Inverted Cylindrical Magnetron Sputtering of Optical Coatings

M. Romach, G. Scherer, J. Eichenberger,
J. Lanzafame and D. Glocker
Isoflux Incorporated

M. Jaszcar and B. Rayner
Kurt J. Lesker Co.

Kurt J. Lesker Company

Isoflux

Introduction

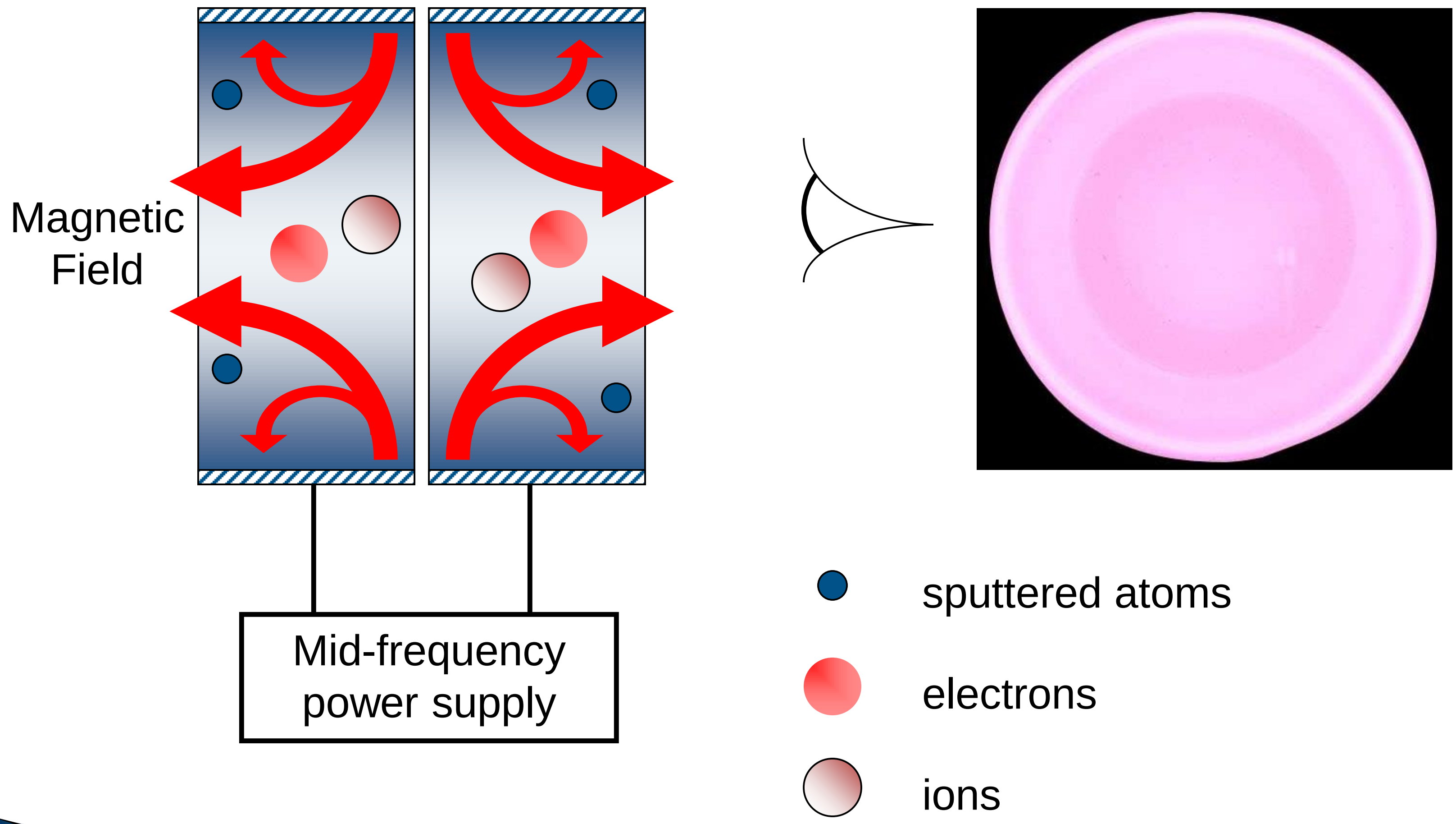
This work explores the use of off-axis cylindrical magnetron sputtering as a method for depositing optical coatings.

Earlier data showed that unbalanced cylindrical magnetrons produce dense plasmas and good off-axis uniformity.

Outline

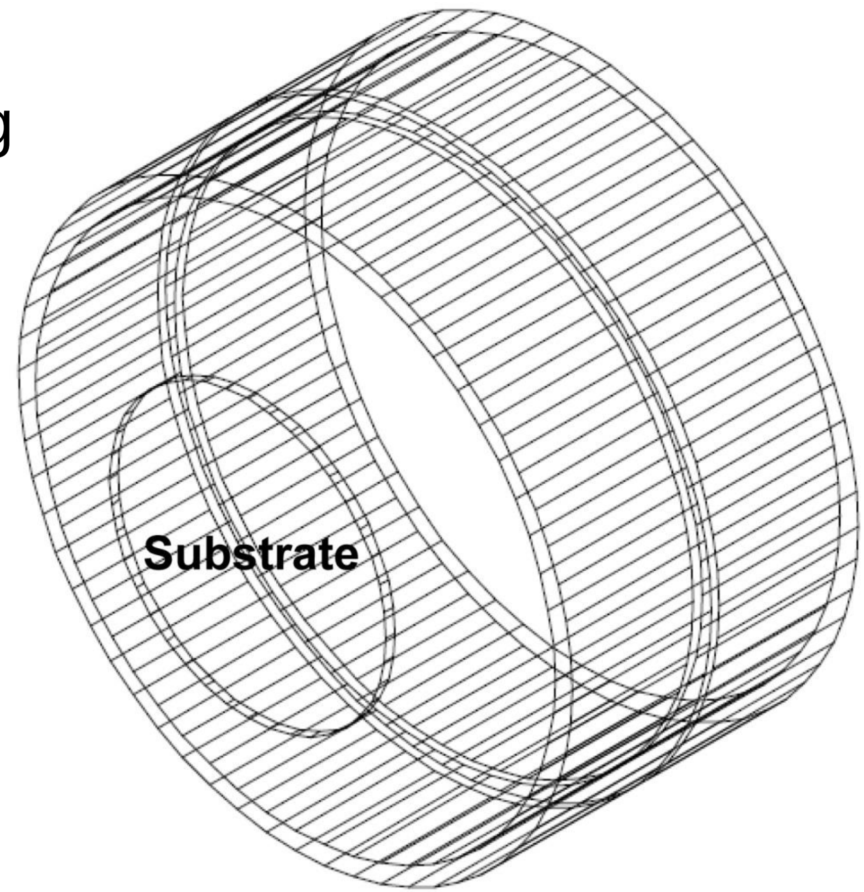
- System description
- Experimental methods
  - Plasma measurements
  - Thickness uniformity
  - Optical properties
- Results
- Conclusions

