High-Rate Metal and Clear Barrier Deposition for Packaging Applications

Roland Trassl

Applied Materials

CCR workshop on Barrier Technologies
Sep 20th 2012, Arlington,VA

Outline

- About the Company
- Web Coating Products
  - Barrier Coatings by Al Metallization
  - Transparent Barriers by Reactive Evaporation
  - Transparent Barriers by Plasma-Assisted Reactive Evaporation
  - Barrier Improvement and Protection by TopCoat
  - High-Barrier Layers by PECVD
- Summary

VISION

We apply nanomanufacturing technology to improve the way people live.

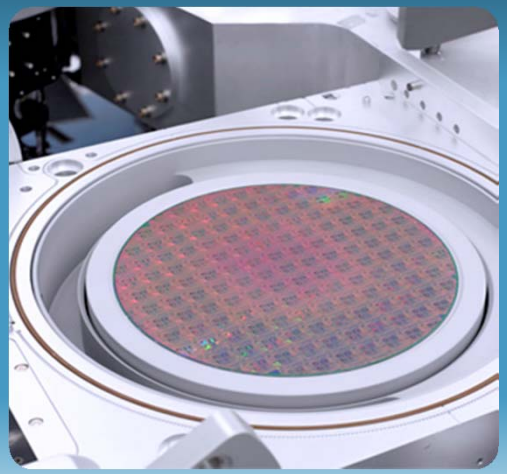
at a glance…

Stock Ticker:	Nasdaq: AMAT
Market Cap*:	$13.8 billion
Fiscal 2011 Revenue:	$10.5 billion
Fiscal 2011 R&D:	$1.1 billion
Founded:	November 10, 1967
Headquarters:	Santa Clara, California
Global Presence:	88 locations in 19 countries
Fortune 500 Ranking:	251
RD&E and/or Manufacturing Centers:	China, Germany, Israel, Italy, Singapore, Switzerland, Taiwan, United States
Employees*:	~14,600 worldwide
Patents:	~10,050 issued

* As of May 16, 2012. Fiscal year-end October 30

The Most Exciting Industries on Earth

Semiconductor

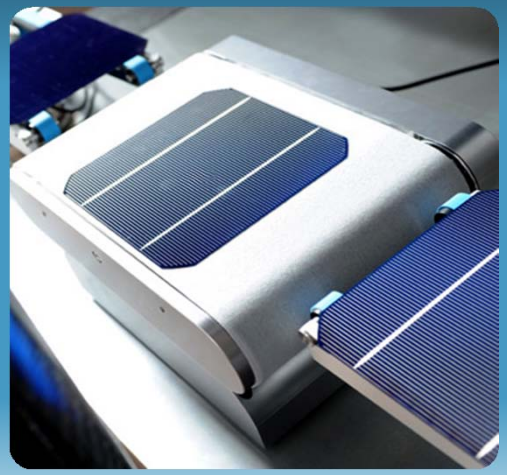


20,000,000x
reduction in
COST PER TRANSISTOR
in 30 years[1]

Display

20x
reduction in
COST PER AREA
in 15 years[2]

Solar



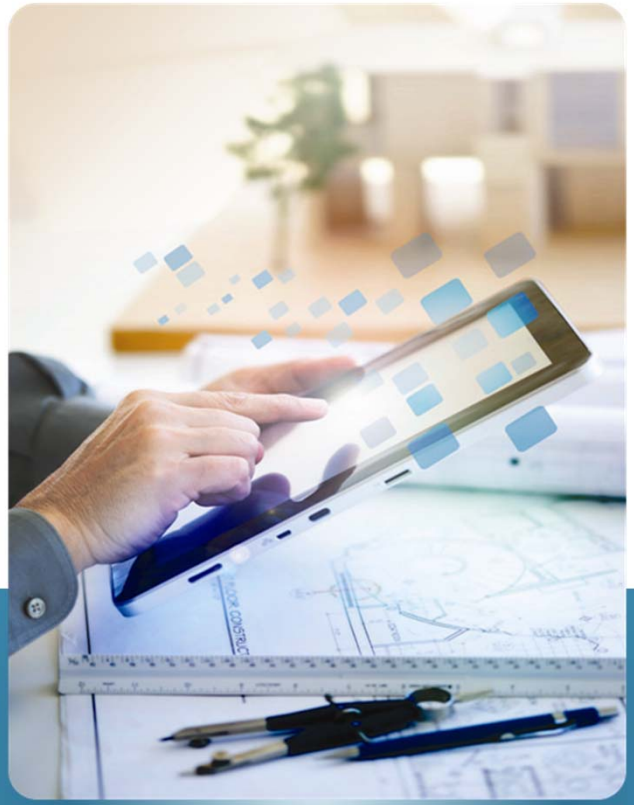
5x
reduction in
COST PER WATT
in 4 years[3]

At 1976 transistor prices,
an iPod® would cost $3.2B

1 Source: SIA, IC Knowledge LLC
2 Source: Display Search, Nikkei BP, Applied Materials
3 Source: Photon Consulting 2012

APPLIED MATERIALS®

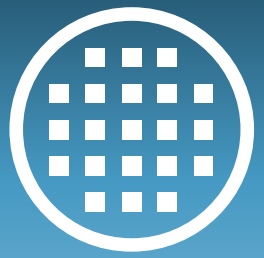
Mega Trends



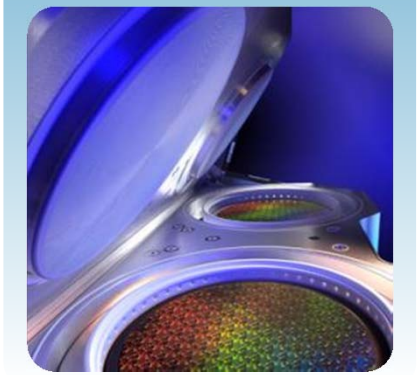
The Mobility Age

Clean Energy

Business Segments

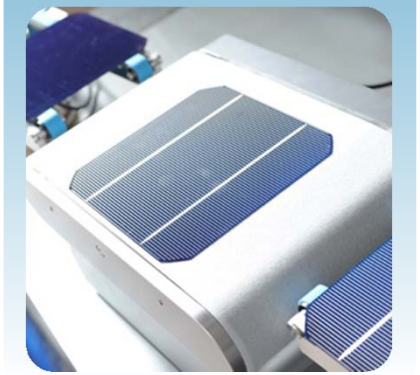


Semiconductor



Display

Energy and Environmental Solutions



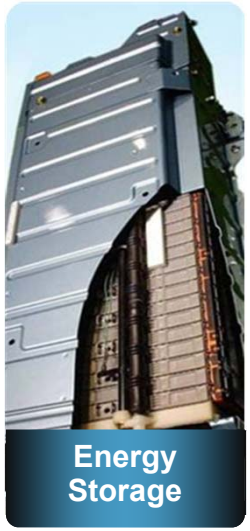
Applied Global Services

Energy and Environmental Solutions

#1 PV Equipment Provider*

Powering the c-Si Roadmap
Driving down cost/watt and balance of system (BOS)

- Advanced cell technologies
- Both scale and technology
- Greater efficiency
- Lower production costs
- Grid parity



Accelerating global photovoltaic (PV) adoption by delivering cost-effective solutions that integrate technology, equipment and materials to improve factory productivity and increase cell efficiency.

* Source: VLSI Research 2012

APPLIED MATERIALS®

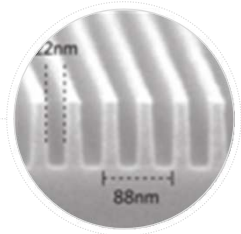
Global Scale and Reach

Technology Center Alzenau

- **Display Coatings**
  - Color Filter
  - TFT
  - OLED

- **Roll to Roll Coatings**
  - Flex Electronics
  - Flex PV
  - Packaging
  - Special applications
- **Solar Coatings**
  - Wafer based solar cells
  - Equipment TF PV

- **New Technologies**
  - Electrochromics
  - Advanced energy products



Challenges for Barrier Coatings at High Productivity

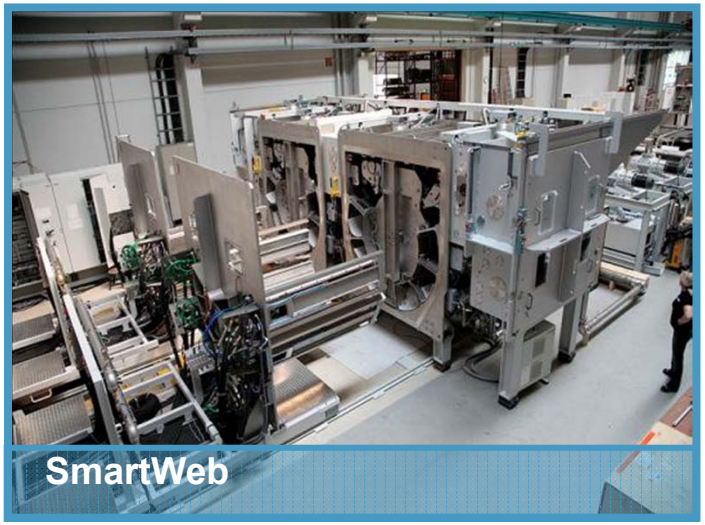
- **Barrier**
  - OTR, WVTR dependent on substrate material
  - wide variety of materials and qualities
- **Layer Properties**
  - high uniformity over large substrates and long coating length
- **Adhesion of the Coating to the Substrate**
  - optimization on downstream processes
- **Minimum Defects**
  - Roll edge, wrinkles, tramlines, splashes, substrate overheating, electrostatic charging, blocking, …….
- **Cost**

Machine Quality

Machine must ensure stable product quality for 24/7 mass production

- **Barrier**
  - Closed-loop inline coating control, stable and homogeneous vacuum conditions, data logging of all relevant machine parameters
- **Layer Properties**
  - Closed-loop inline process control
- **Adhesion of the Coating to the Substrate**
  - Substrate Pretreatment
- **Minimum Defects**
  - High quality winding system, general machine lay-out

Web Product Portfolio



Most advanced modular R2R sputtering system for flexible electronics and PV (up to 1.4m wide)

Applications

- Flex Touch Panels (ITO, Dielectric Layers, Metals)
- Flex PV (TCO Front Contact, Metal Back Contact)
- Display (TFT)

World`s largest & fastest evaporation metallizers for packaging (up to 20m/sec coating speed)

Standard applications

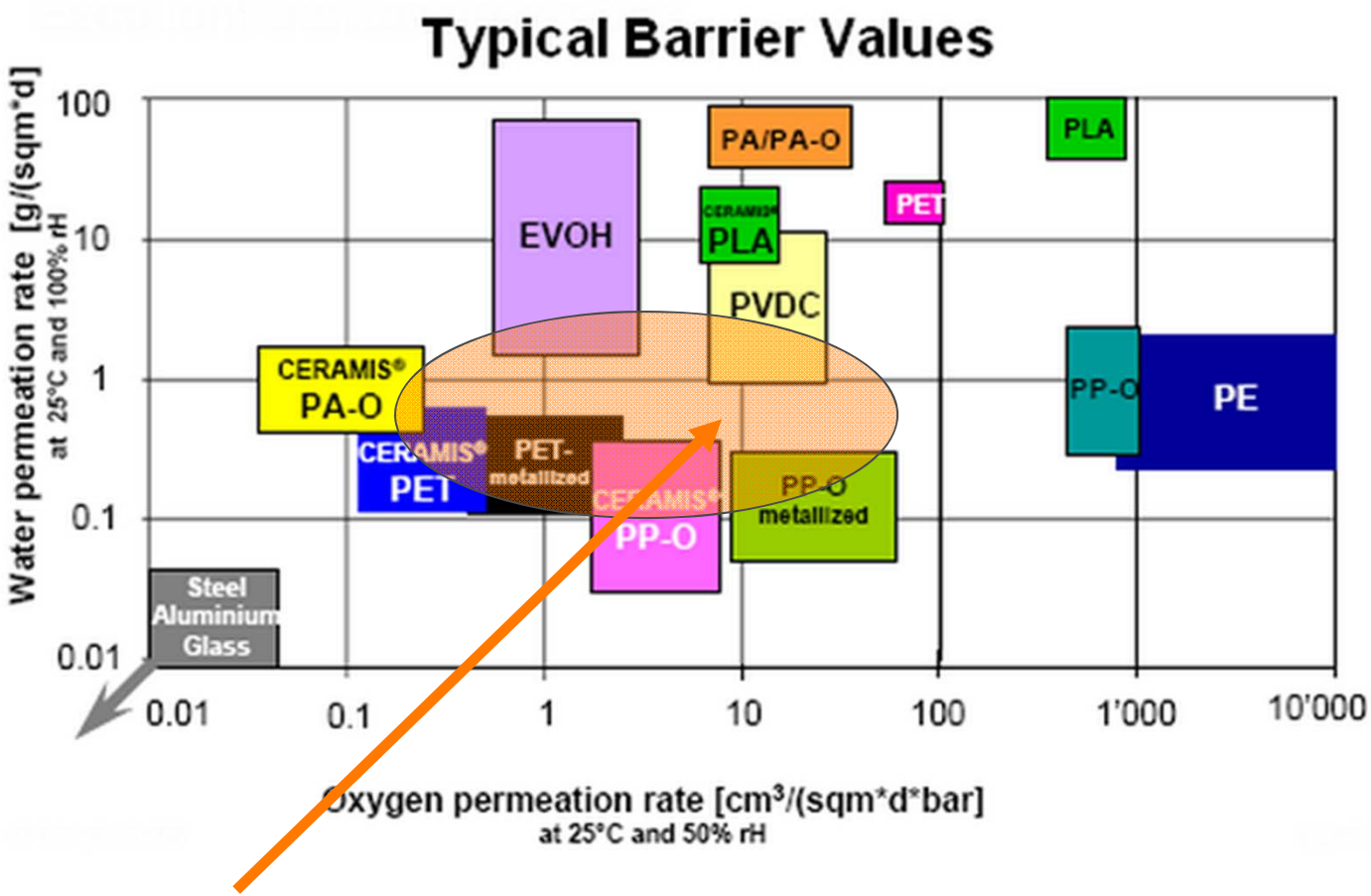
TopMet Std. for Al Barrier Metallization

New advanced applications

TopMet Clear for transparent AlOx barrier layers
TopMet Freshure® for enhanced barrier performance

Large Installed Base >625

Barrier Landscape



Source : Alcan Packaging

Targeted range for TOPMET barrier

TopMet® - the Machine ...

