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Advanced Reactive Sputtering Process Control Technology and Systems

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Nova Fabrica

www.novafabrica.biz

NOVA FABRICA
HIGH VACUUM AND THIN FILM COMPONENTS

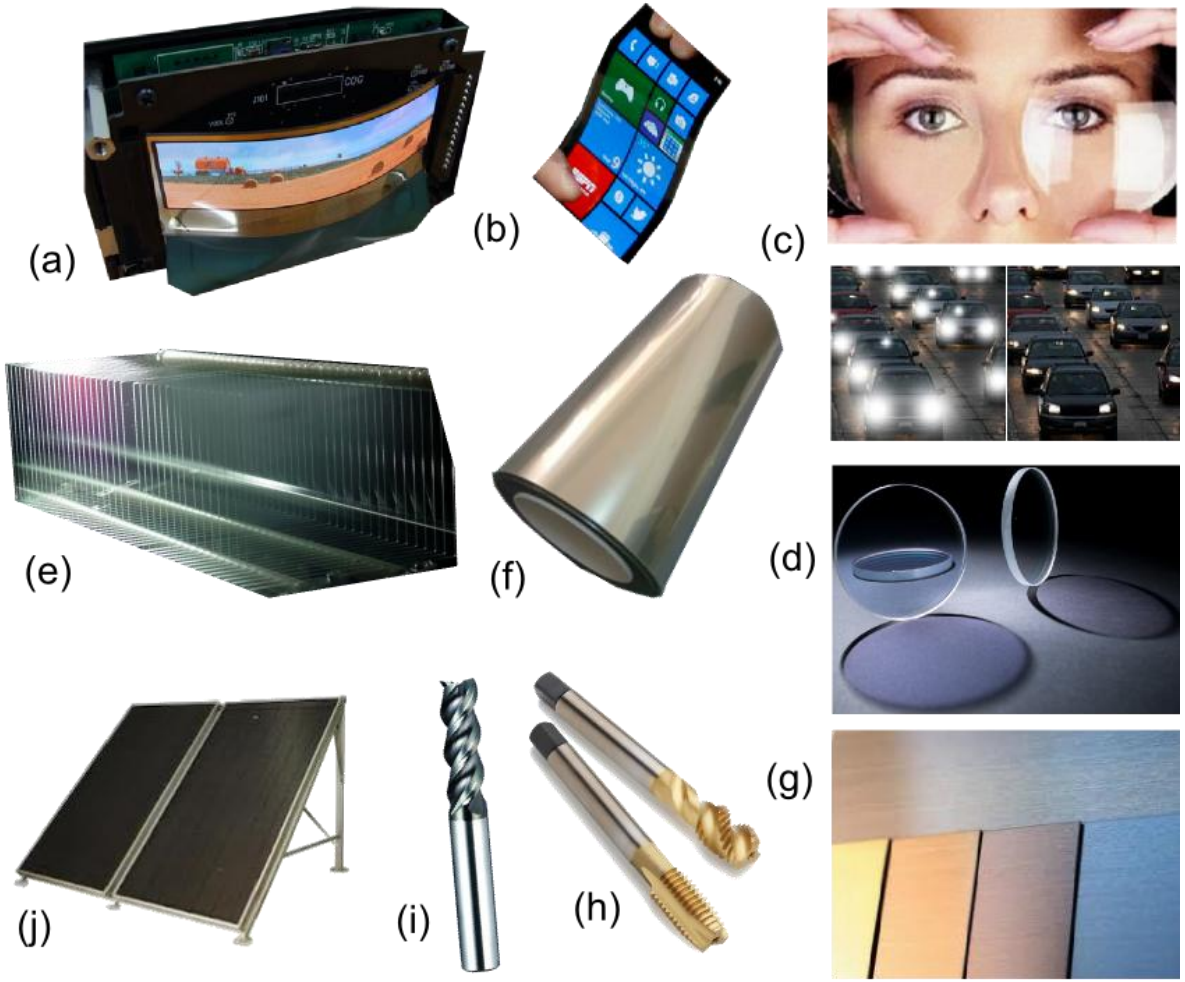
- Founded in 2013 the company is based in Lithuania (northern EU).

- NF are involved in two business areas:
  - Manufacture of thin film components (e.g. FloTron process control systems)
  - Distribution/resale of thin film products in the Baltic States area.

Reactive Sputtering

- Reactive Sputtering is a process where a target of one chemical composition is sputtered in the presence of a gas or a mixture of gasses that will react with the target material to form a coating of a different chemical composition.
- Example: Si + Ar/O_2 -> compound SiO_2 coating.
- Argon is in most cases the main gas and the amount of a reactive gas introduced into a process chamber is controlled to either achieve certain amount of doping or produce a fully reacted compound.