Dual Unbalanced Cylindrical Magnetron

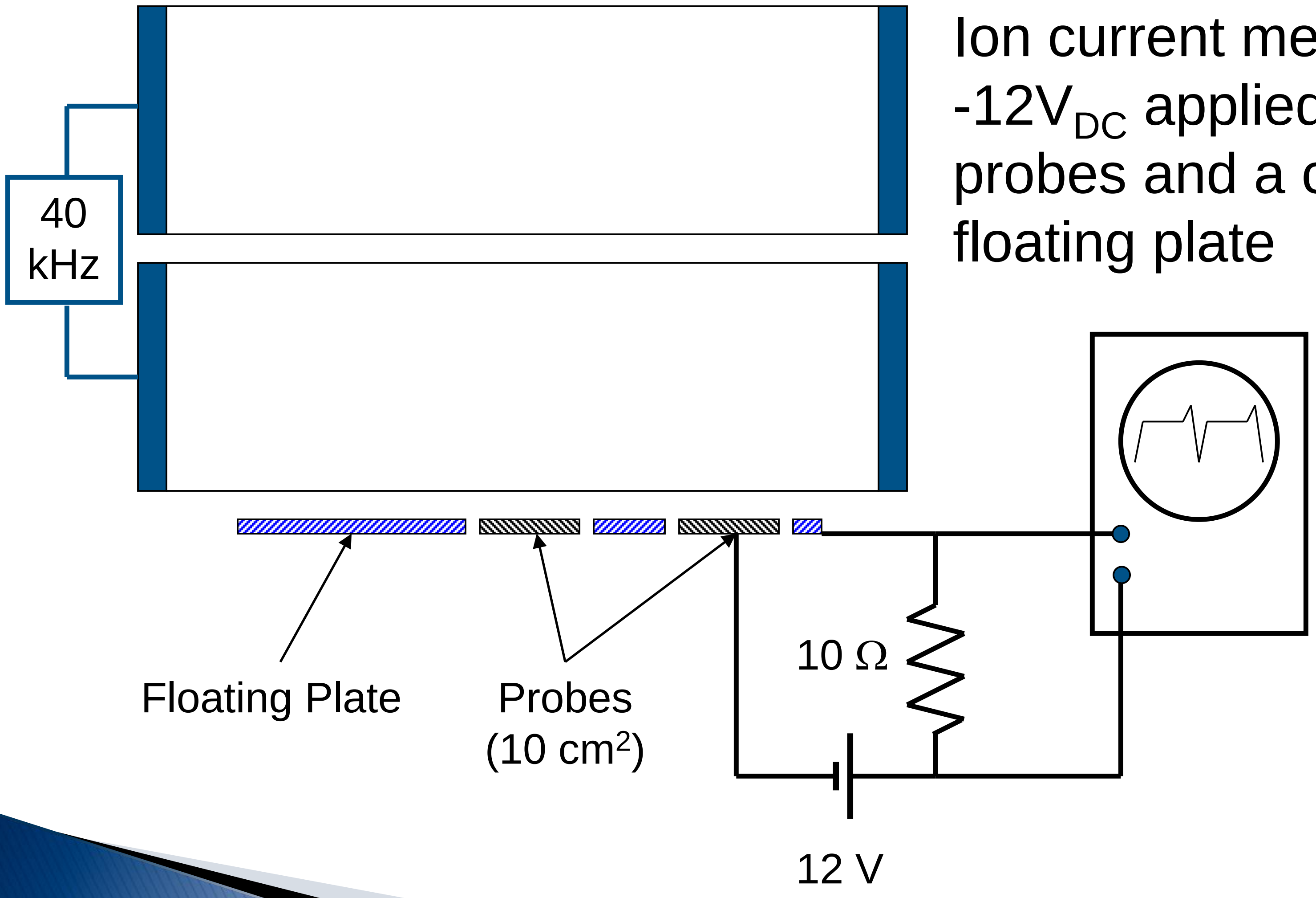


System Description

- Two 330 mm ID, 102 mm long targets for each material
- 40 kHz power
- Substrates placed off axis
- Ta_2O_5 and SiO_2 sputtered in poisoned mode
- No substrate heat or motion

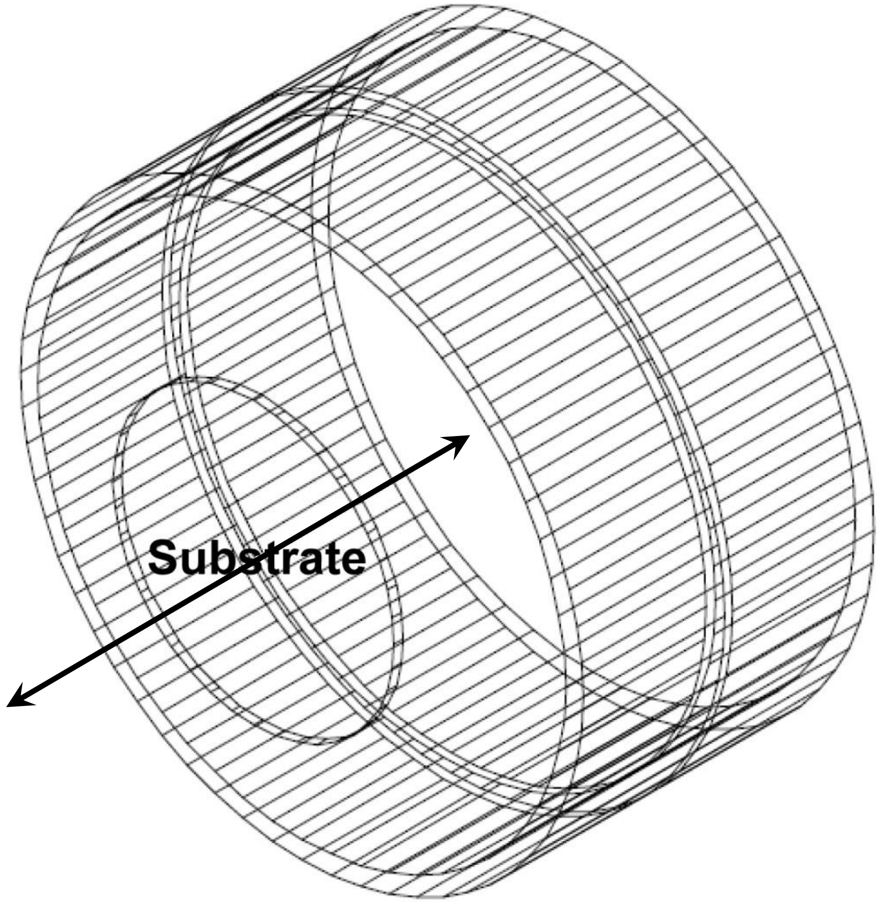


Floating Potential and Ion Current Measurements



Ion current measured with $-12V_{DC}$ applied between probes and a co-planar floating plate