Barrier and Decorative Coating

Improved freshness & shelf life

Decorative coating

- Wide range of substrates from thin plastic films; **PET, OPP, BOPP** & more, to pre-coated papers
- Extremely thin, highly uniform layer of **Al**uminum or **AlOx** as protective barrier to improve freshness and longer shelf life and/or decorative coating for packaging materials.

... to metallize the materials for sophisticated packaging systems.

APPLIED MATERIALS®

Industry Proven Since Early 1990s

TopMet® 4450

World`s largest & fastest evaporation metallizers for packaging (up to 4.5 m wide, 20m/sec coating speed)

- Recognized as industry standard for:
  - Flexibility
  - Productivity
  - Reliability
  - Quality
- Over 50 years of flexible coating technology experience
- ~ 200 TopMet® coaters; 600+ overall coating systems installed worldwide

Overview Product Family

TopMet® Systems for Film and/or Paper Substrates

1250 1650 2050 2450 2850 3250 4450

Substrate types:

- PET, OPP, BOPP, CPP, PVC , Nylon: 10-60µm
- Paper: 20-200g/m²

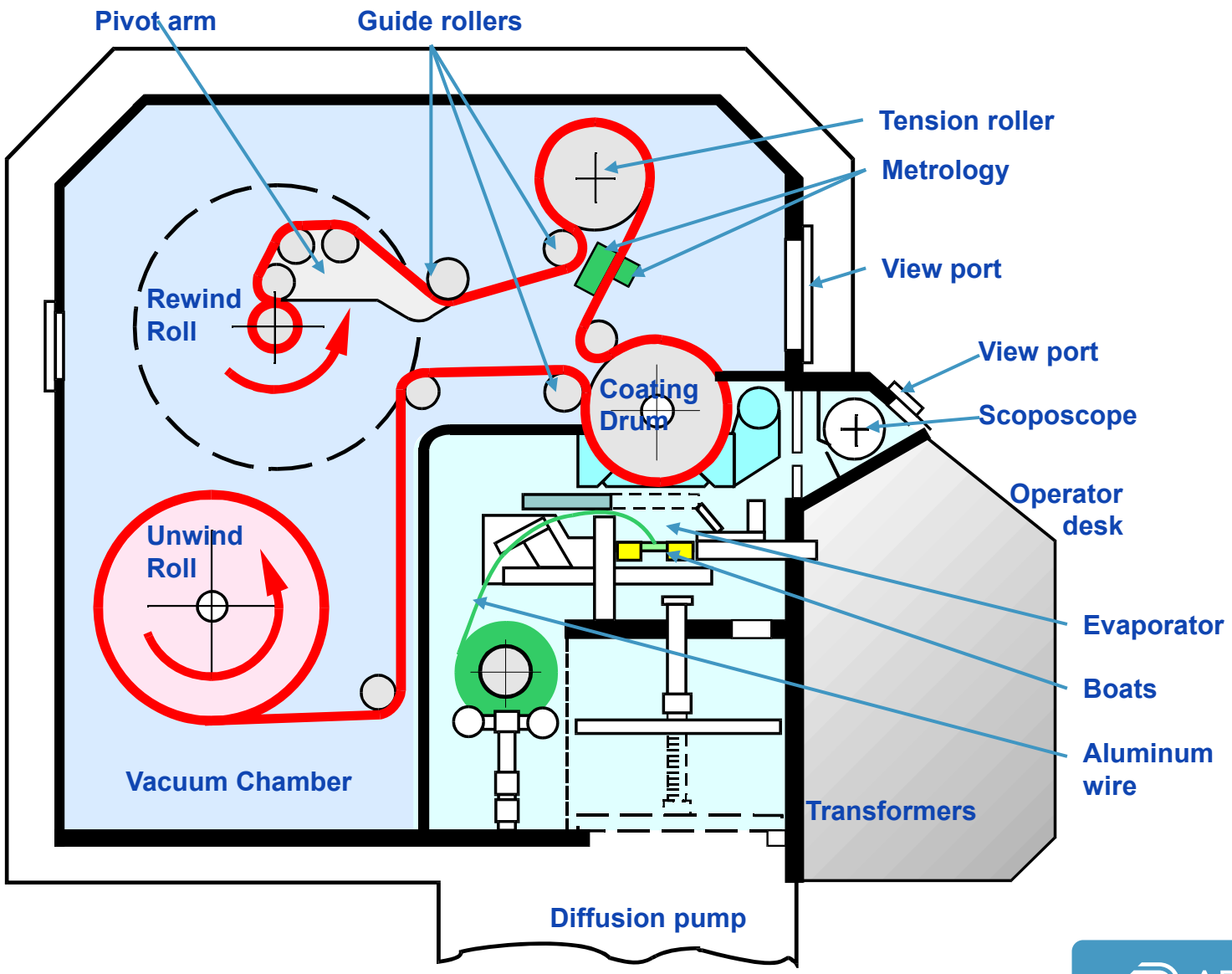
Standard Roll Diameter: 1000 mm

Optional for Film: 1250 mm
Optional for Paper: 1500 mm

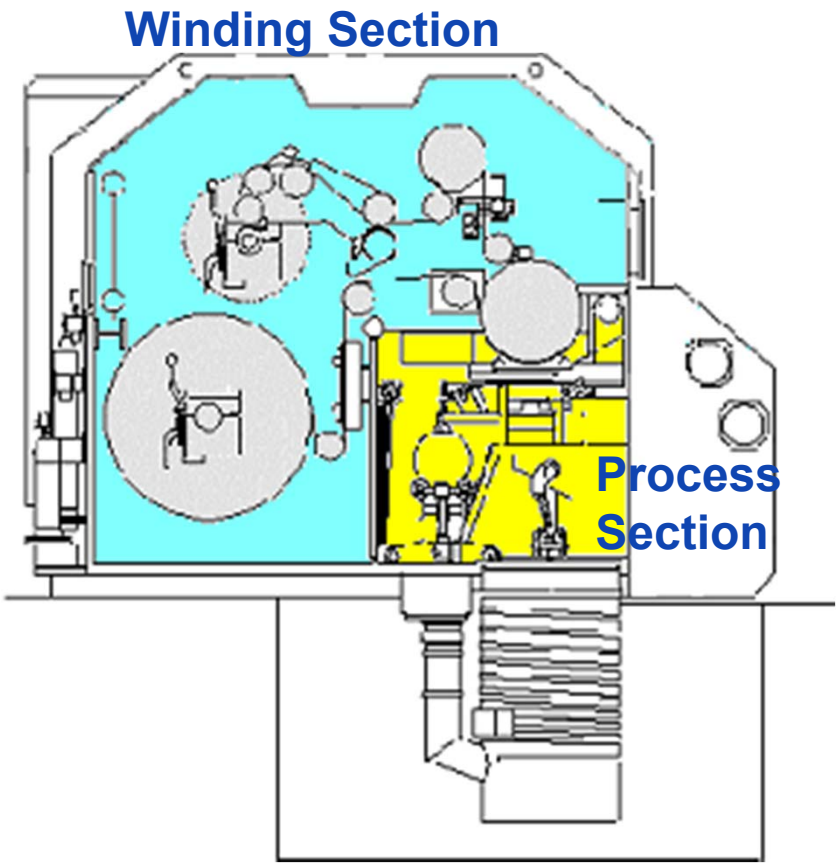
Possible Coating Speed

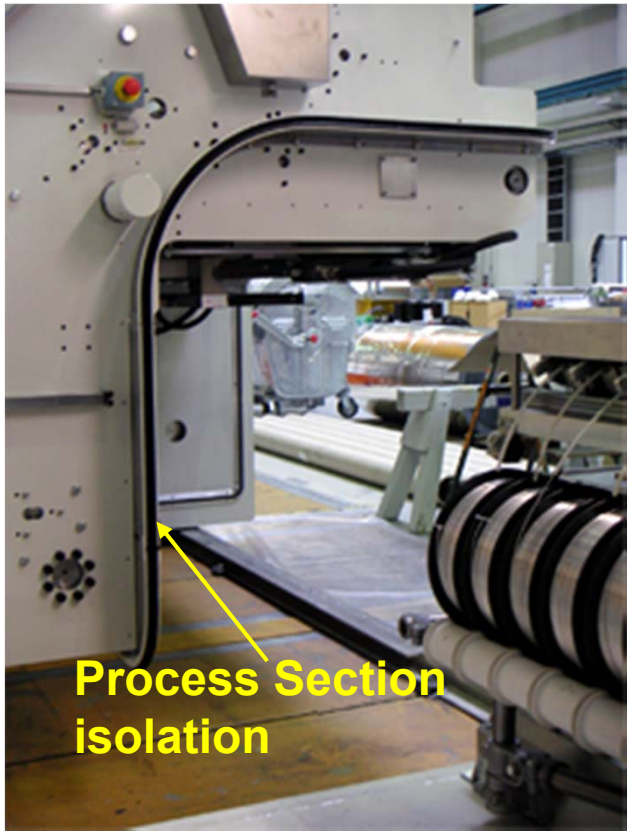
1 - 14 - 17 - 20 m/sec

Basic System Layout – Al Metallization



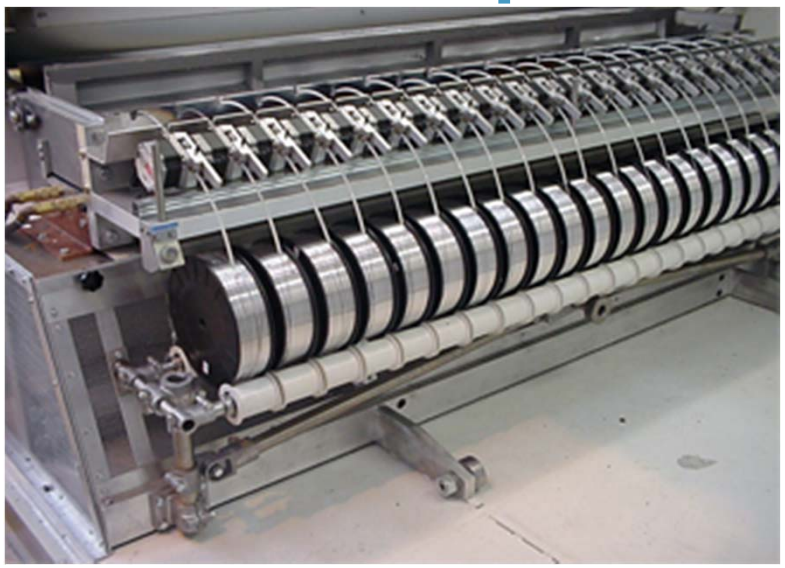
The two chamber-principle ...