Applications of Reactive Sputtering

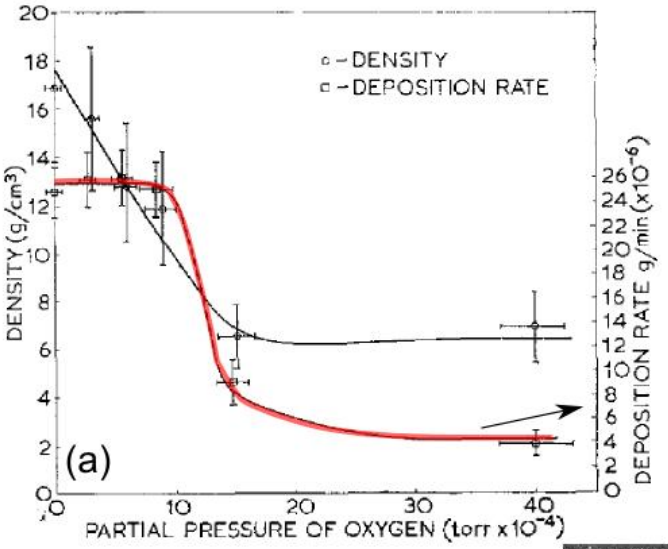


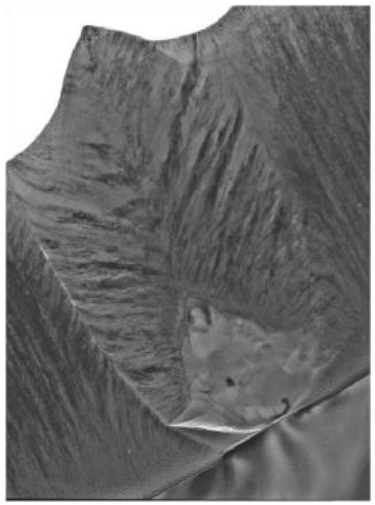
a) and (b) devices with an OLED screen, (c) anti-reflective coatings, (d) laser optics elements (e) ITO coated glass, (f) ITO coated polymeric web, (g) decorative oxide coatings (h) TiN coated taps, (i) DLC coated end-mill, (j) Ti-O-N thermal solar absorber.

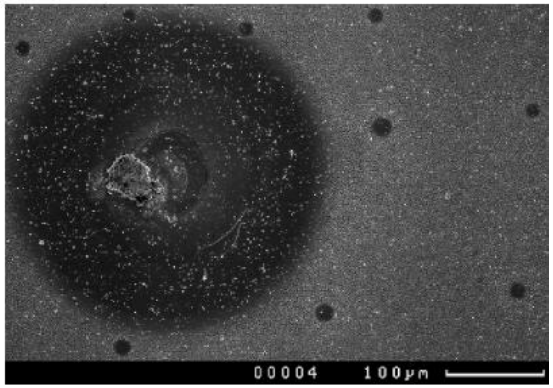
Why Reactive Sputtering?

- Operation in the so called 'transition' region (explained in the later slides) allows high coating deposition rates to be obtained (normally using AC or p-DC power),
- Provides a superior alternative to sputtering ceramic compound targets with RF power.
- Can provide significant cost savings as well as production rate advantages.

Target poisoning





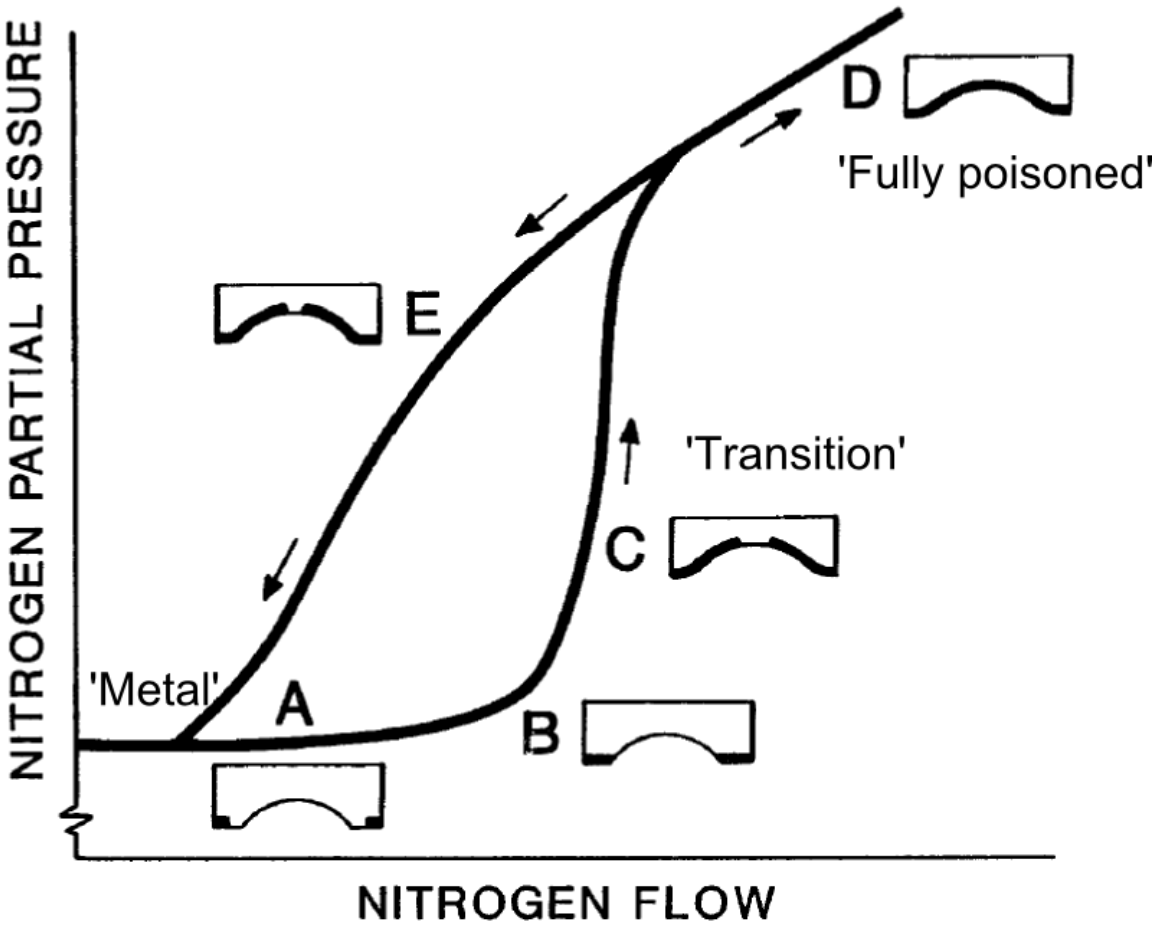


(a) Deposition rate decrease due to target poisoning (after Hollands , 1968),
(b) an arc in a magnetron discharge (courtesy of Deposition Sciences, Inc.),
(c) a TEM micrograph showing an example of a droplet incorporated in a ceramic coating and resultant structure evolution,
(d) SEM micrograph showing arc damage on the surface of a ceramic coating.