Thickness Uniformity vs. Source to Substrate Distance



- 200 mm diameter Si substrates
- Distance from substrate to end of cathode varied
- Ta_2O_5 deposited at 4.0 kW and several pressures
- Relative thickness across substrate measured using spectral reflectance
- Optimum position chosen for optical coatings

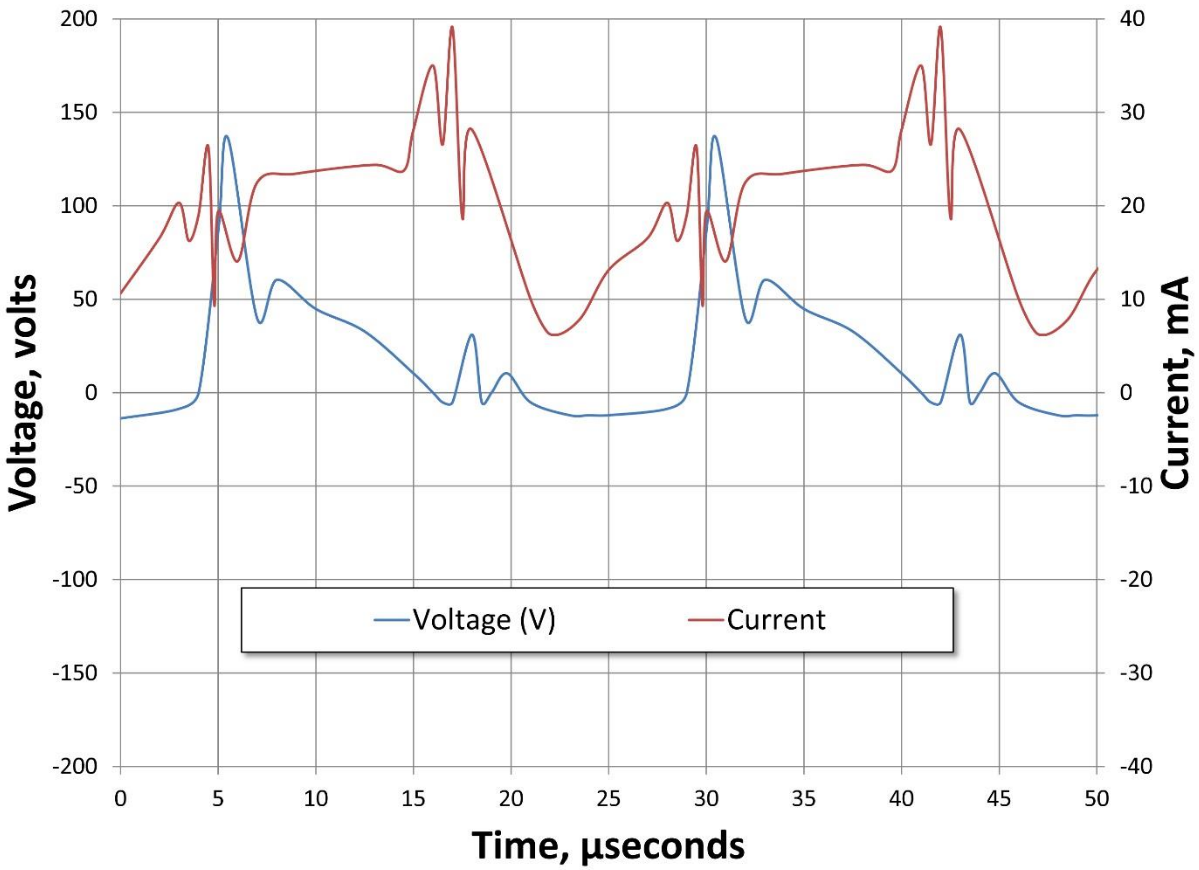
Coating Conditions and Optical Measurements

	Power (kW)	Pressure (mT)	Ar Flow (sccm)	O_2 Flow (sccm)	Rate (nm/min)
Ta_2O_5	4.0	1.2	25	25	12
SiO_2	2.0	2.1	35	50	13

- Two independent sets of ellipsometry measurements
  - n and k as functions of wavelength for Ta_2O_5 at radial positions of 0, 50 and 100 mm
  - n_{633} and thickness for Ta_2O_5 and SiO_2 at radial positions of 0, 50 and 100 mm
  - n_{633} and thickness for Ta_2O_5 and SiO_2 as functions of temperature