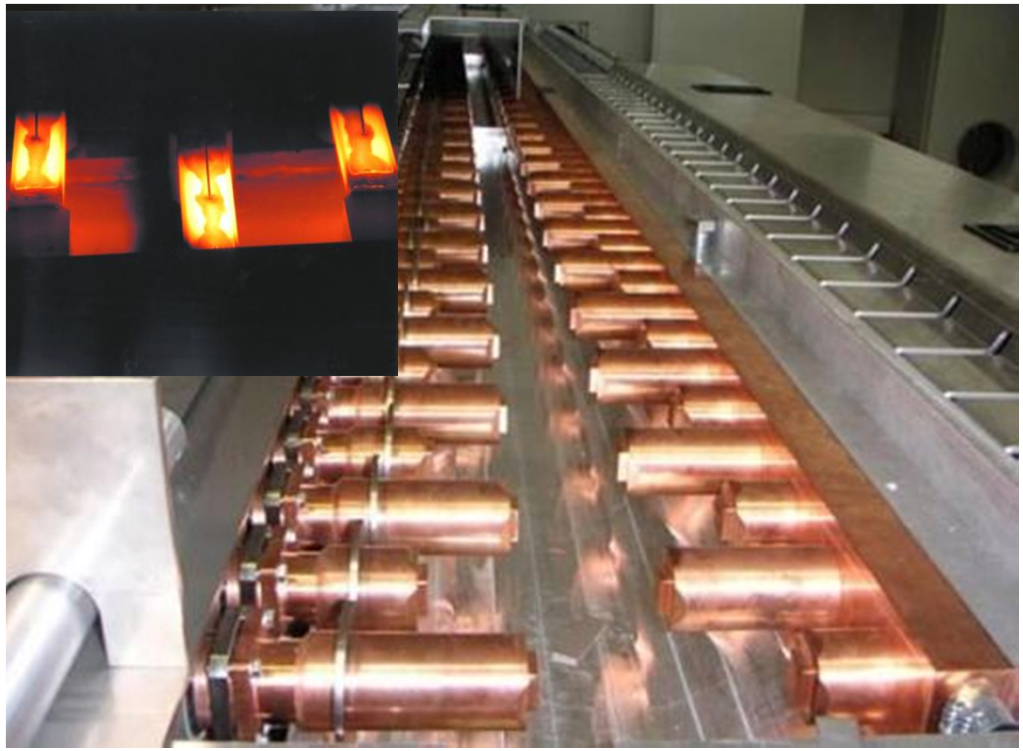




Patented chamber separation by a pneumatic sealing.
Inflation by ambience pressure during pump down.

HiRES™ TopMet® high rate evaporator



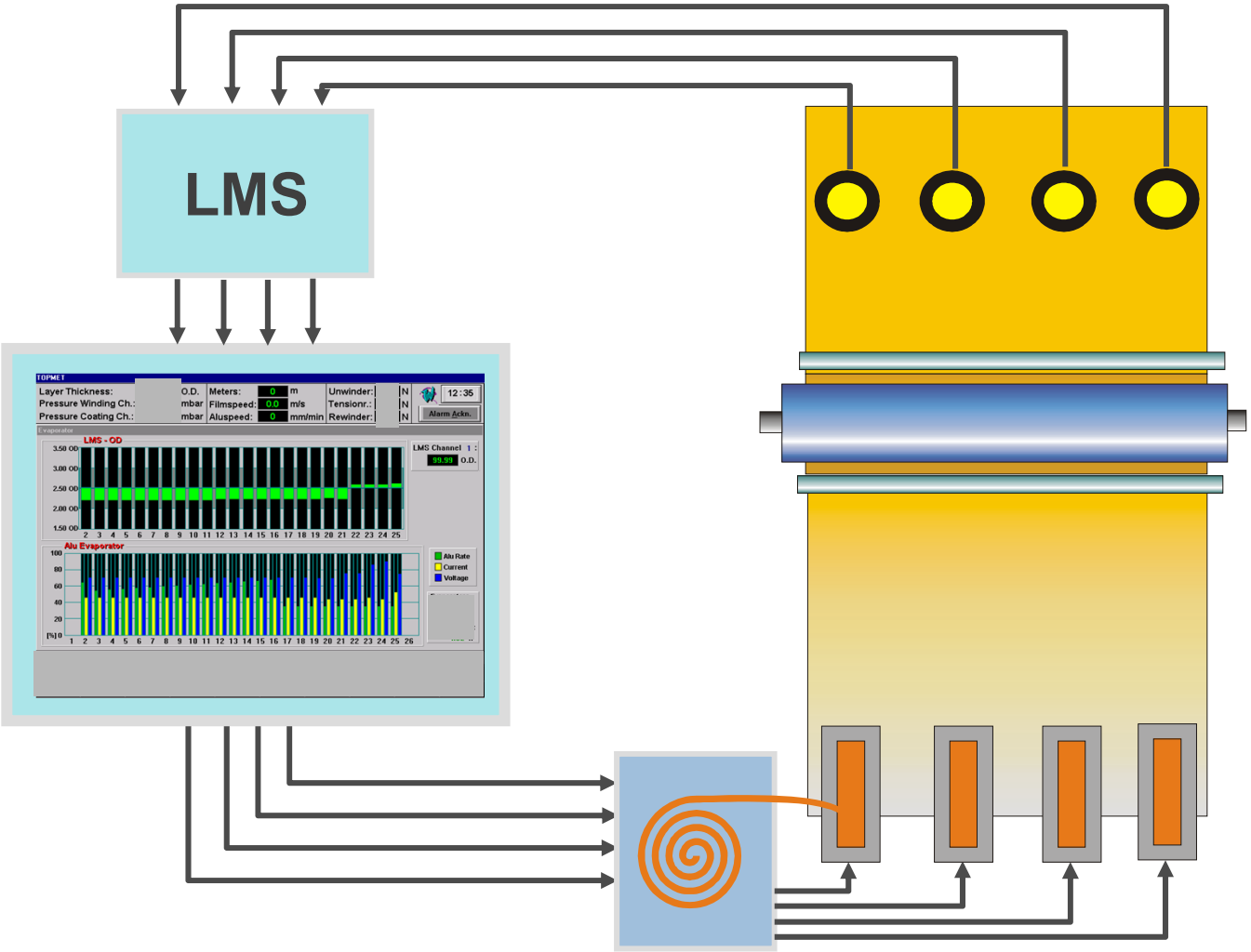


- 25% higher coating speed
- Better layer uniformity
- 10%+ lower costs/sqm or costs/kg
- 5% higher Al efficiency
- System down time less due to bigger roll diameters (1250mm)

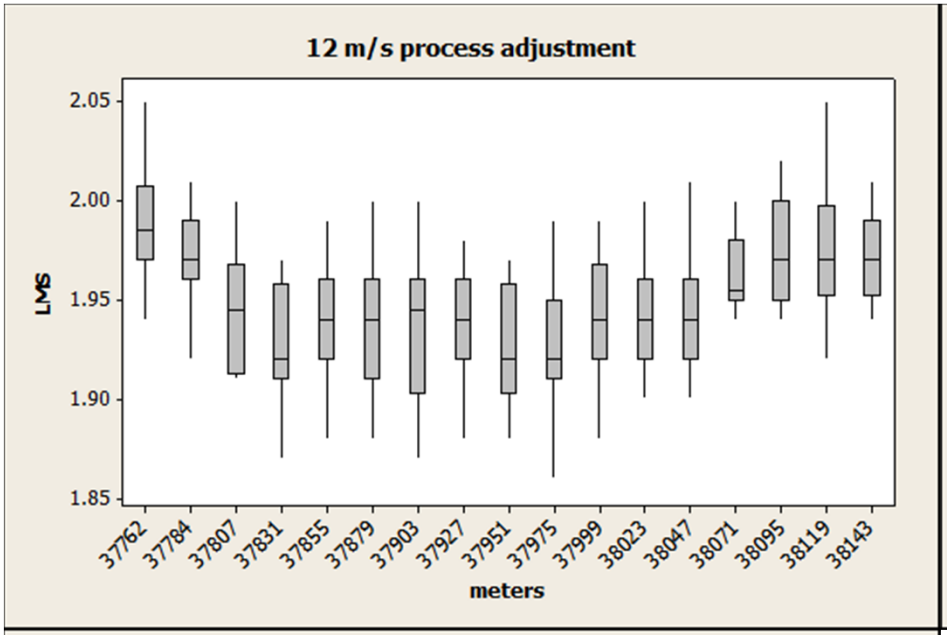
The solution is..

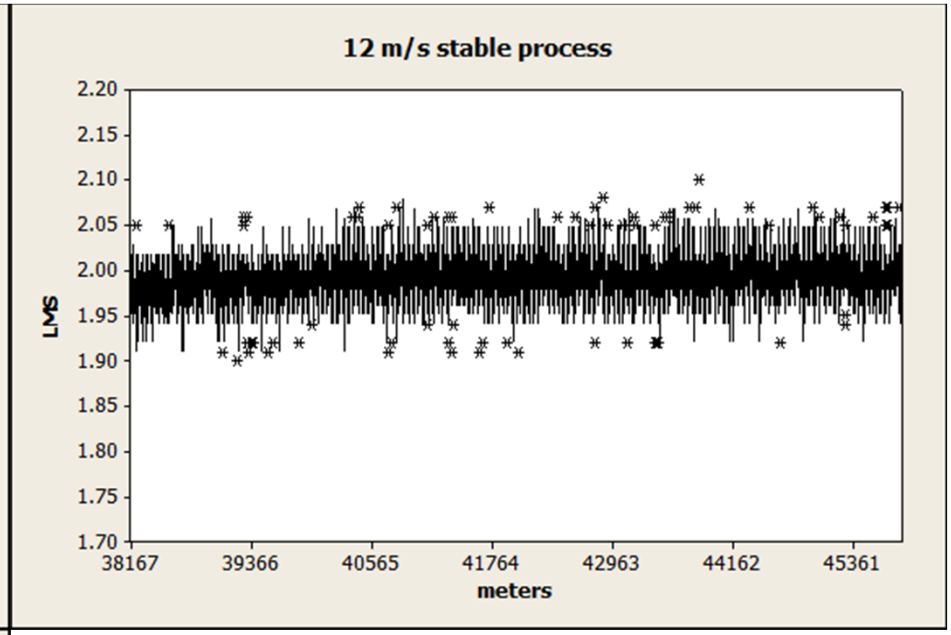
HiRES™ =
HIGH RATE EVAPORATOR SYSTEM
with patented staggered-boat design