Target Poisoning Mechanisms

- Essentially three magnetron sputtering target poisoning mechanisms can be taking place:
  - Chemisorption,
  - Ion implantation and
  - Diffusion (hot processes, e.g. HIPIMS).
- The thickness of the compound formed depends on the location in the racetrack.
- AC and DC processes ---> a few nanometre compound layers.
- "Hot" processes, e.g. Hot Target Sputtering (HTS) or High Power Impulse Magnetron Sputtering (HIPIMS), can have pronounced diffusion taking place, with diffusion profiles extending as deep as a few tens or even hundreds of nanometres.

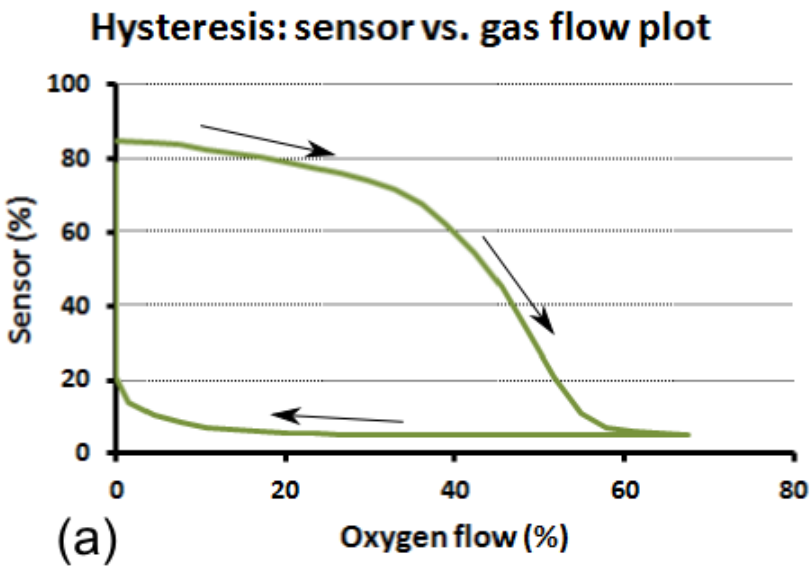
Fast Transition

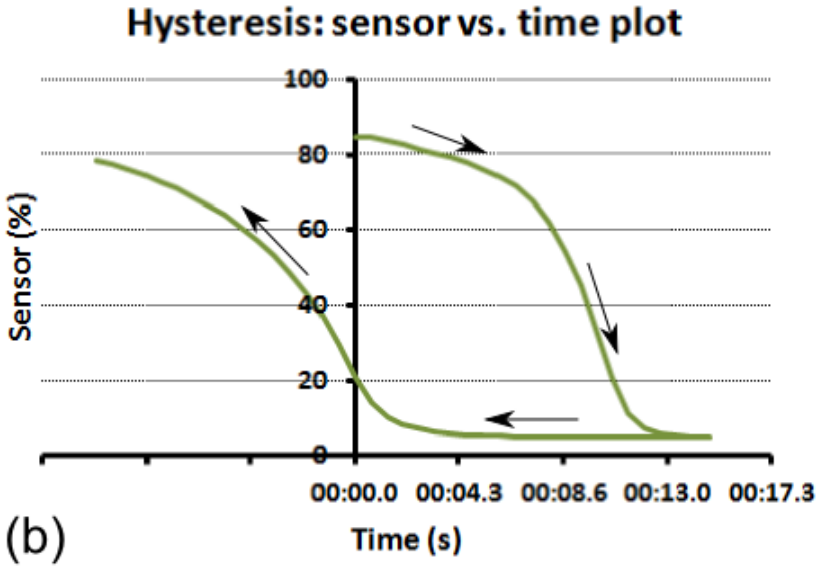


Target poisoning during reactive sputtering (B. Sproul).

- Largely understood as undesired effect.
- Opens opportunities
- to produce better coatings faster and
- fine tune film chemical composition and properties.
- etc.

Hysteresis





After M Audronis et al. 2012

- Time effect, so can be represented as 'sensor vs. time'

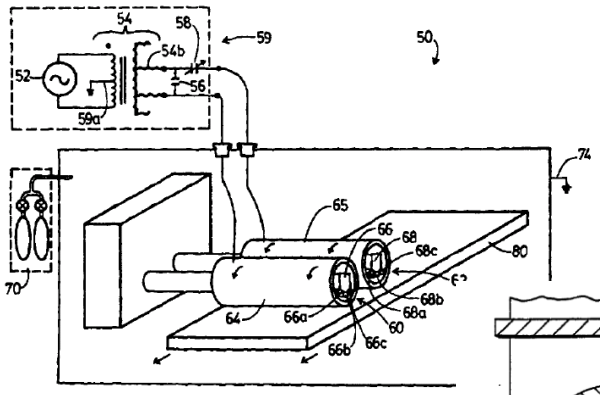
Reactive Sputtering process control

- Fast changing processes require use of fast feedback loops,
- Algorithms of choice:
  - PID (most widespread; can be used for reactive sputtering)
  - PDF (robots, auto-pilots , temperature control, motor control, etc.; can be used for reactive sputtering),
  - Fuzzy logic .

