WISE 2000, International Workshop on Spectroscopic Ellipsometry,
8 – 9 May 2000

DUV (150 – 350nm) Characterization of Materials: A new instrument, the Purged UV Spectroscopic Ellipsometer ,

Pierre BOHER,,
SOPRA S.A., 26 rue Pierre Joigneaux, 92270 Bois-Colombes, France,

Outline of the talk:

- **Introduction.**
- **Presentation of the purged UV spectroscopic ellipsometer.**
- **Experimental results:**
  - ***CaF_2 substrate***
  - ***LaF_3 film on CaF_2 substrate***
  - ***Photoresists and antireflective coatings***
  - ***Cr and CrOx layers on glass***
  - ***Transmittance of SiOF substrate***
  - ***Extended PUV range***
- **Conclusion**

introduction:

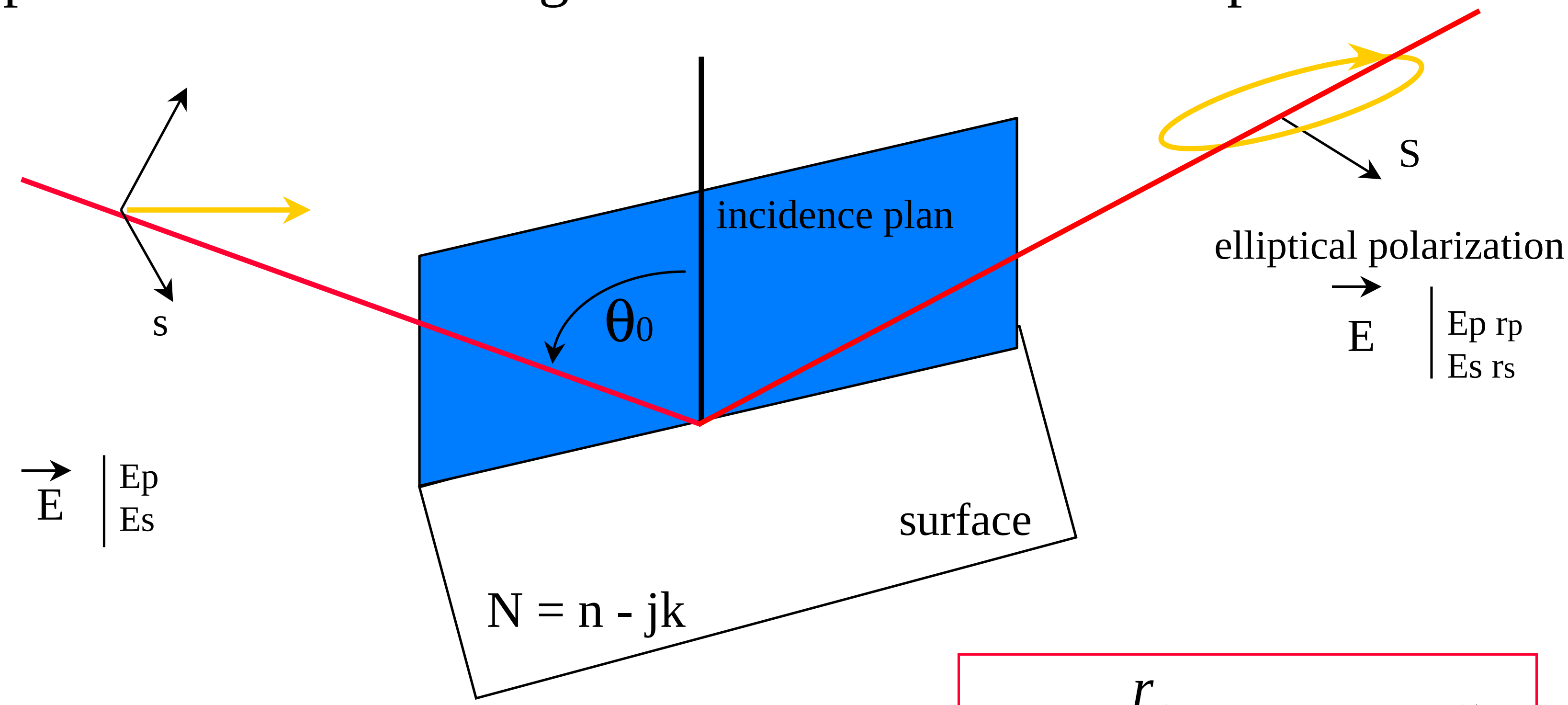
- **157nm lithography successor of 193nm generation.**
- **Need to characterize accurately new materials (resists, ARC) and optics at this new wavelength.**
- **Strong correlation between thickness and indices due to low thickness values.**

  ⇒ ***Good candidate --> spectroscopic ellipsometry***
- **Need of additional photometric measurements (transmittance of the optics for example).**

⇒ ***New instrument: <u>Purged UV ellipsometer</u>***

SE Basic theory

Ellipsometry determines and analyzes the change of the polarization state of light after reflection on a sample



$$\rho = \frac{r_p}{r_s} = \tan\psi \, e^{j\Delta}$$

Advantages of ellipsometry

• Ellipsometry is an absolute technique (no need of reference spectrum or reference sample)
• Ellipsometry gives twice more informations than reflectometry (ψ and Δ instead of R)
• The phase Δ is very sensitive to surface layers
• As ellipsometry measures the polarization state and not the intensity, it is less sensitive to light intensity fluctuations.

