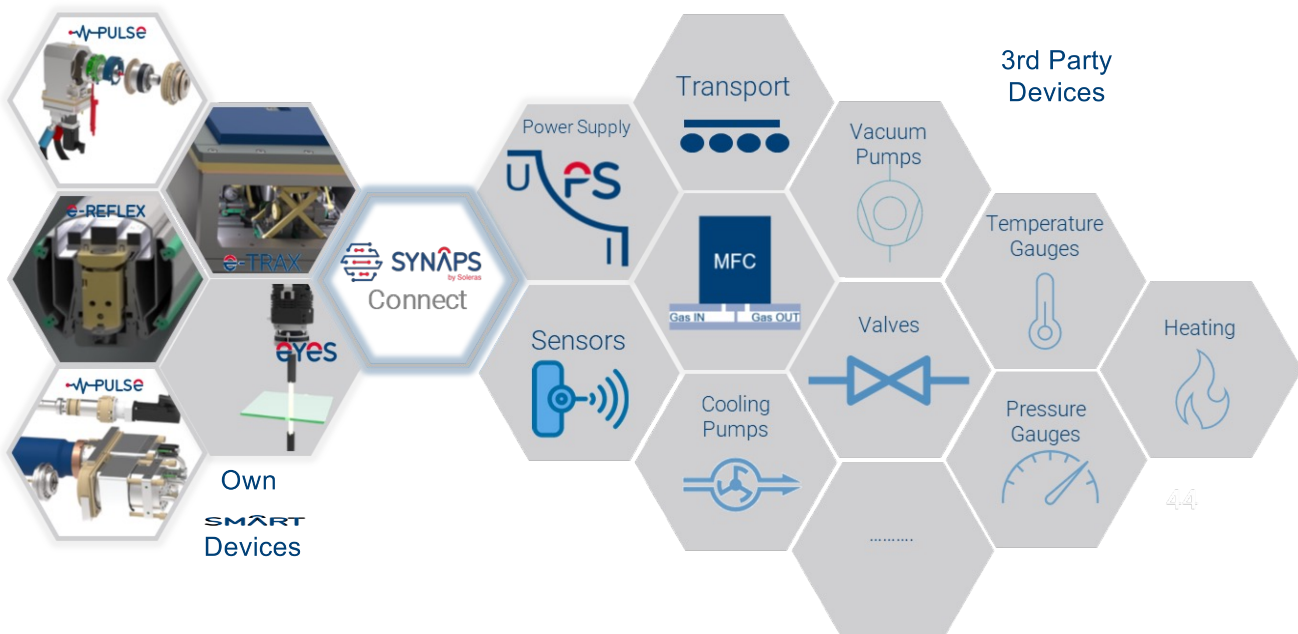
XRD illustrates the presence of crystalline $LiCoO_2$ with a preferred growth of (003) plane.

CV shows typical $LiCoO_2$ behavior: Co^{3+}/Co^{4+} transition during lithiation and delithiation

III) Integrated Coater Solutions

Smart Components Controlling Your Process

Soleras is offering easy-to-use process control tools which can be integrated in a software platform.



Synaps communicates and drives 3rd part devices and Soleras' smart components

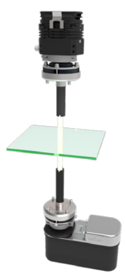
Soleras' smart components allow bidirectional communication:

- Setting parameters
- Reading sensor data
- Actuating motorized devices

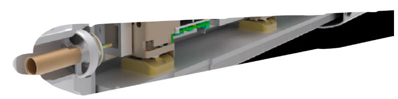
Providing:

- Better understanding of process and equipment condition
- Control and improvement of the deposited layer properties

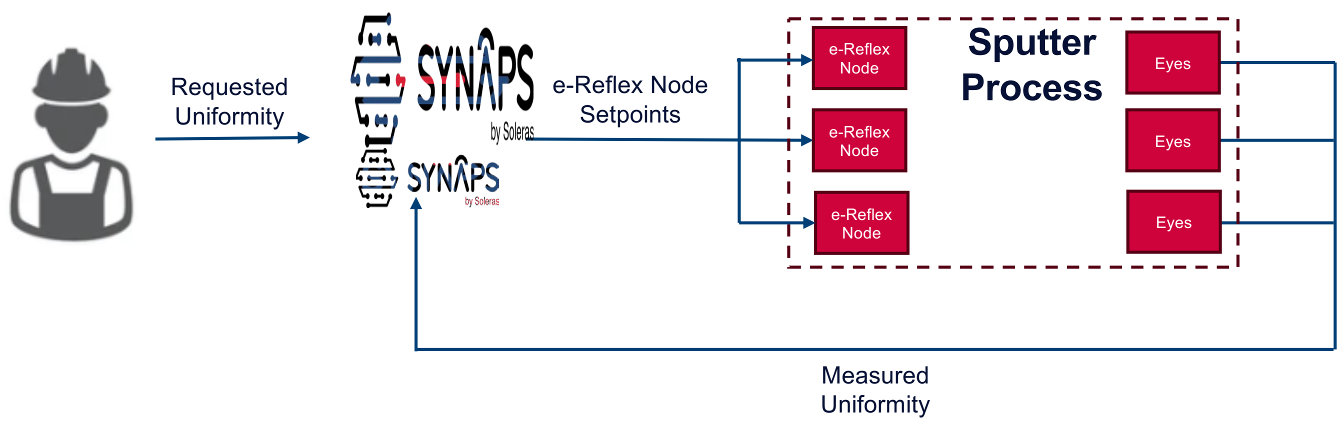
Tuning Film Uniformity through Synergy between Eyes and e-Reflex with Synaps Closed-Loop