Feedback signals

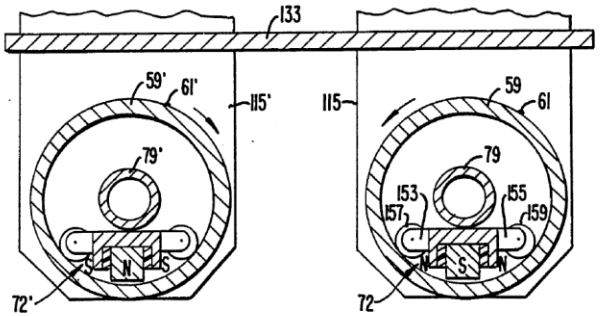
- Target Voltage [Applied Films Lab (US), 1978]
  - Free of charge; not suitable for multi-zone processing; only some materials.
- P.E.M. [Von Ardenne (DE) 1982, Bell Labs (US) 1981]
  - High speed, excellent signal quality, suitable for large area multi-zone processing. Prone to disturbances and drifts due to moving substrate, target erosion, etc.
- Mass spectrometer [Bill Sproul, 1983]
  - Excellent speed and signal, expensive.

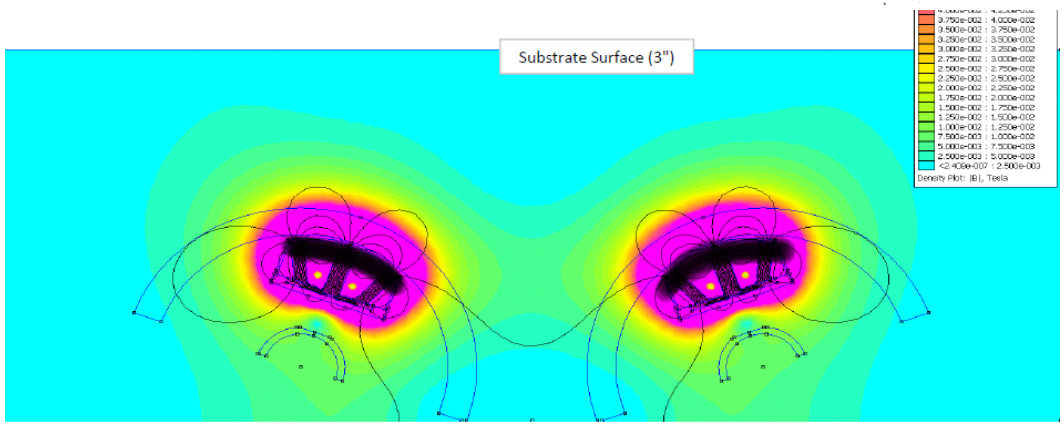
Dual magnetron AC / Bipolar p-DC



Dual AC setup.
BOC, 1995

Dual closed field setup.
BOC, 1989





Magnet Arrays: 20d. Tilt, opposite polarities

- Dual magnetron alternating anode/cathode set-ups provide excellent process stability .
- Originally practiced with two same polarity arrays,
- Closed-field configuration with varying tilt angles may reduce plasma impedance and allows plasma substrate interaction control.
- *Asymmetric* dual magnetic arrays seem to be unnecessary luxury.
- Power supplies available from EN Technologies, Huettinger, AE, etc.