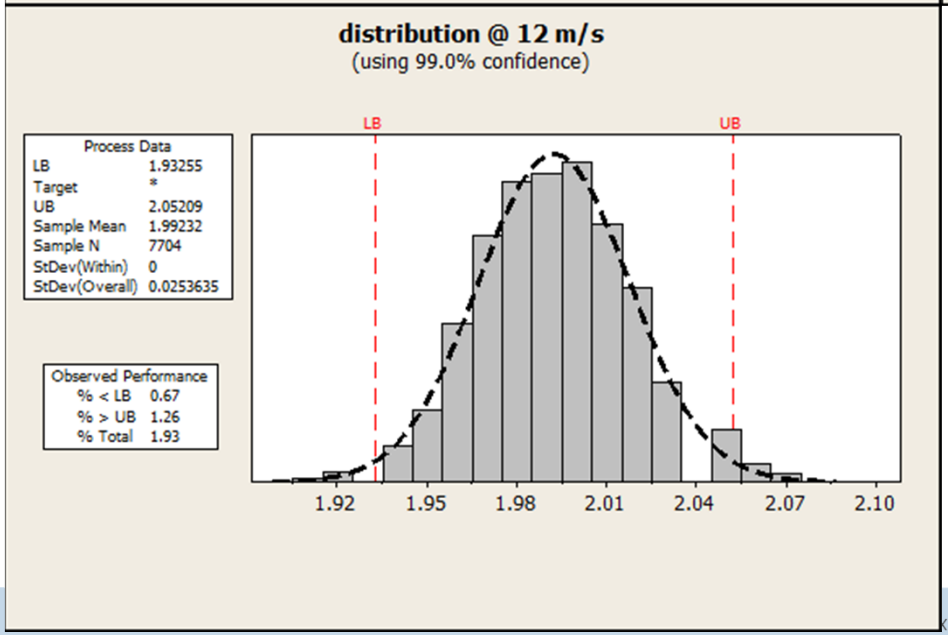
In-Line Process Control



Uniformity of Al Evaporation



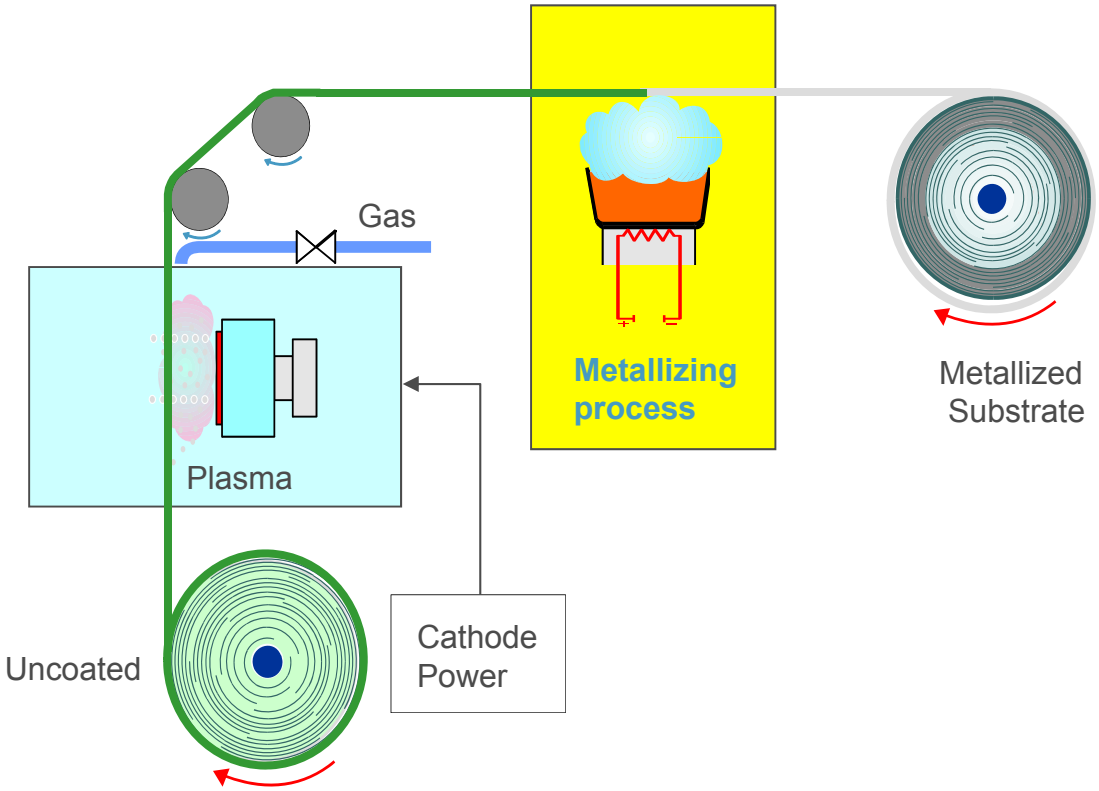


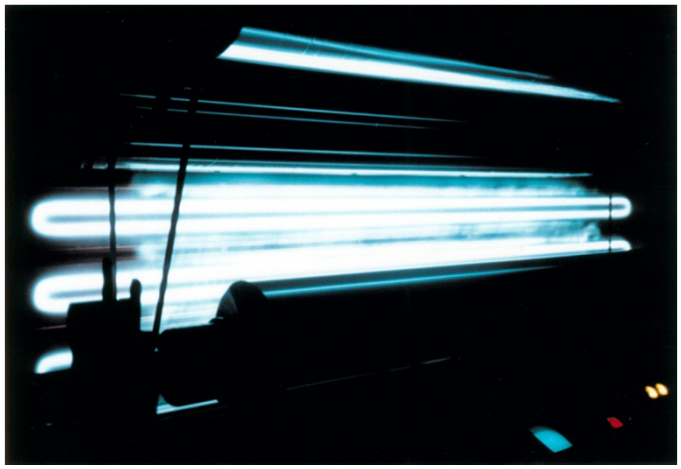


- 2σ uniformity ~ ± 2.5%

Adhesion: TreatMag™ for Substrate Pre-treatment

- Adhesion is key issue for later processing like laminating or retorting
- Can be influenced with inline plasma pretreatment





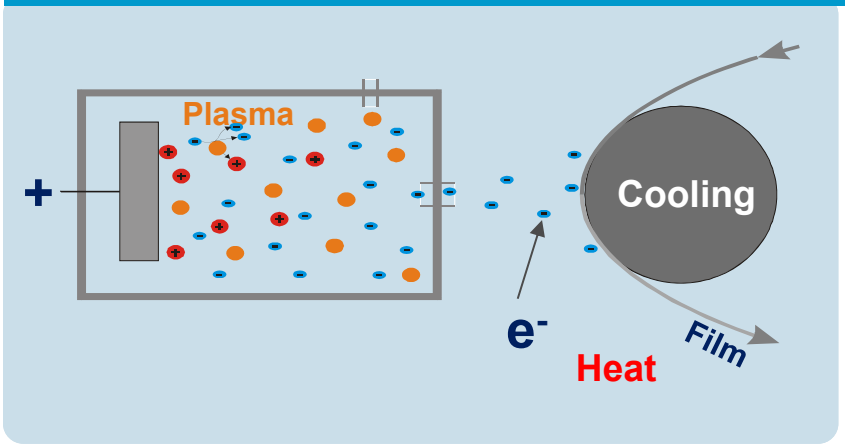
eCharge : Advanced Film Cooling

Innovative System Increases Web Speed & Quality

Benefits

- Better cooling allows higher speeds for heat sensitive films
- Example: eCharge boosts CPP film coating speed from 8 to 13 m/s
- Resulting in 62% boost in speed and 26% reduction in CoO

eCharge System



Problem

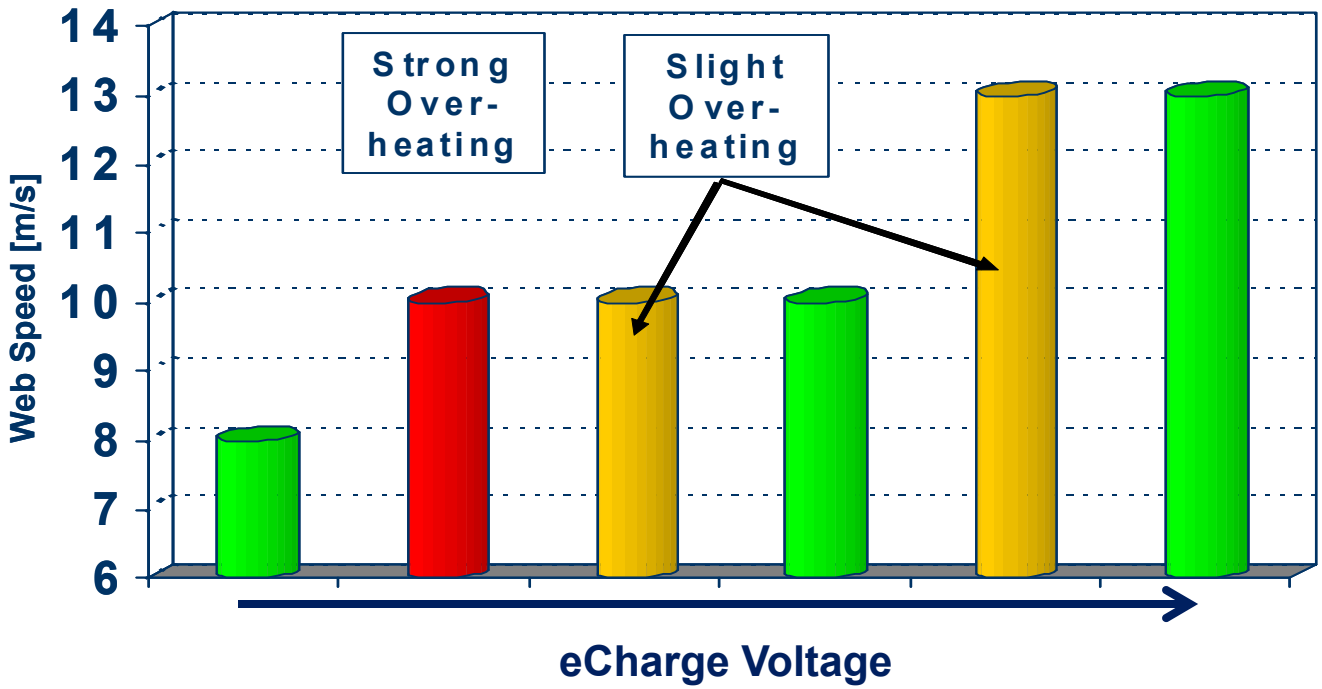
- Normal winding tension leaves small gaps between film and coating drum
- Low contact force=poor heat transfer

Solution

- Apply electrostatic charge to film to increase contact force and improve heat transfer

Patented eCharge enables faster coating speeds for heat-sensitive substrates

Effect of Electron Charging on Coating Productivity



CPP film

20 micron thickness

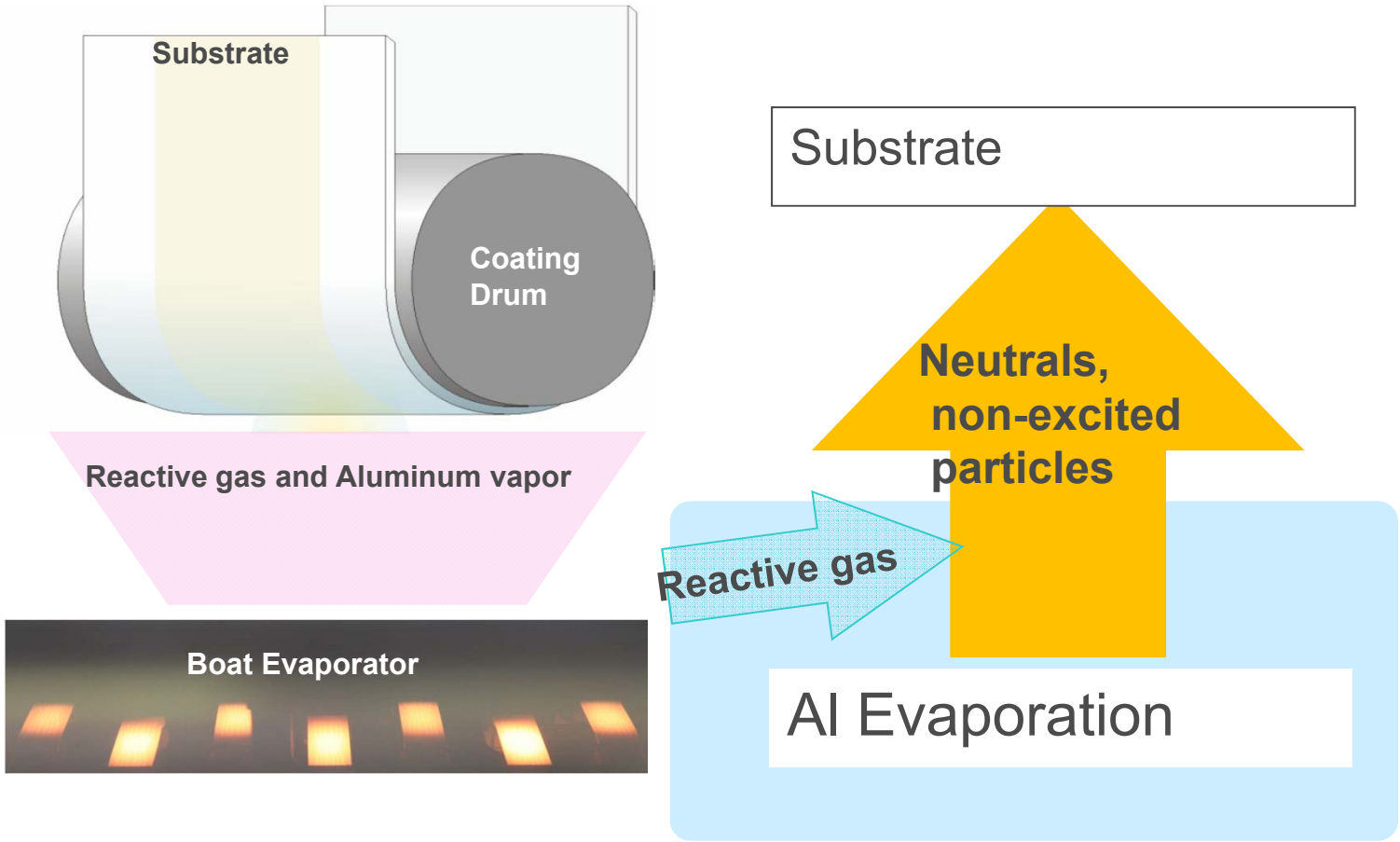
SUBSTRATE	NO E-CHARGE	WITH E-CHARGE
CPP 20µm	web speed: 10m/s tram lines: Increased Potential	web speed: 13 m/s tram lines: none
PLA 25µm	web speed: 6m/s tram lines: Increased Potential	web speed: 10m/s tram lines: none

Barrier Performance of Metallized Substrates

substrate	OTR [cc/m^{2}day]	WVTR [g/m^{2}day]
PET	0.1 – 0.7	0.1 – 0.6
OPP	15 – 30	0.1 – 0.3
CPP	16 – 40	0.1 – 0.5