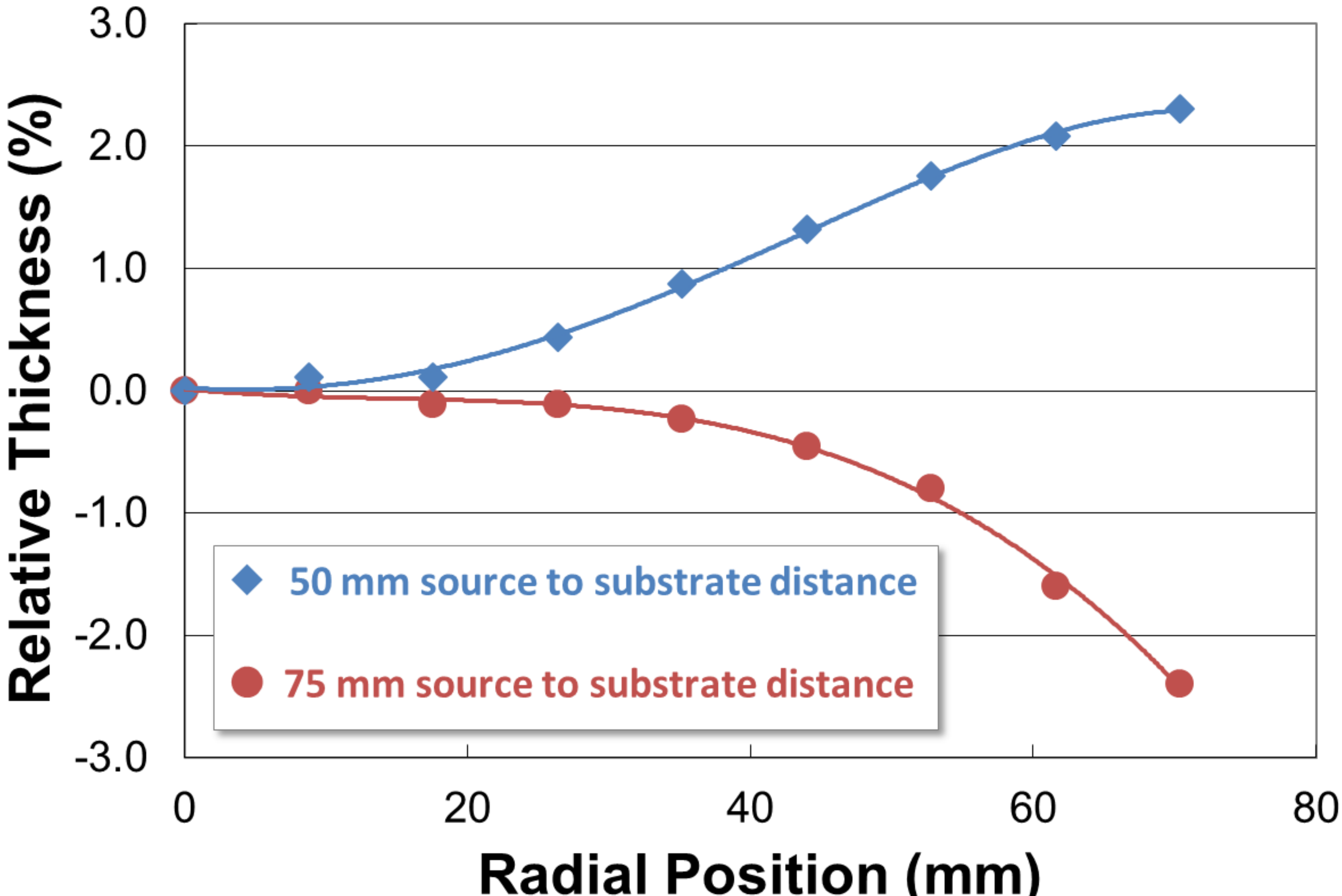
Experimental Results

Floating Potential and Ion Current

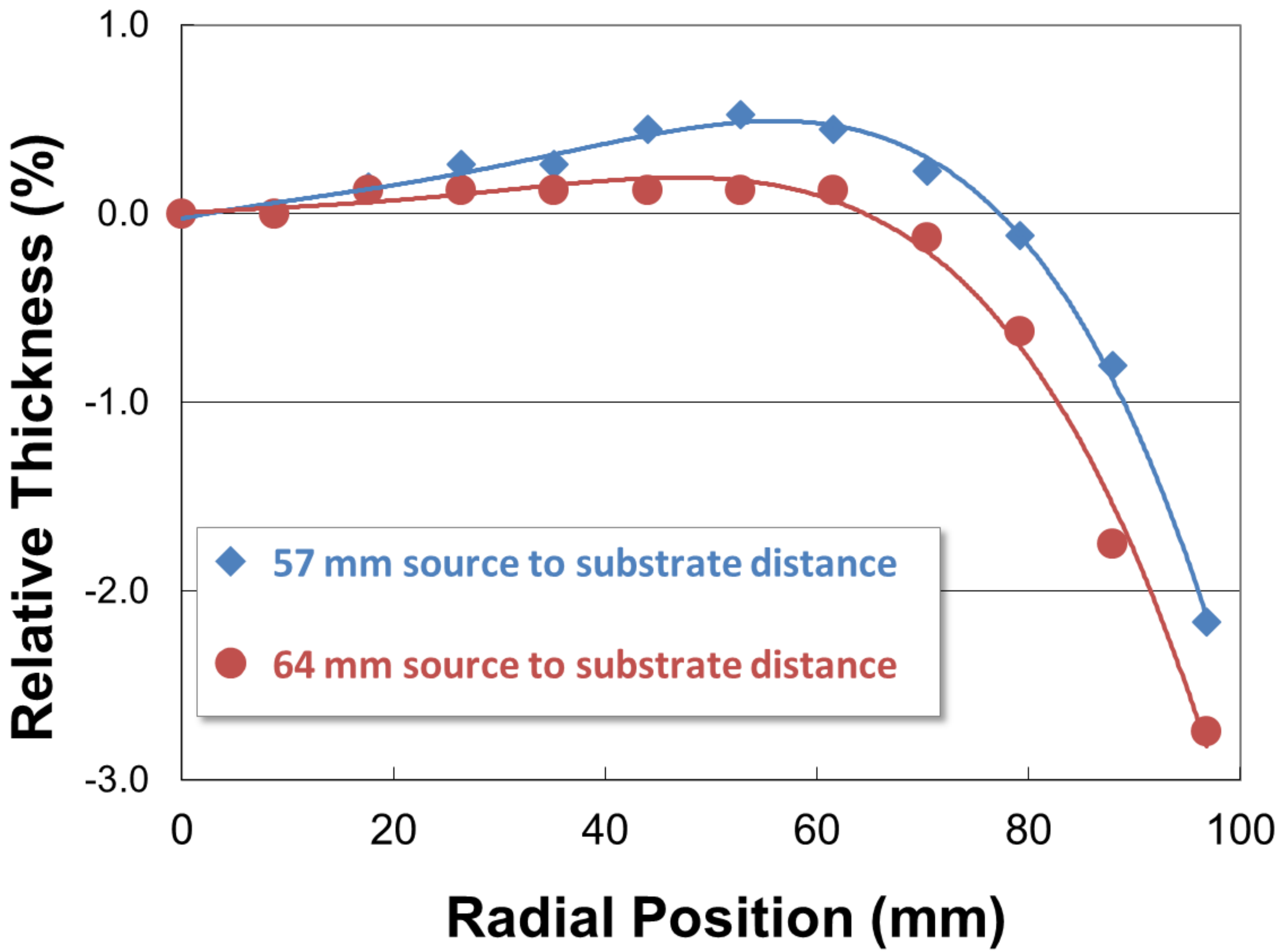


- Floating potential peaks when adjacent target becomes anode
- Ion flux equals 1.2 X 10^{16} /cm^{2}s at center, about half that at edge
- Flux comparable to other ion enhanced processes