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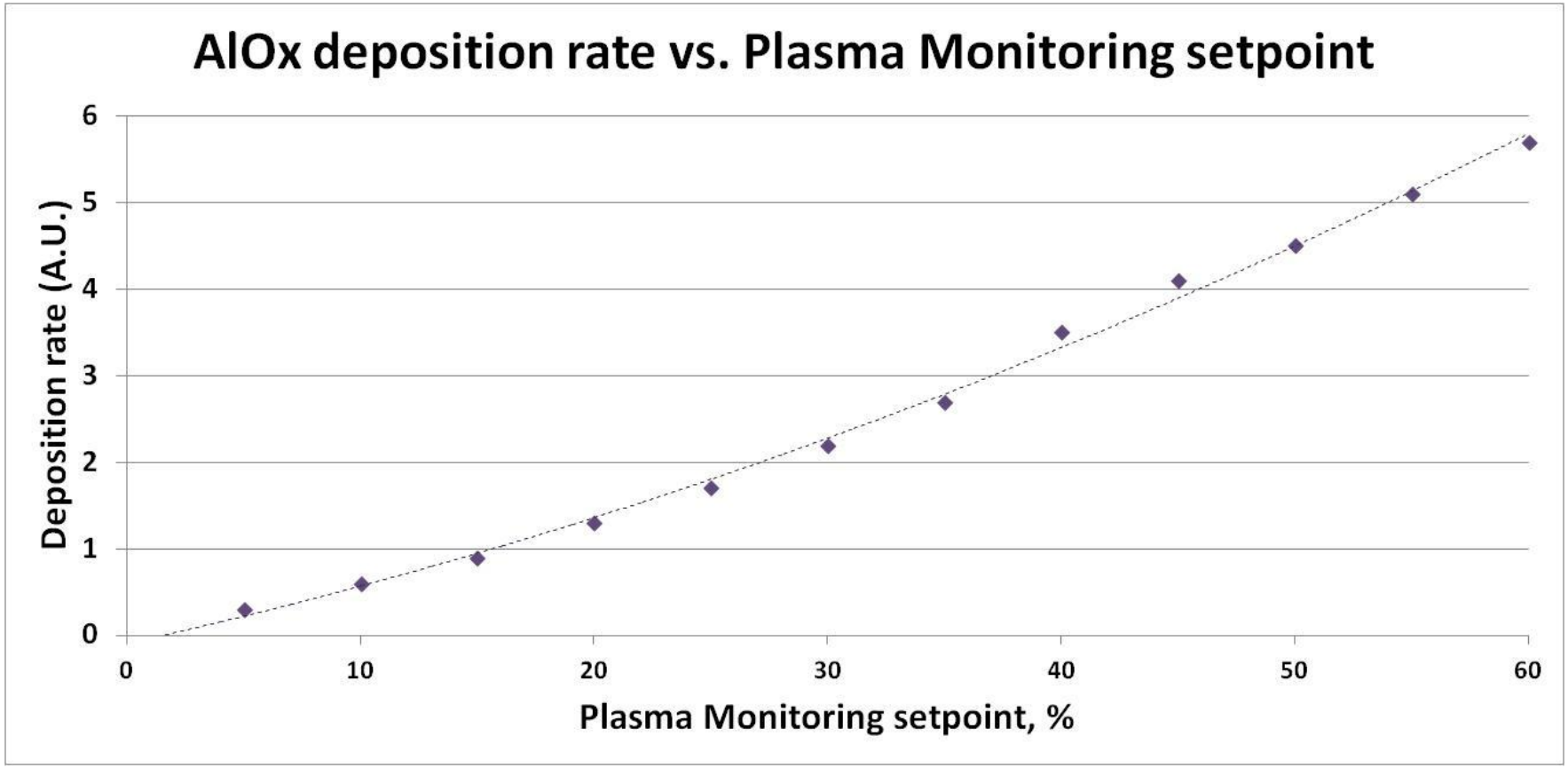
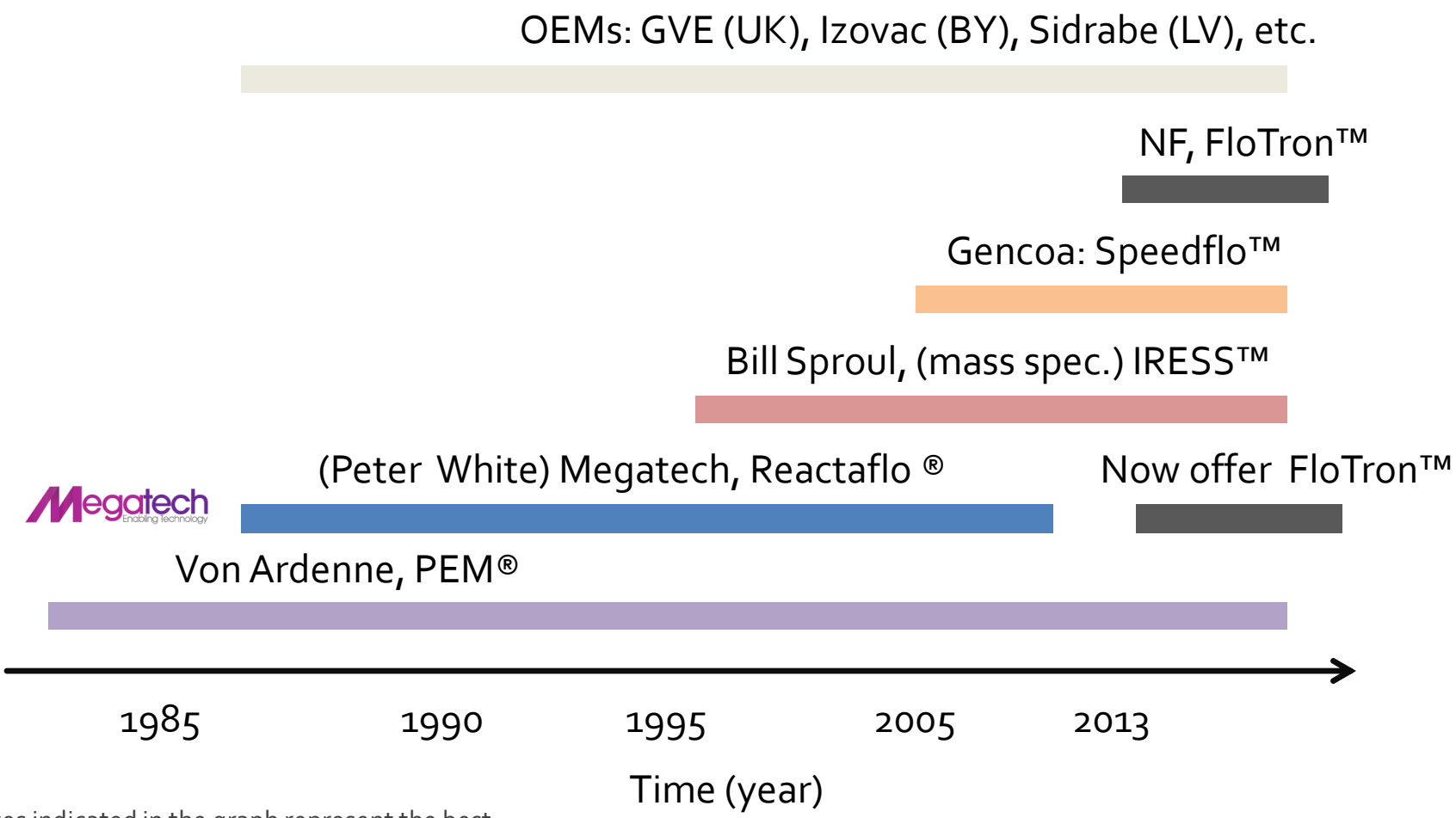
Increased deposition rate and accurate film composition/properties control

Example: AlOx Deposition rate vs. PM set-point



Historical Reactive Sputtering control systems development



(note : dates indicated in the graph represent the best knowledge of the authors and may not be accurate.)