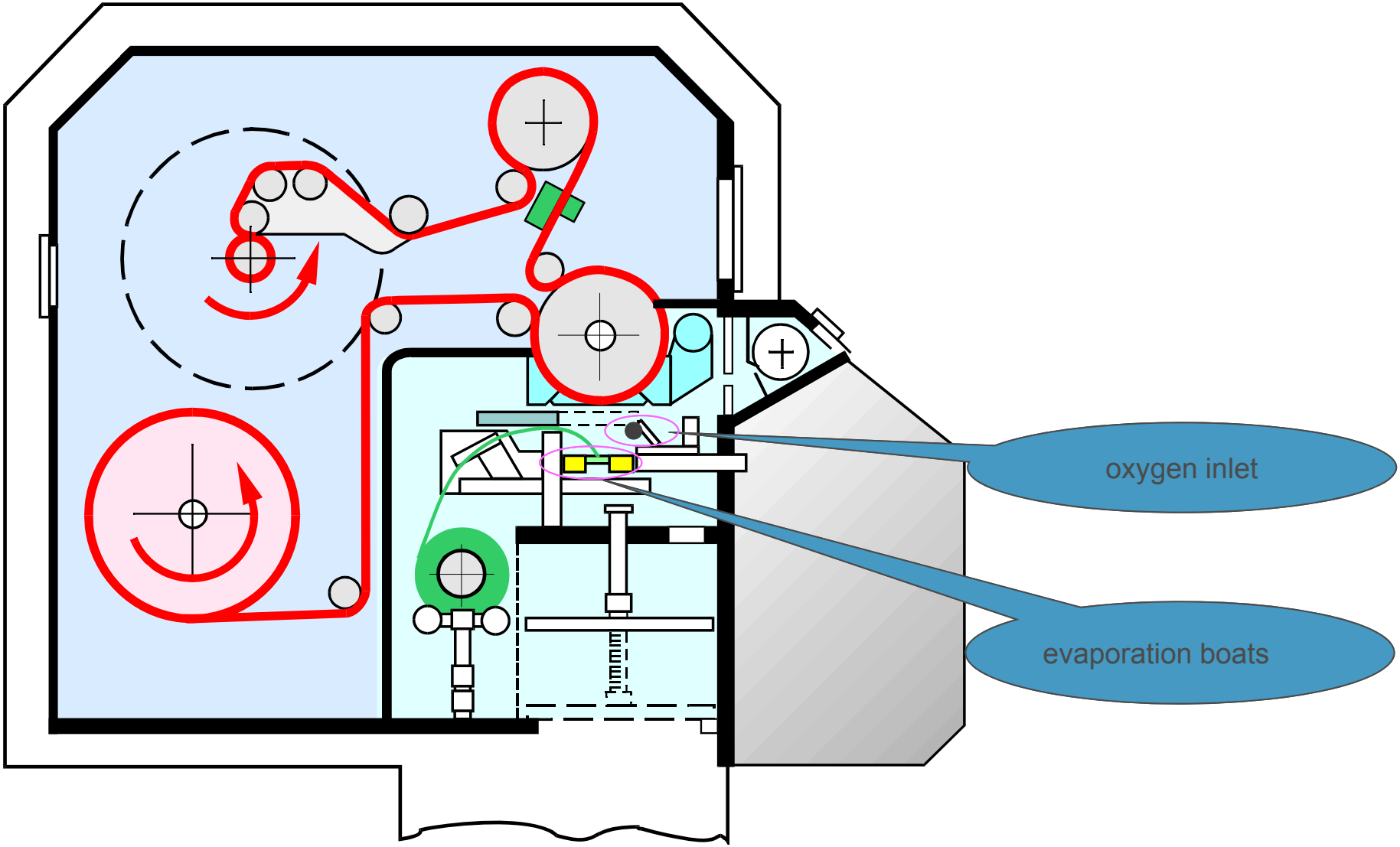
measurement conditions:
OTR @ 23°C, 50% RH
WVTR @ 38°C, 90% RH

Reactive AlO_x - Evaporation



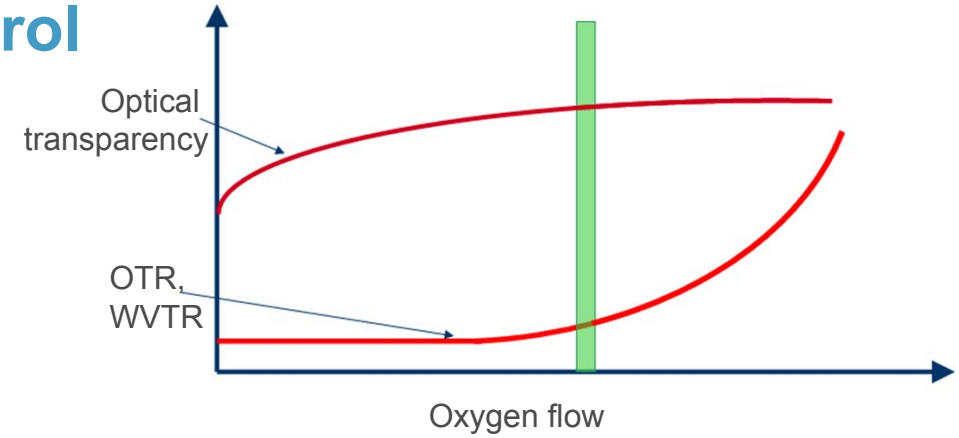
Evaporation of Al + Oxygen Inlet = AlO_x on Substrate

Basic System Layout – AlOx

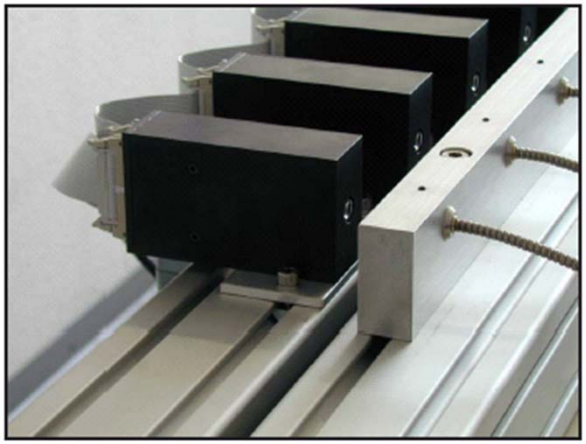


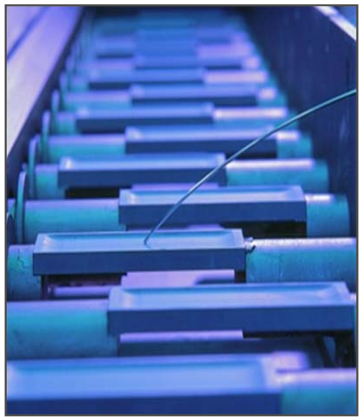
Reactive AlO_x - Evaporation:
Optical Inline Coating Control

Evaporation of Al in oxygen:
- increase in optical transparency
- decrease in barrier performance

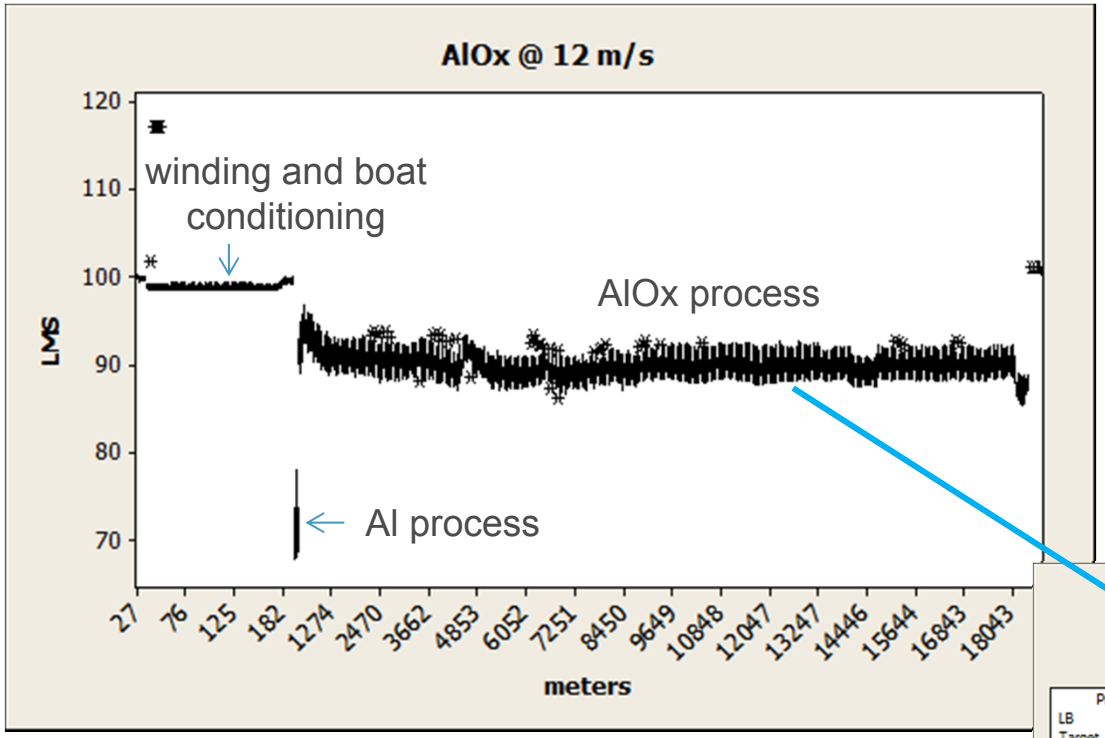


Due to the narrow process window optical inline coating control is essential

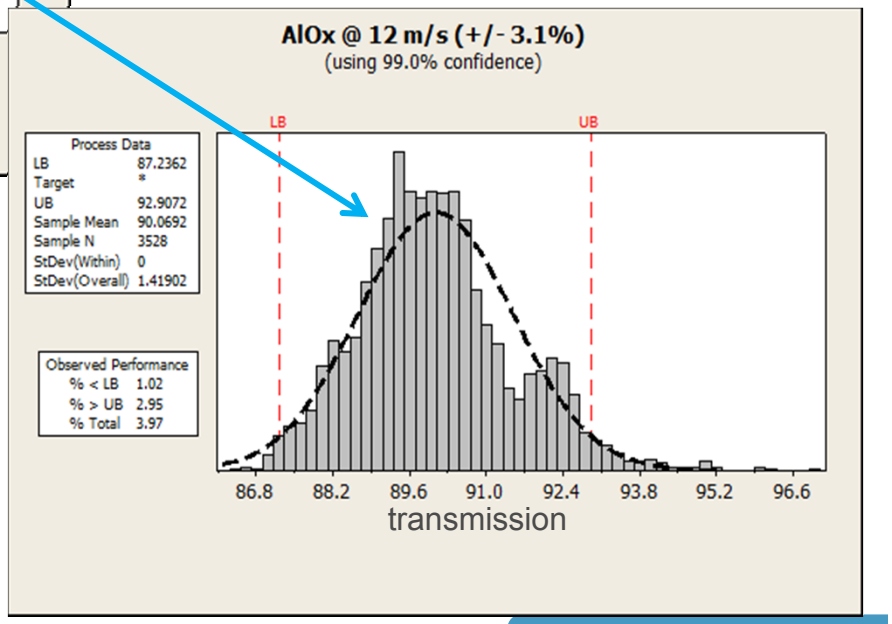




AlOx ECON – Performance



coating width: 1250 mm
process speed: 12 m/s



AlOx uniformity over complete foil ~ ± 3% (2-sigma)

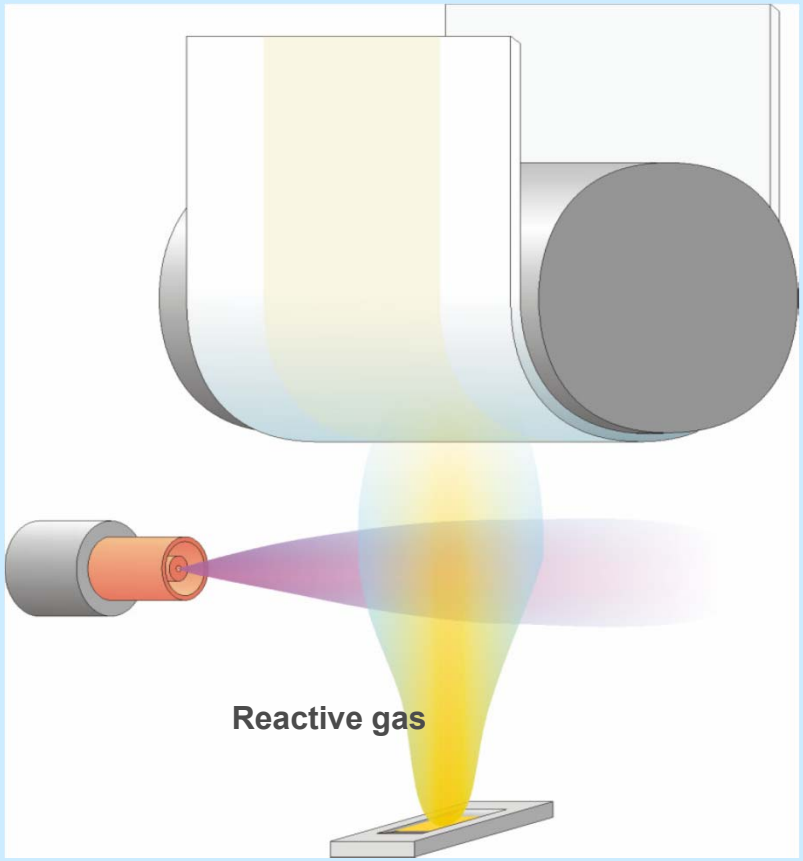
Barrier Performance of AlOx Coated Substrates