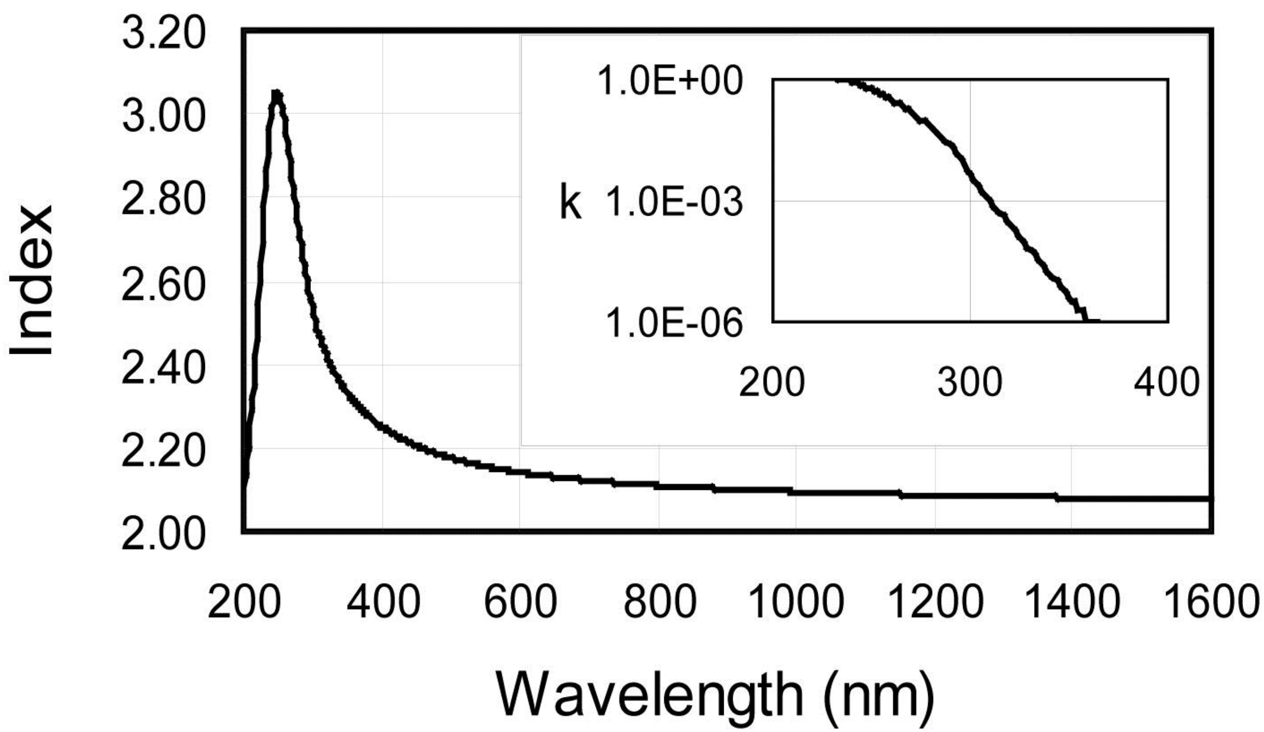
Thickness Uniformity



Thickness Uniformity

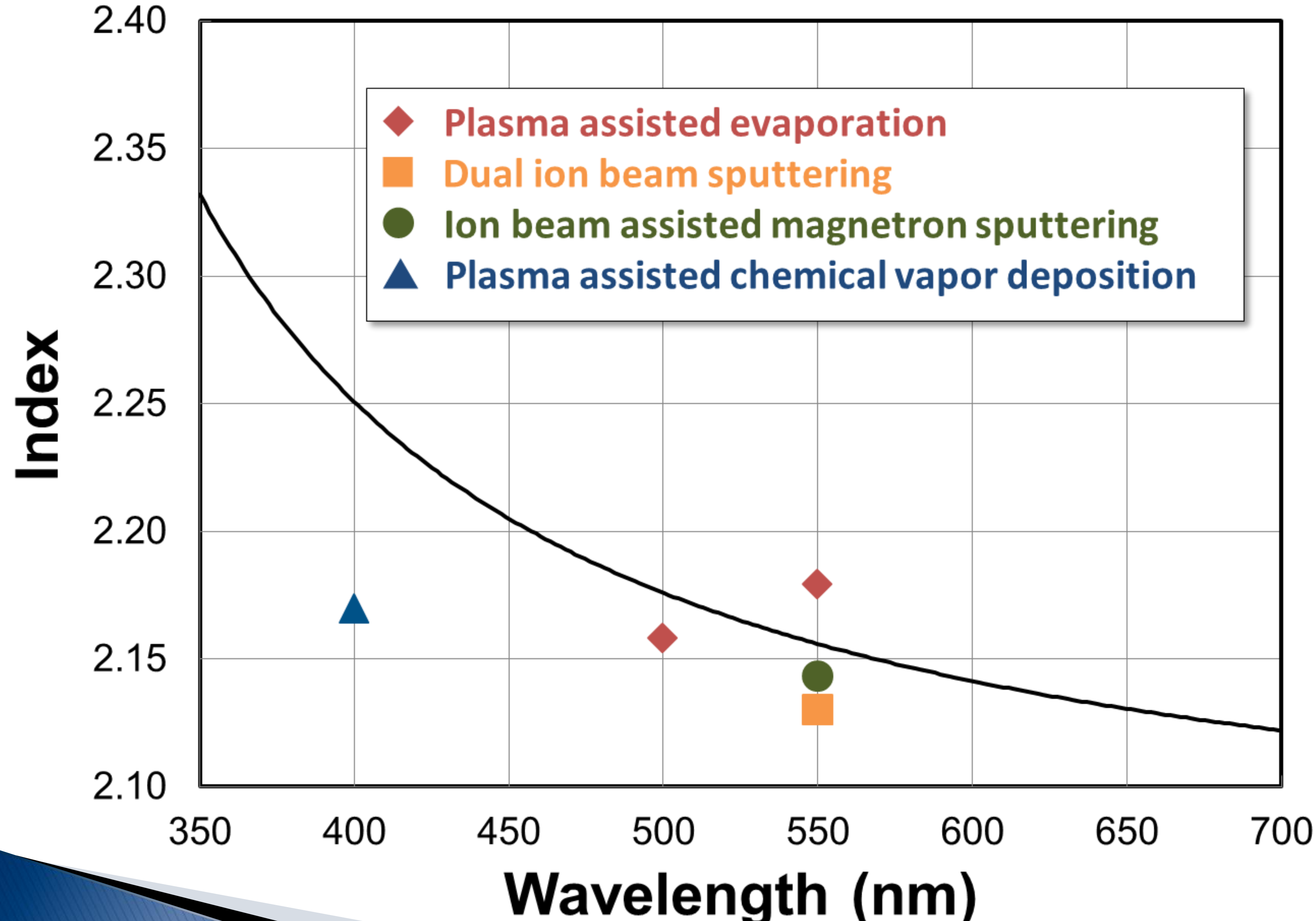


Real and Imaginary Indices for Ta_2O_5