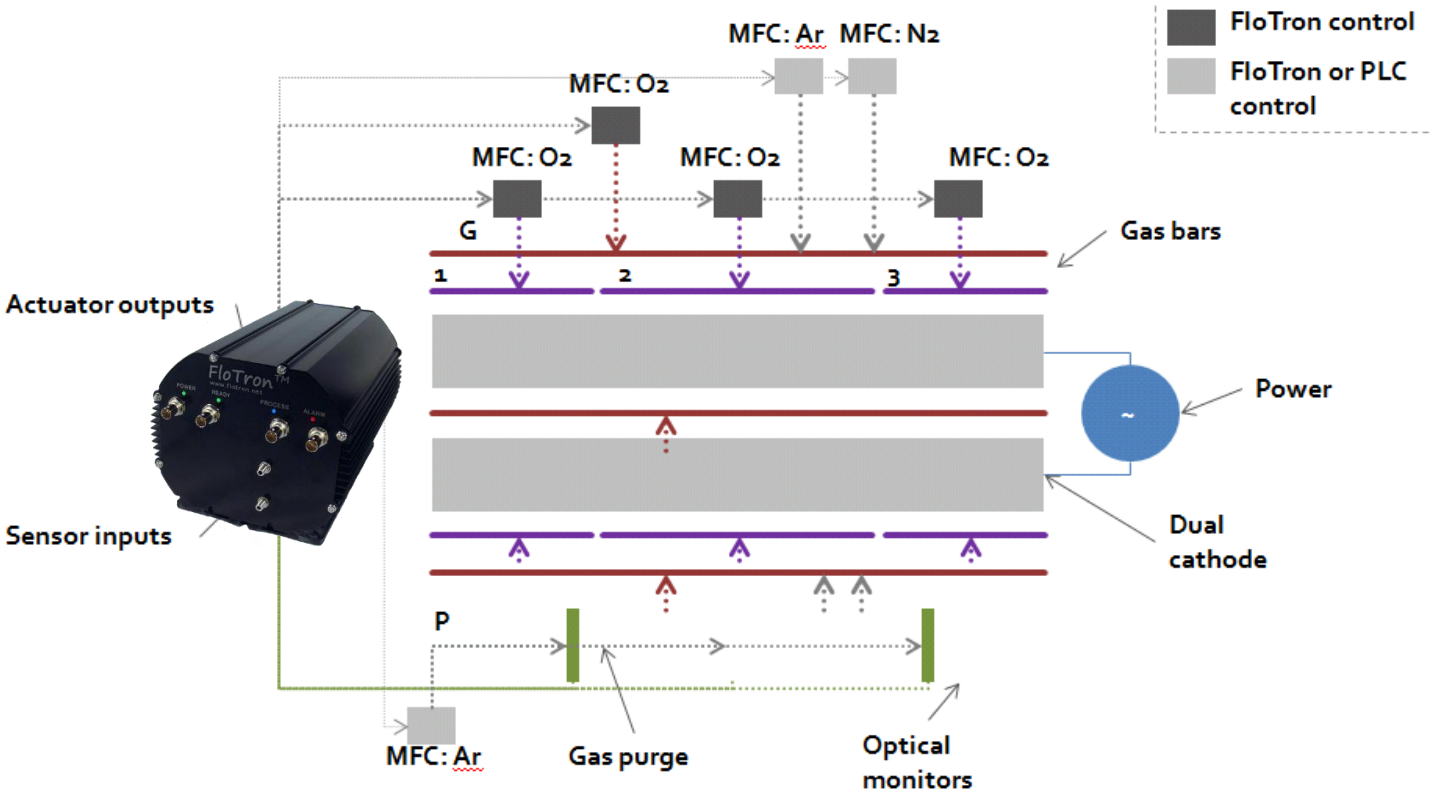
FloTron™ Solutions for Reactive Sputtering and Reactive Plasma Processing

www.flotron.net

Figure: FloTron ™ X3

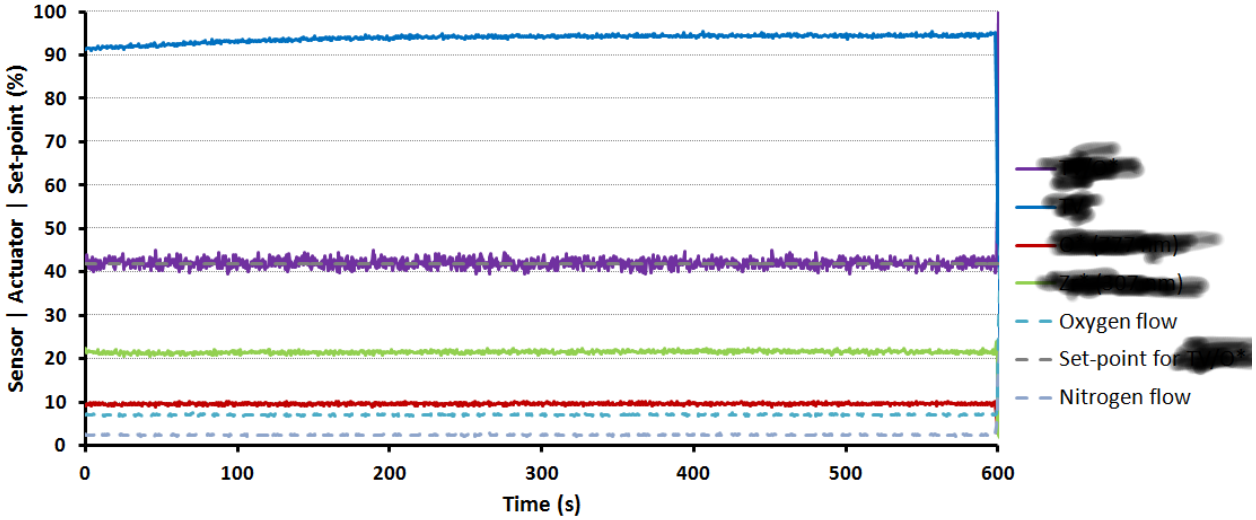
1. FloTron™ – ultra fast precision process monitoring & control systems.
2. 6 models (3 / 5 / 9 channel) to suit any Reactive Sputtering process requirement.
3. Many advantages. Too many to mention all.
4. Some features and application examples given in the following slides.