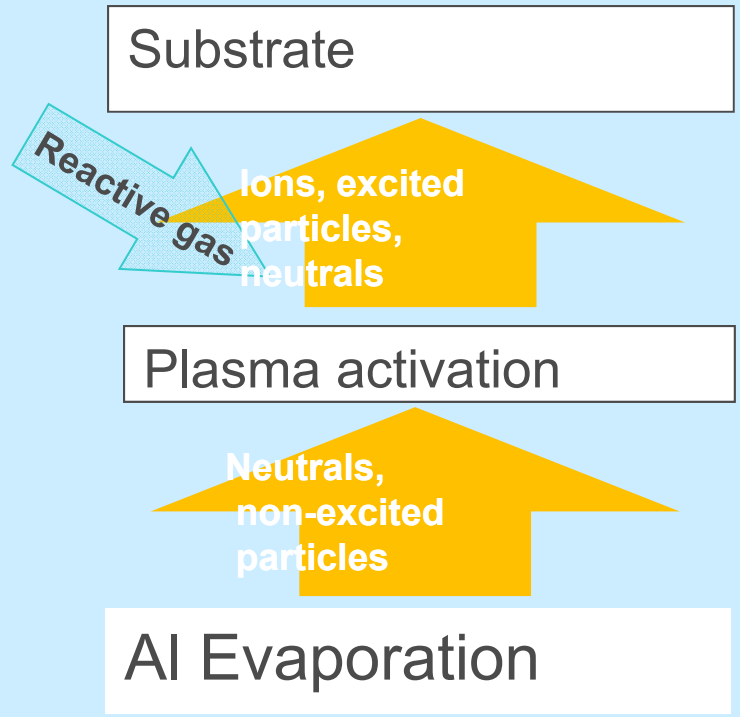
reactive evaporation

substrate	OTR [cc/m^{2}day]	WVTR [g/m^{2}day]
PET	0.8 – 1.2	0.3 – 0.7

measurement conditions:
OTR @ 23°C, 50% RH
WVTR @ 38°C, 90% RH

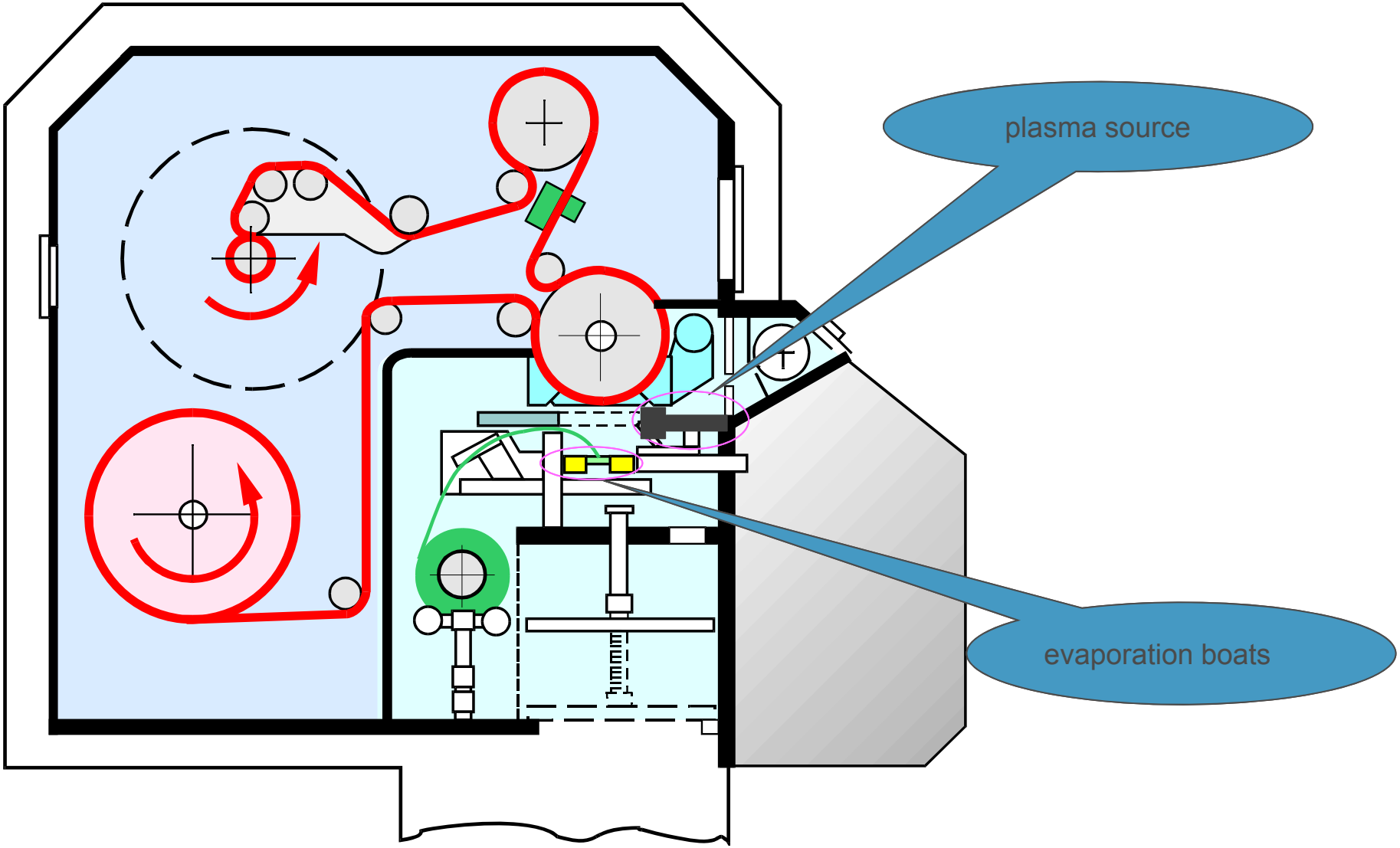
Plasma-Assisted AlO_x - Evaporation



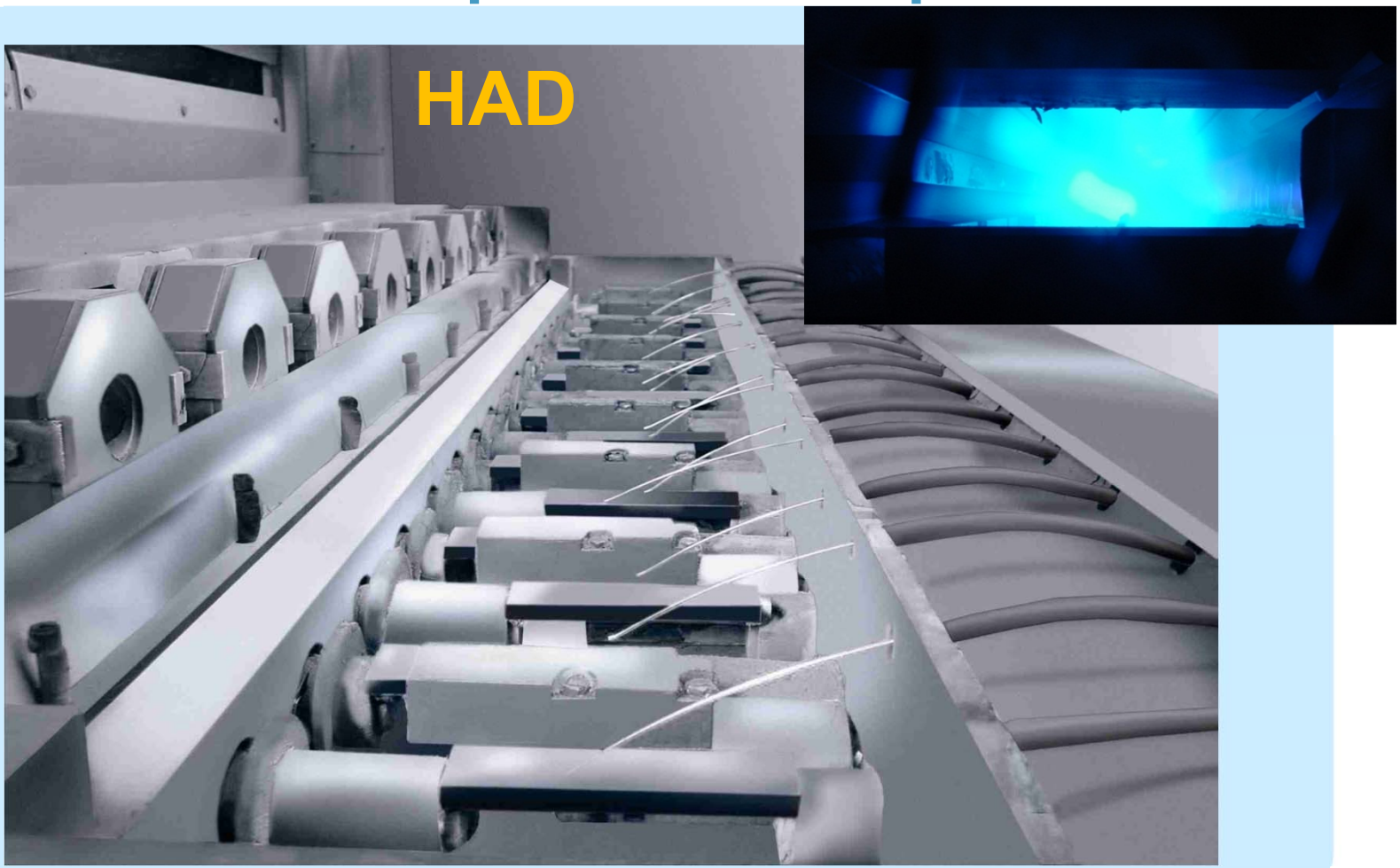


New advanced process developed by and up scaled with the Fraunhofer FEP in Dresden

Basic System Layout – AlOx – HAD



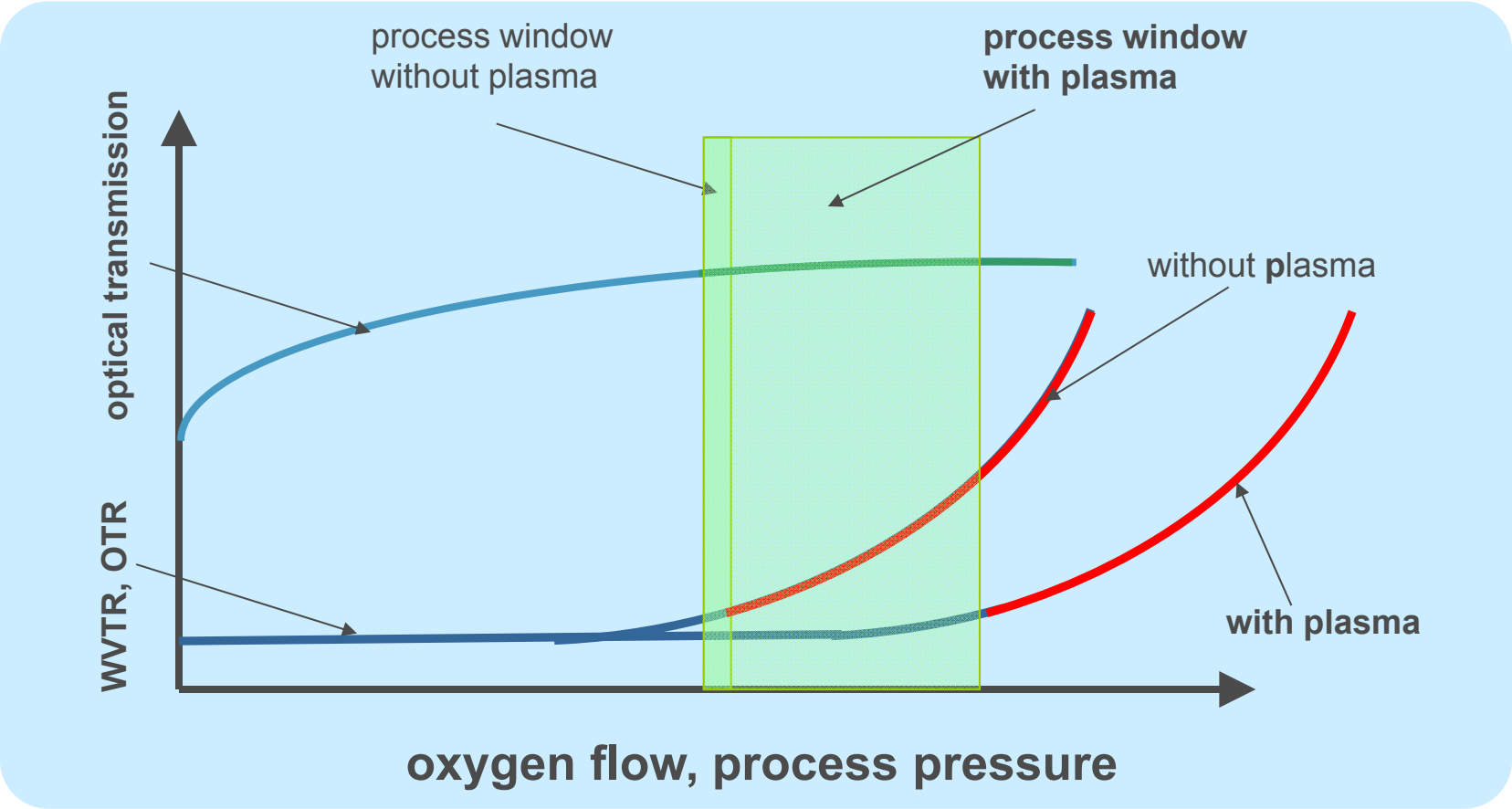
Plasma Assisted Evaporation in TopMet CLEAR™