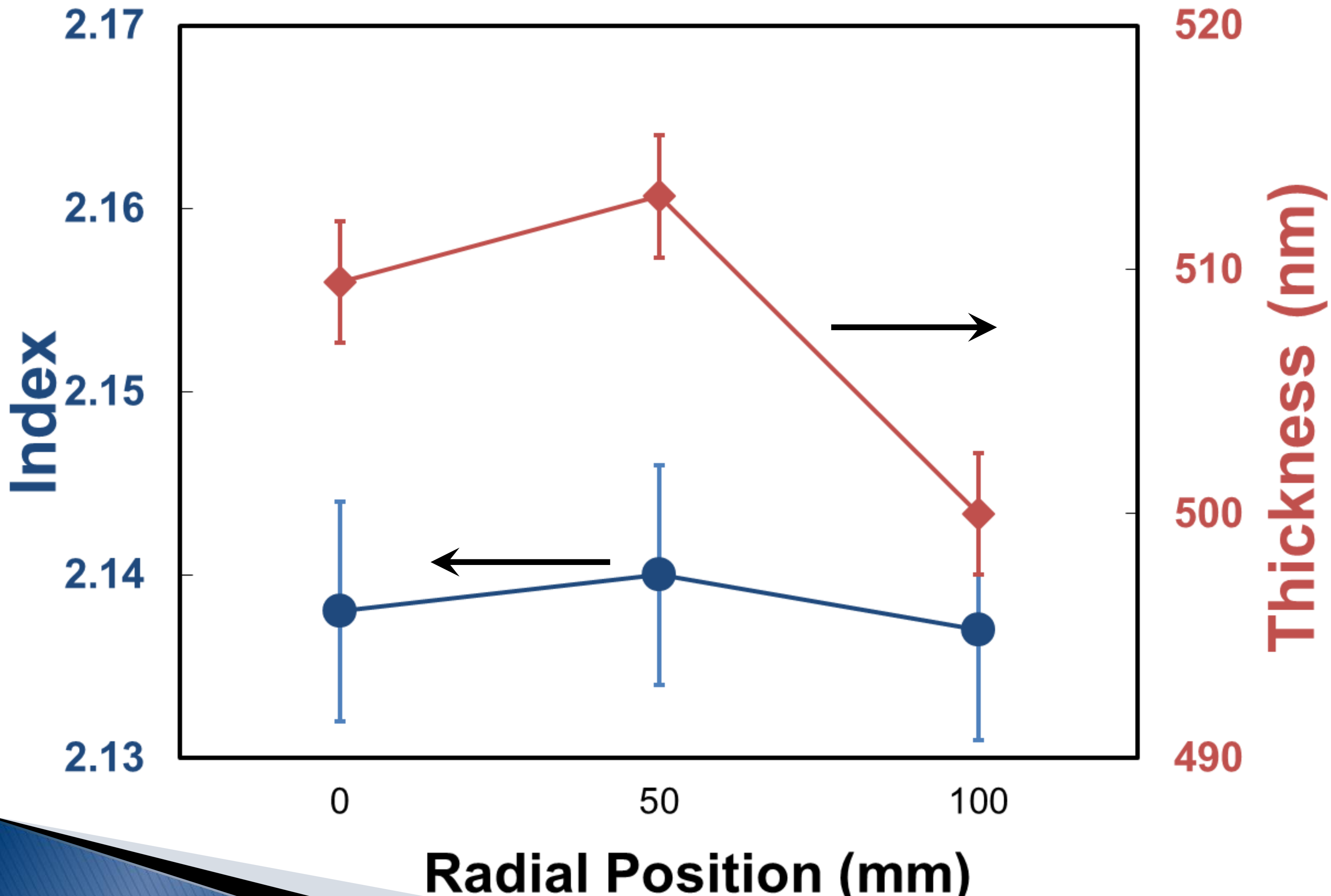


- Three radial positions indistinguishable on this scale
- For $\lambda > 360$ nm, $k < 1 \times 10^{-6}$