Dual-spectrometer FloTron™ (X5 or X9) for large area Reactive Sputtering



- Economical way to produce large area films by reactive sputtering using two reactive gases (e.g. Ti-O-N, Zr-O-N, Cr-O-N, etc.)

Reactive magnetron sputtering of Zr and Hf oxides for laser optics



- Dual sensor control,
- Nitrogen is not essential,
- Better films and faster can be produced without Nitrogen.

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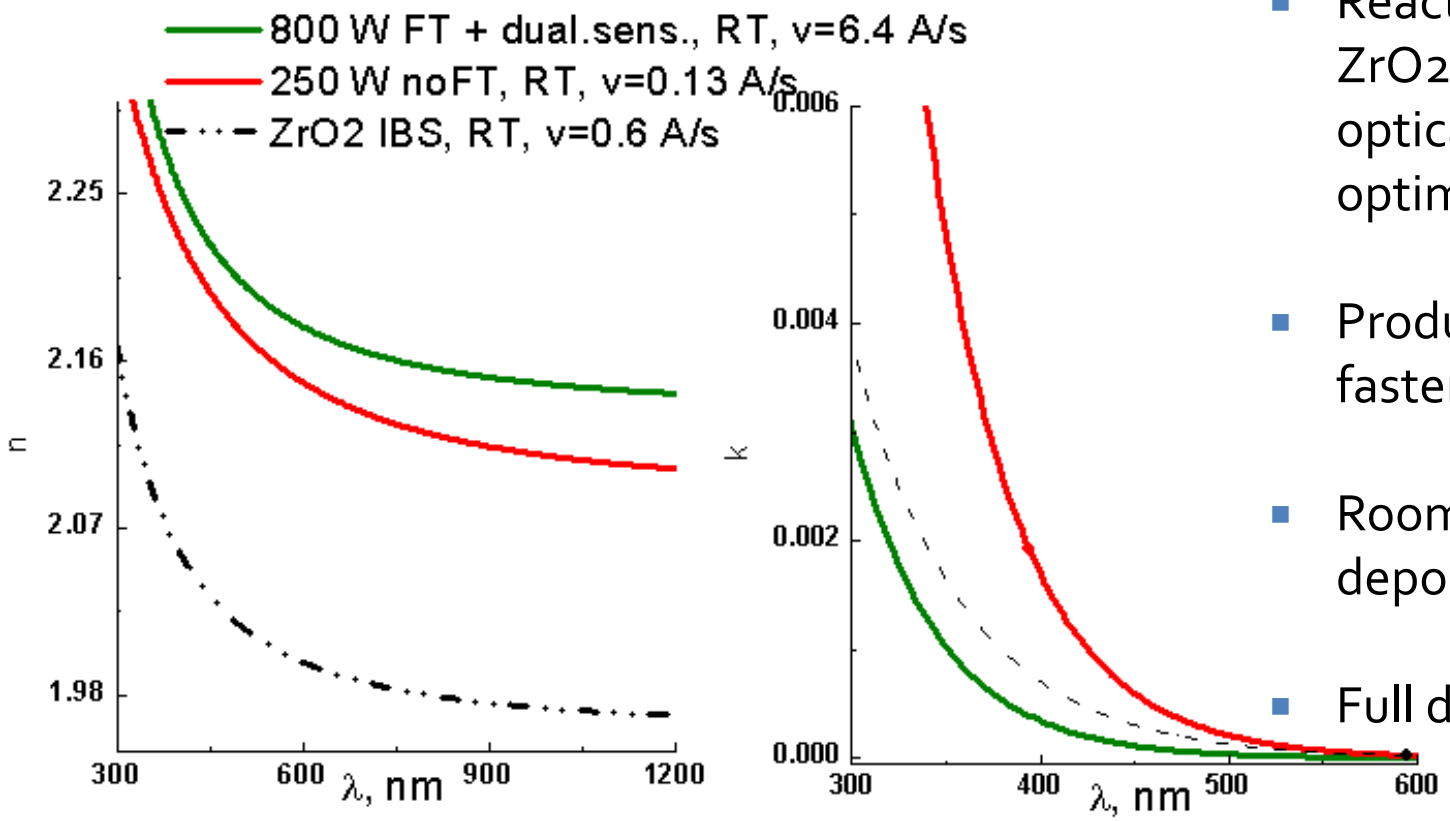
Kurt J. Lesker Company

ISSP 2013 July 10-12, 2013 Kyoto Research Park Kyoto, Japan
THE 12th INTERNATIONAL SYMPOSIUM ON SPUTTERING & PLASMA PROCESSES

Reactive magnetron sputtering of Zr and Hf oxides for optical applications



- Reactively sputtered ZrO2 film posses better optical properties than optimized IBS ZrO2
- Production speed is x10 faster.
- Room temperature deposition
- Full details at ISSP 2013