AlO_x process proven for web speed ≤ 8m/s and coating length 50,000m

Process Window

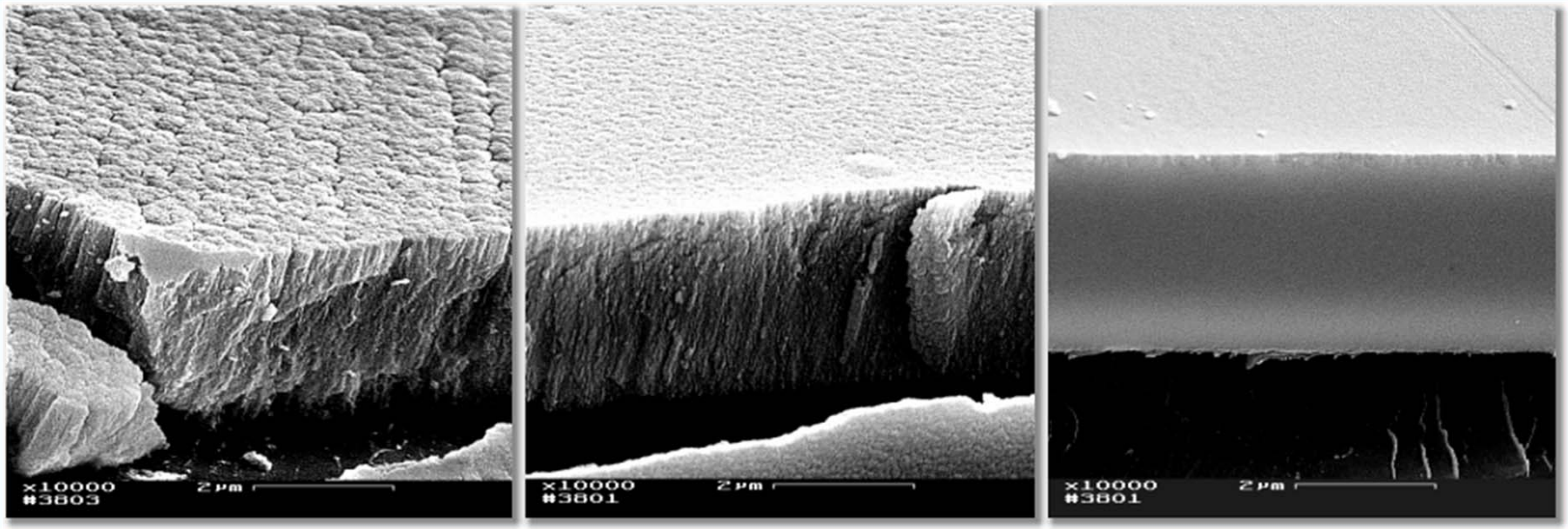
for Reactive Evaporation with Plasma Assistance



With plasma increased process window

Effect of Plasma Activated Evaporation: Al_2O_3 on PET

Al_2O_3 by Reactive Evaporation



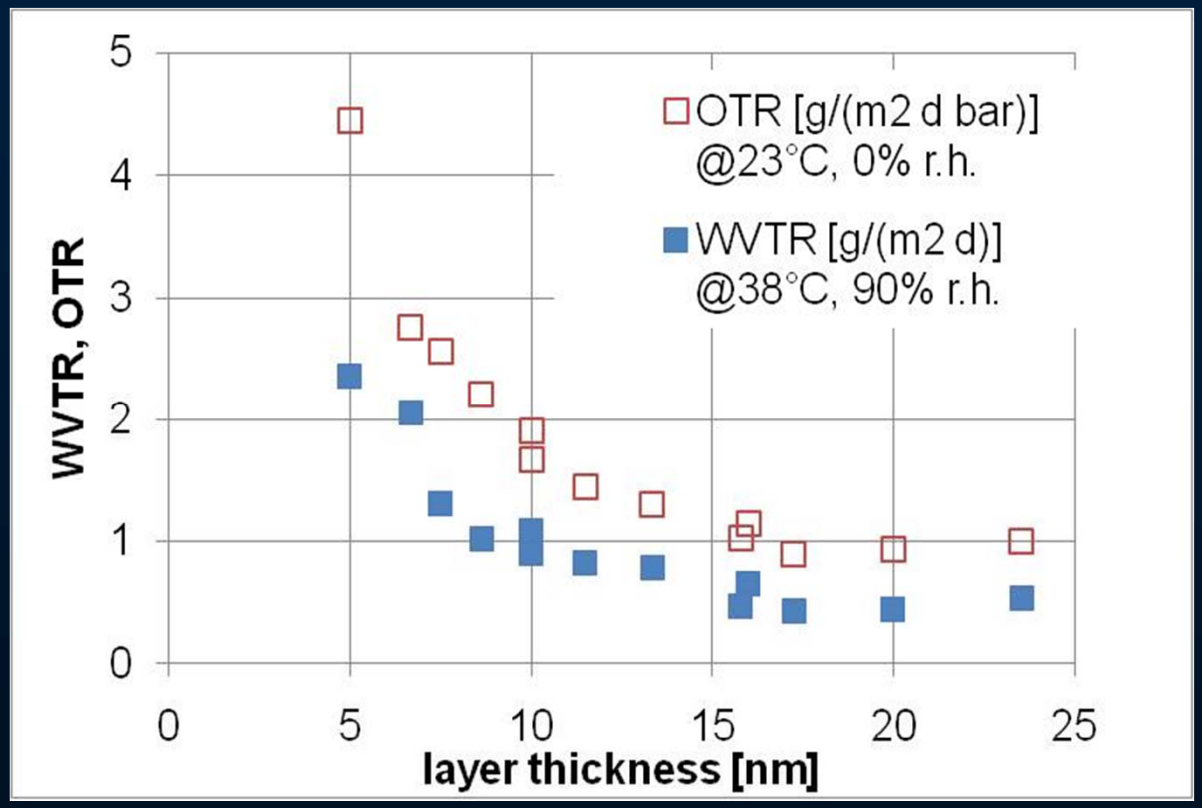
No Plasma	Low Plasma Density	High Plasma Density

Fraunhofer FEP

Plasma assistance creates denser and more uniform coating structure

APPLIED MATERIALS®

Barrier Properties of Plasma-Assisted AlO_x Process

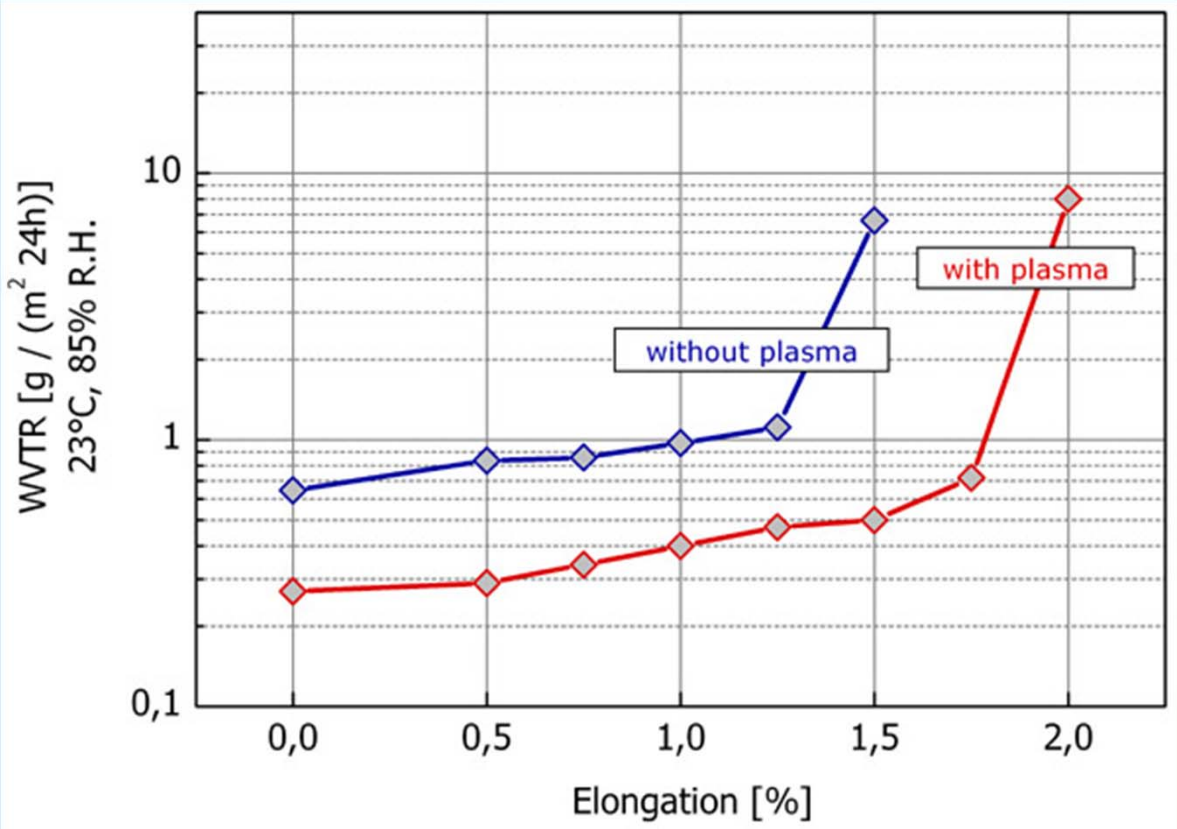


- Substrate: RHBY 12µm
- Optical transmission ≥98%

Fraunhofer Institut Elektronenstrahl- und Plasmatechnik

Optimal barrier properties at low layer thickness

Mechanical Barrier Stability AlO_x with Plasma



Fraunhofer FEP

- **Improved mechanical stability due to plasma assisted process.**
- **Better downstream robustness**

Barrier Performance of AlOx Coated Substrates

reactive evaporation

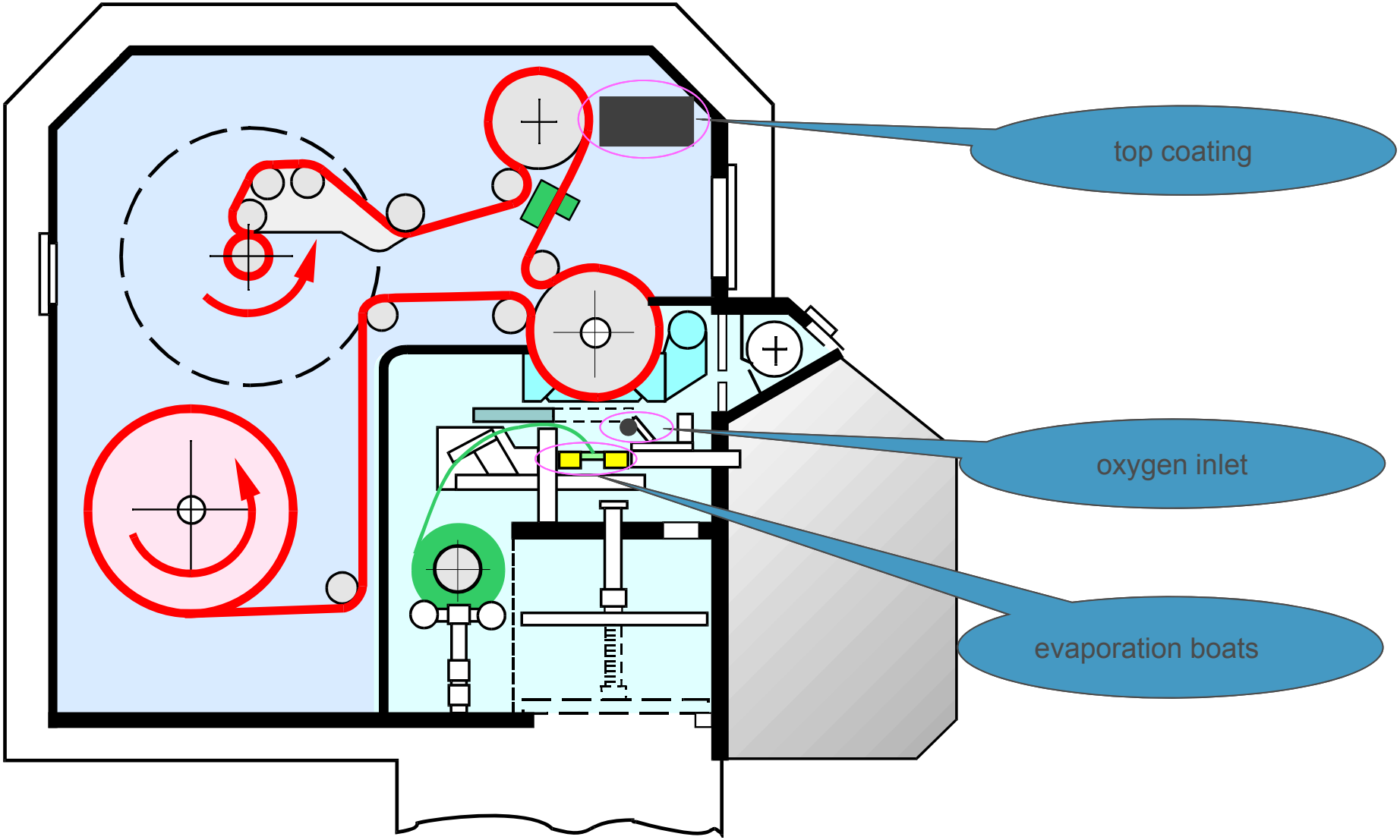
substrate	OTR [cc/m²day]	WVTR [g/m²day]
PET	0.8 – 1.2	0.3 – 0.7