Eyes
In-situ spectroscopy
- Creating spectral time-based data (UV to NIR) with high sampling rate
- Self calibrating devices with status monitoring



e-Reflex
Online magnetic field adjustment with absolute node positioning
- Including condition monitoring (temperature, water flow, …)



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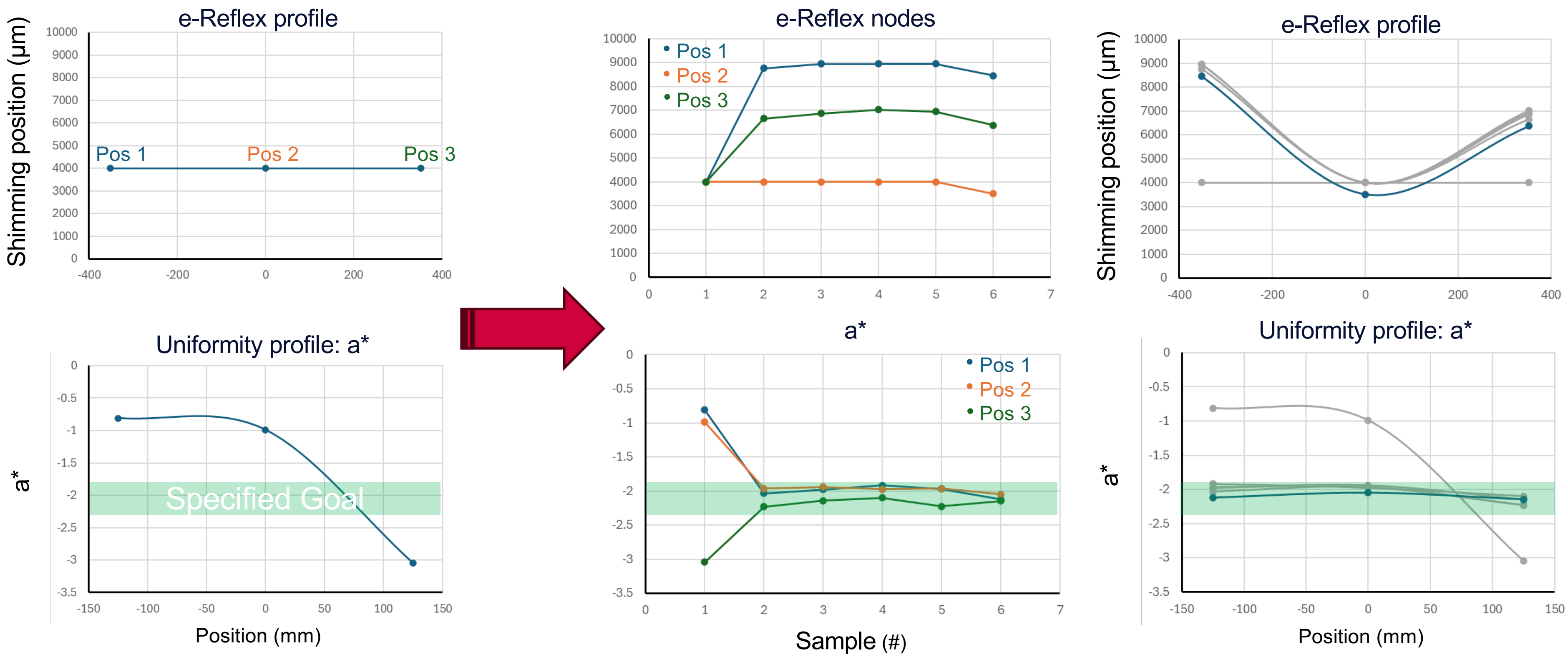


Key Takeaways

What We've Learned

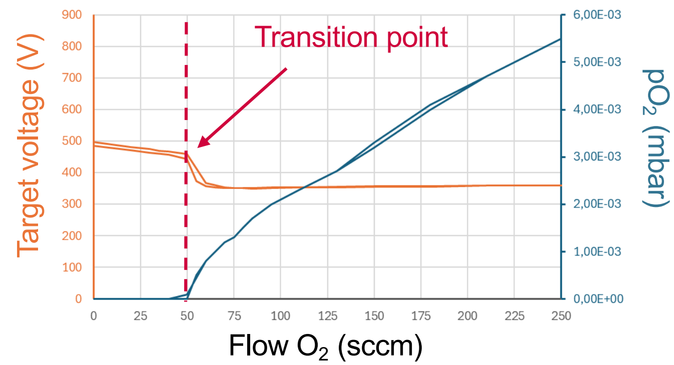
Depositing oxide thin films via **ceramic target** has multiple benefits:

✓ Lack of hysteresis behavior

✓ Lower O_2 consumption

✓ Higher DDR possible

✓ Tuning of chemical and optical properties

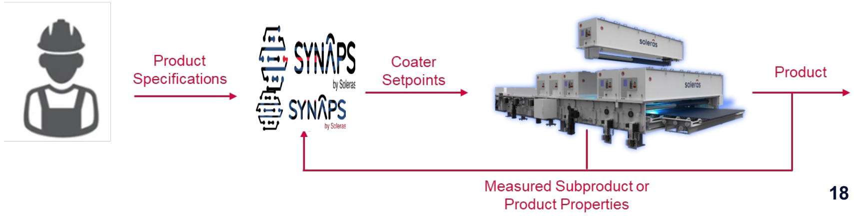


Film uniformity can be inline controlled

through the integration of **Soleras' smart devices and software**

- Synergetic effect between Eyes and e-Reflex

  tuning film uniformity via Synaps Closed-Loop controller

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Thank you!
Any questions?

Kenny Vernieuwe
Thin Film Expert
T: +32 498 18 93 00
kenny.vernieuwe@soleras.com