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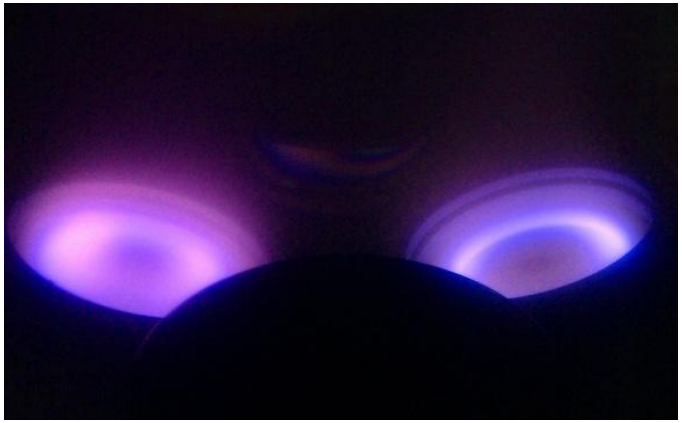
Dual loop feedback control of mixed oxide sputtering processes.



Kurt J. Lesker Company

- K.J. Lesker sputtering system.
- Unique dual loop control approach for Nb –Si.
- Both Nb (p-DC) and Si (RF) operate in the 'transition' region.
- Room temperature deposition.
- Excellent film properties

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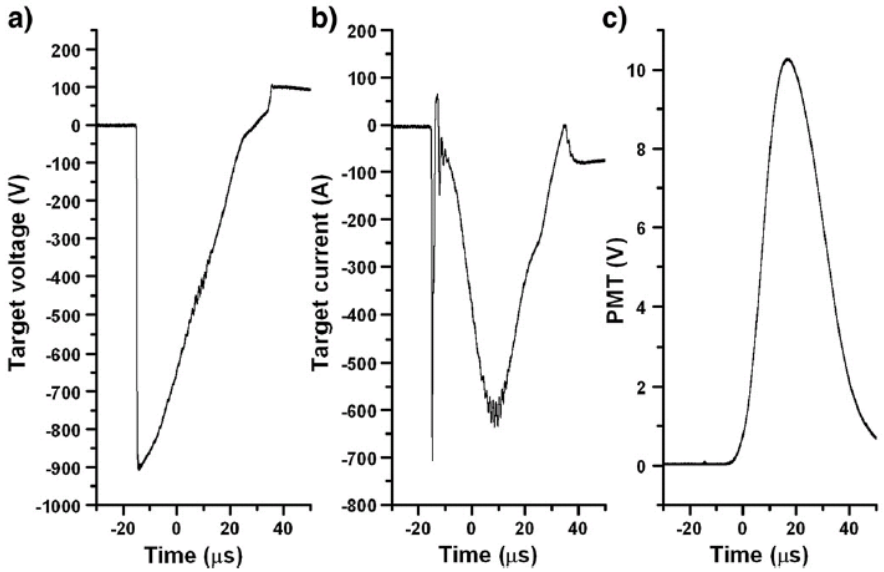
Optical Interference Coatings (OIC)

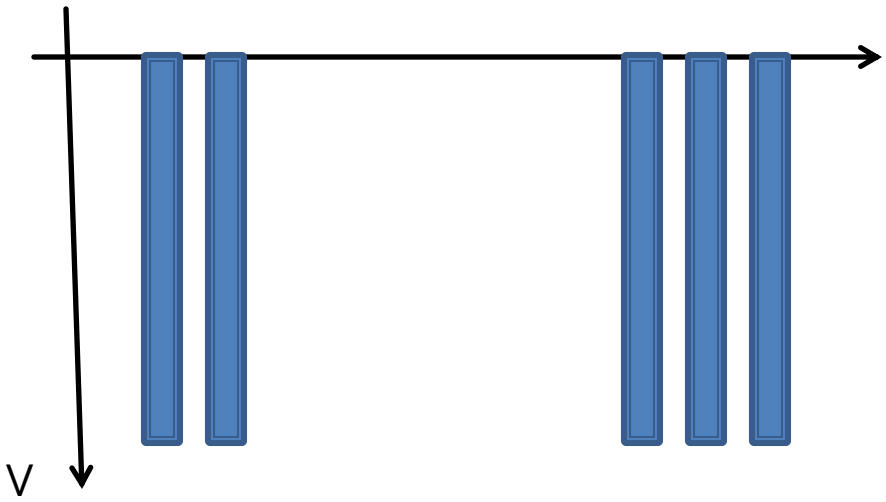
16 - 21 June 2013

Fairmont Chateau Whistler, Whistler, British Columbia, Canada

Reactive HIPIMS monitoring and control



Conventional HIPIMS pulse and light detected by a PMT module. After Audronis et. al 2010.



Schamatic of HIPIMS exhibit multiple pulses

- New power supply technologies - complex pulse patterns.
- Intelligent HIPIMS plasma monitoring sensor, which provide excellent signal for a wide range of HIPIMS pulse frequencies and will deal comfortably with pulses coming in at irregular intervals.
- The signal provided by the new sensor is straight forward to interpret and convenient to use.

FloTron™ OEM integration

- Integration of an OEM device using only software libraries (e.g. DLLs) can be difficult.
- PROIFIBUS interface for quick, convenient and natural integration with PLCs and HMIs.
- Other FIELDBUS interfaces available (PROFINET, EtherCAT, etc.)

Conclusions

- Reactive Sputtering field is as fascinating and fruitful as ever.
- New developments in both process technology and hardware are plentiful (some covered in this presentation).
- More is on the way.

Thank you!