plasma-assisted evaporation

substrate	OTR [cc/m²day]	WVTR [g/m²day]
PET	0.5 – 1.0	0.3 – 0.5
OPP	25 – 40	0.15 – 0.4
PLA	25 – 70	>0.12

measurement conditions:
OTR @ 23°C, 50% RH
WVTR @ 38°C, 90% RH

Basic System Layout – Al/AlOx + Top Coat



Freshure® Top Coat

Specification of process step	OTR [cc/m²/day @23°C; 0% RH]	
	12µmPET-AlOx without Freshure® Top Coat	12µmPET-AlOx with Freshure® Top Coat
After Coating	1.2	0.6
After printing (rotogravure)	6.0	1.3
After retort*)	5.8	1.7

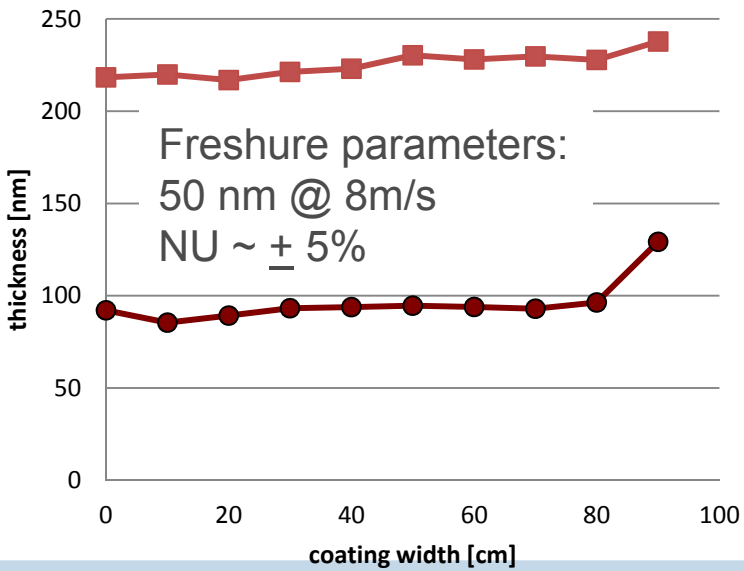
**) Laminated against OPA/CPP. Retort condition: 30 min at 121ºC*

Better Barrier: Freshure® Top Coat provides better barrier and protects the film during down stream processing

Better Printability: Freshure® Top Coat provides good ink adhesion without loss of glossy appearance of metallized film

Source: DSM

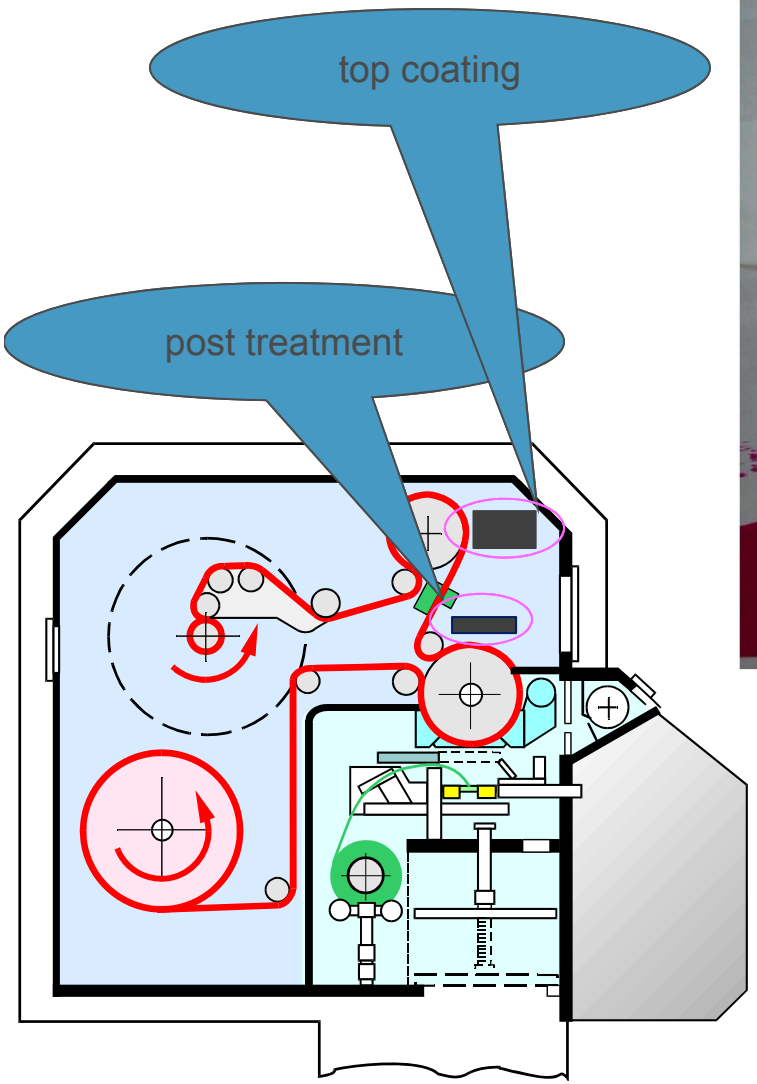
Freshure® Top Coat



oxygen barrier improvement on PET by Freshure Top Coat

top coat acts as protection for barrier layer
possibility to eliminate downstream processes

Freshure® Top Coat



improvement of adhesion through post treatment
→ printability of barrier-coated substrates

Barrier Performance of Freshure® Coated Substrates

single coat

substrate	OTR [cc/m²day]
PET	~3
OPP	40
PLA	20
OPA	1

measurement conditions:
OTR @ 23°C, 50% RH
WVTR @ 38°C, 90% RH

Barrier Requirements for Electronic Applications

DISPLAY

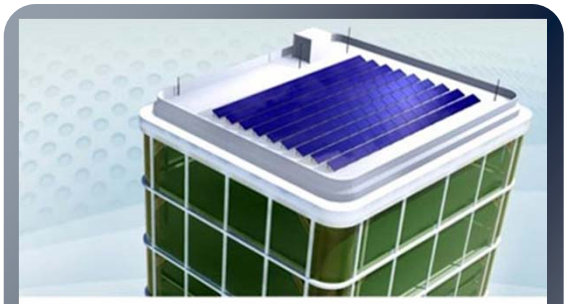
Electrophoretic Displays

OLED Displays

Barrier Performance ($g/m^2/day$)	Application
10^{-6}	OLEDs
10^{-5}	Solar Cells
10^{-4}	Thin-Film Batteries
10^{-3}	Sensors, Electrophoretic Displays
10^{-2}	RFID Electrochromic Displays
10^{-1}	Medical Packaging Food Packaging

New Barrier Techn.

Single Layer



ENERGY & ENVIRONMENTAL

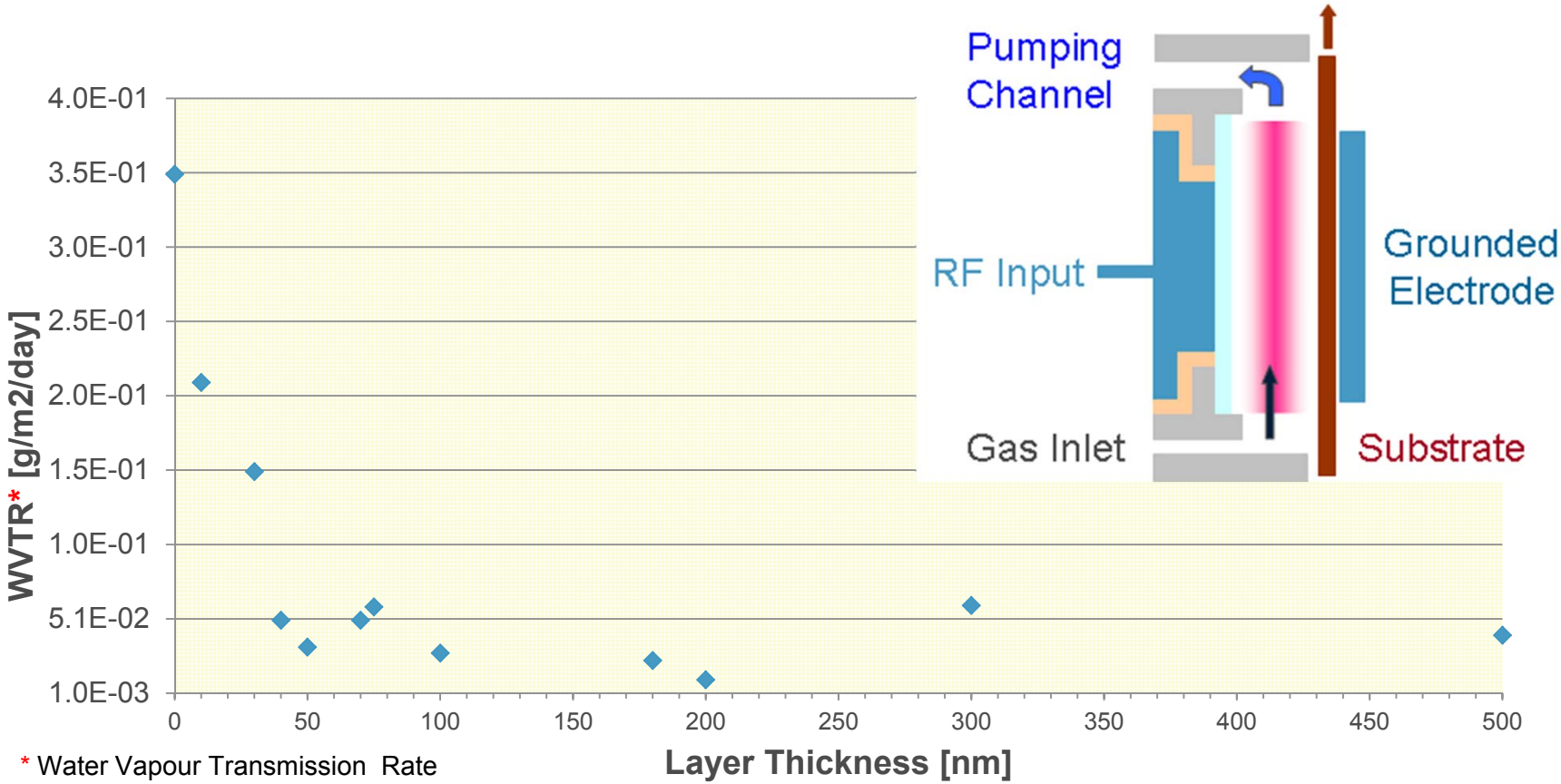
Flex PV

OLED Lighting

Flexible TFB's

Barrier required to protect active layers from oxygen & water vapour

PECVD SiNx Barrier Coating on Polyimide @ 200°C



* Water Vapour Transmission Rate

With a Film Thickness for Approximately 50nm WVTR decreases to 2.0E-2 g/m²/day

Summary

- High rate metallization process with excellent uniformity
- Different processes for AlOx based on thermal boat evaporation
  - Without plasma: For transparent barrier on PET
  - With plasma: For robust transparent barrier on PET, OPP, CPP, PLA
- Stable processes based on proven technology
- Environmental-friendly coatings
- High process flexibility for metallizing, different transparent AlOx-processes (depending on required coating properties) and for Freshure® top- or single coating
- Development of new R2R processes, e.g. PECVD, for future high-barrier requirements

Turning innovations
into industries.™