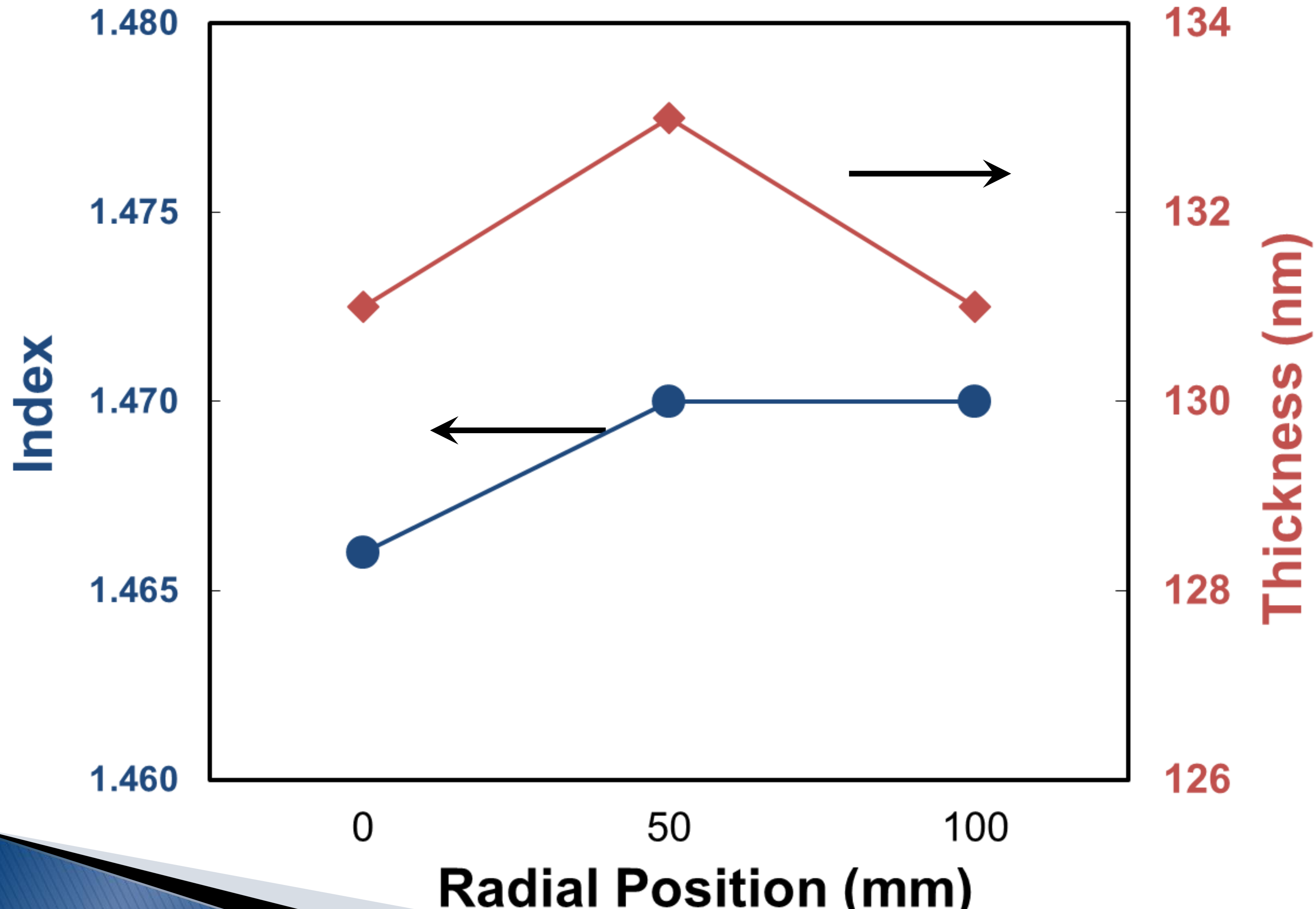
Comparison of Ta_2O_5 Indices



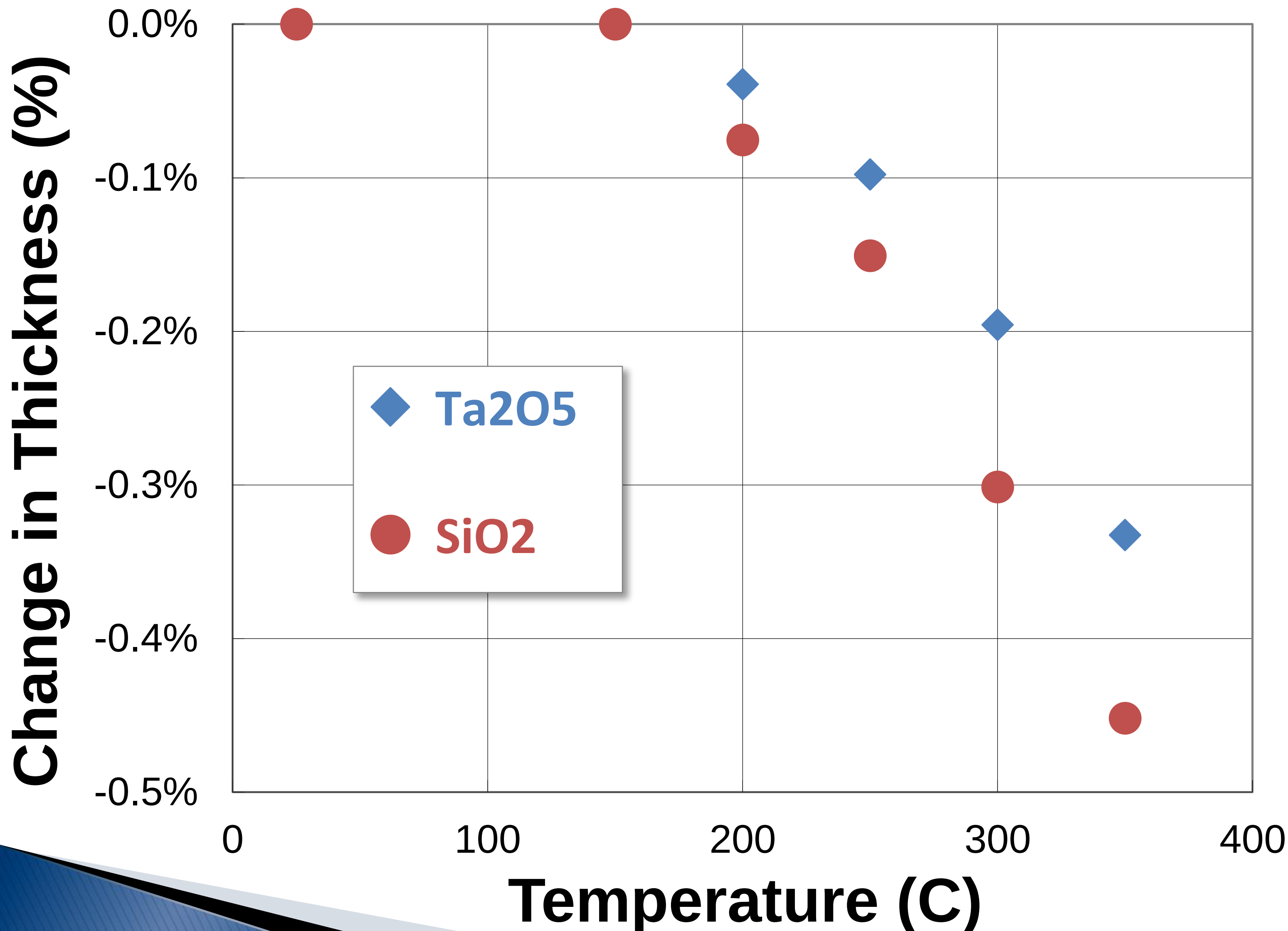
Index (633 nm) and Thickness of Ta_2O_5 vs. Radial Position



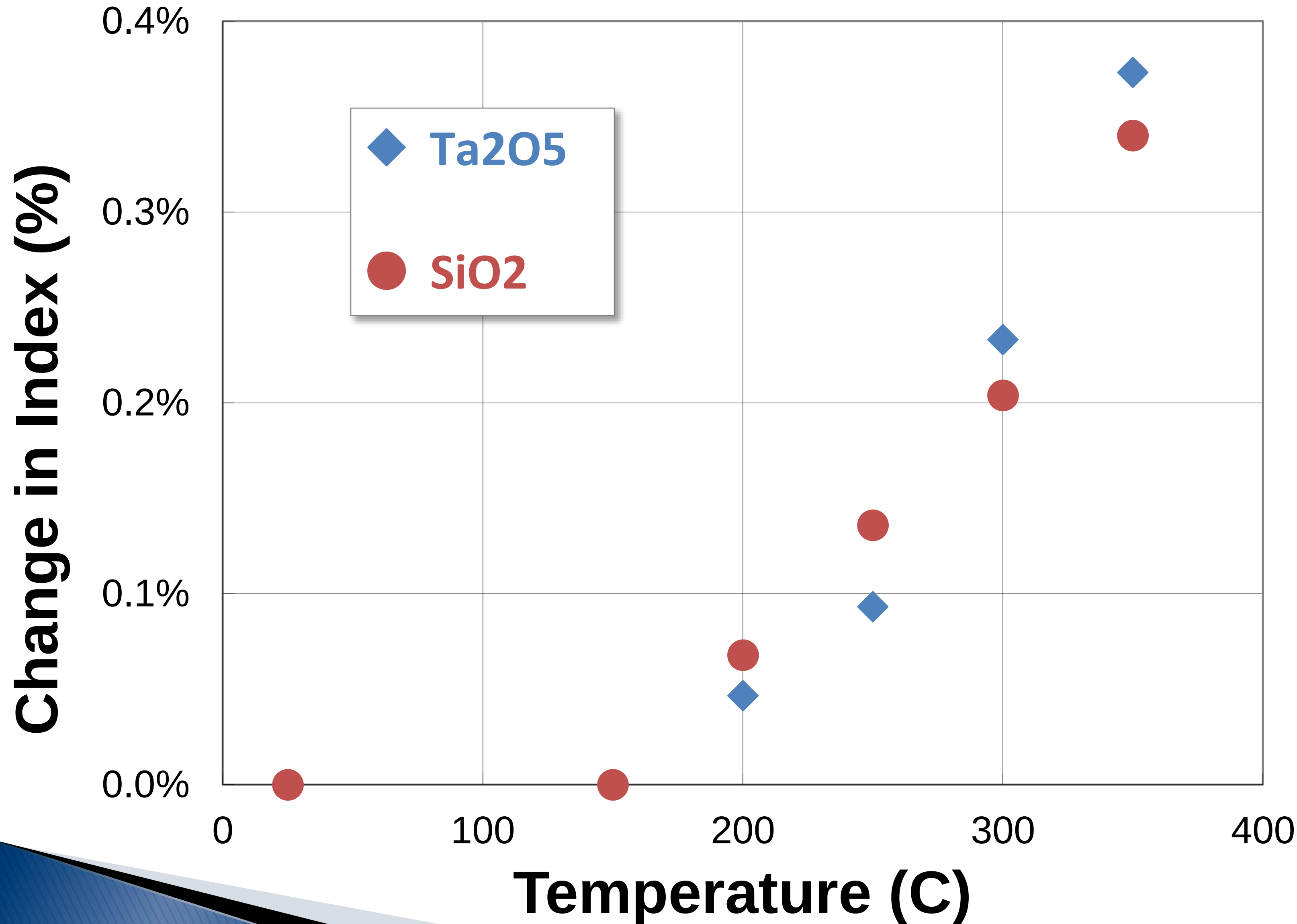
Index (633 nm) and Thickness of SiO_2 vs. Radial Position



Change in Thickness vs. Temperature



Change in Index vs. Temperature



Conclusions

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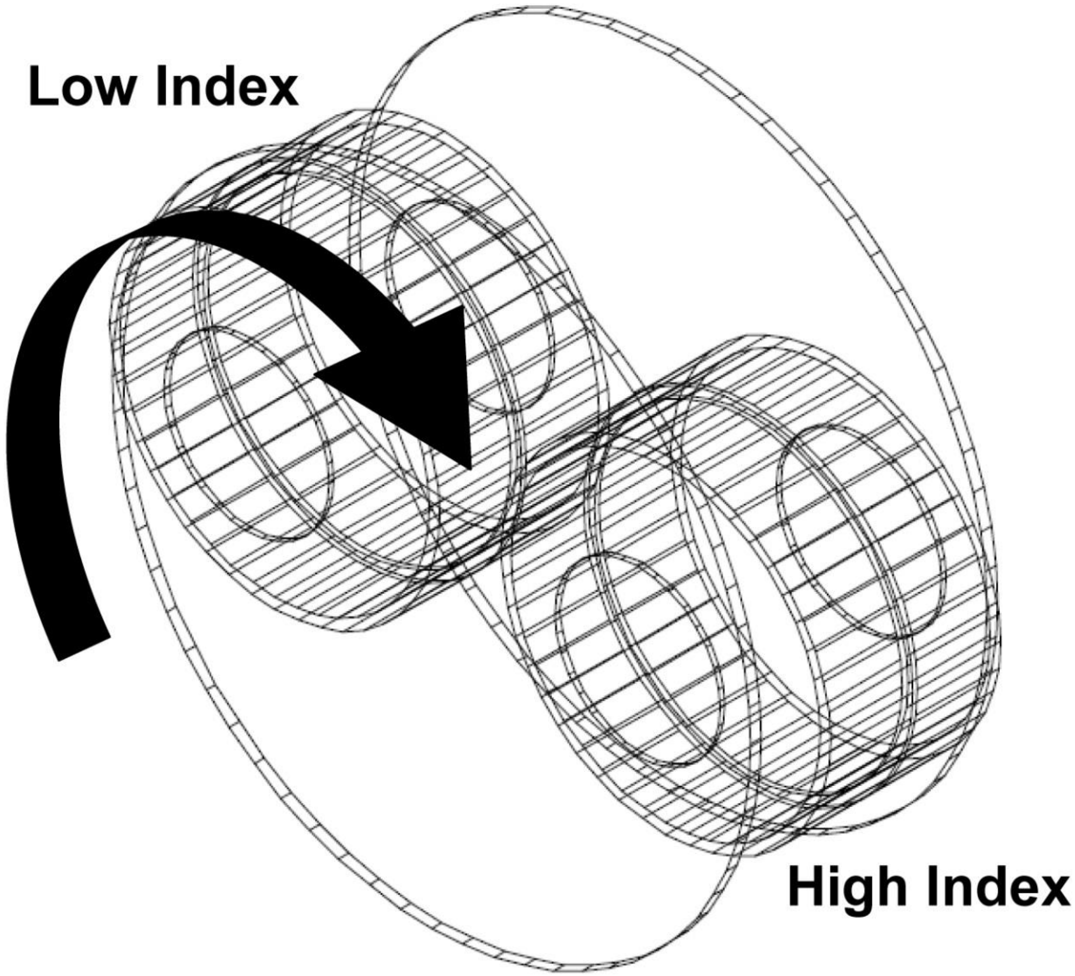
- Off-axis sputtering with unbalanced cylindrical magnetrons produces coatings with excellent thickness uniformity and optical properties:
  - Significant low energy ion bombardment
  - Thickness uniformity ±0.25% over ϕ160 mm and ±1.3% over ϕ200 mm on stationary substrates
  - Excellent temperature stability with changes comparable to those seen in other ion enhanced coatings – Δnd < 0.1% over 350 C

Conclusions, continued

- Level of ion bombardment adjustable through magnetic field imbalance
- Configuration reduces damage from energetic O^- and O_2^-, important for sensitive materials like OLEDs
- Design lends itself to very simple, high throughput coaters

Coater Design



- High and low index materials deposit on multiple substrates simultaneously
- No substrate rotation, only indexing
- Extremely simple, robust source design
- No uniformity masks or shields