Ellipsometry allows to characterize directly the optical indices (n,k) of bulk materials :

$$N^2 = (n - jk)^2 = \sin^2\theta_0 \left[1 + \left(\frac{1-\rho}{1+\rho} \right)^2 \tan^2\theta_0 \right]$$

SOPRA

Ellipsometer setup

⇒**Minimized beam path.**
⇒**Deuterium lamp as source.**
⇒**Double monochromator included in the polariser arm (avoid photobleaching)**
⇒**MgF_2 Rochon polarizers on stepper motors.**
⇒**Detection by a photomultiplier in photon counting mode.**

Ellipsometer characteristics

⇒Rotating analyser instrument.

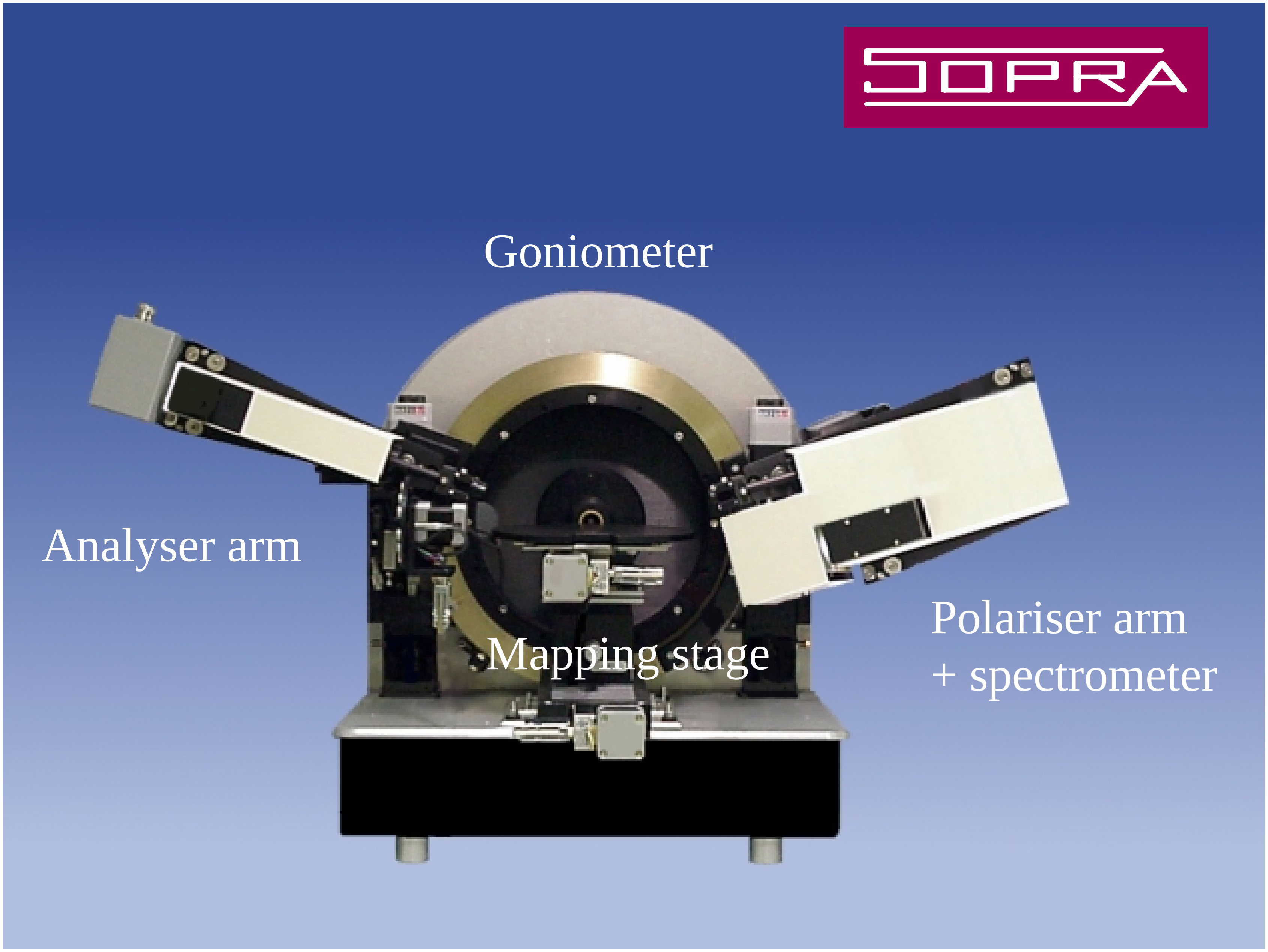
⇒Spectral range 145-350nm extendable in the visible range.

⇒3 measurement modes possible:

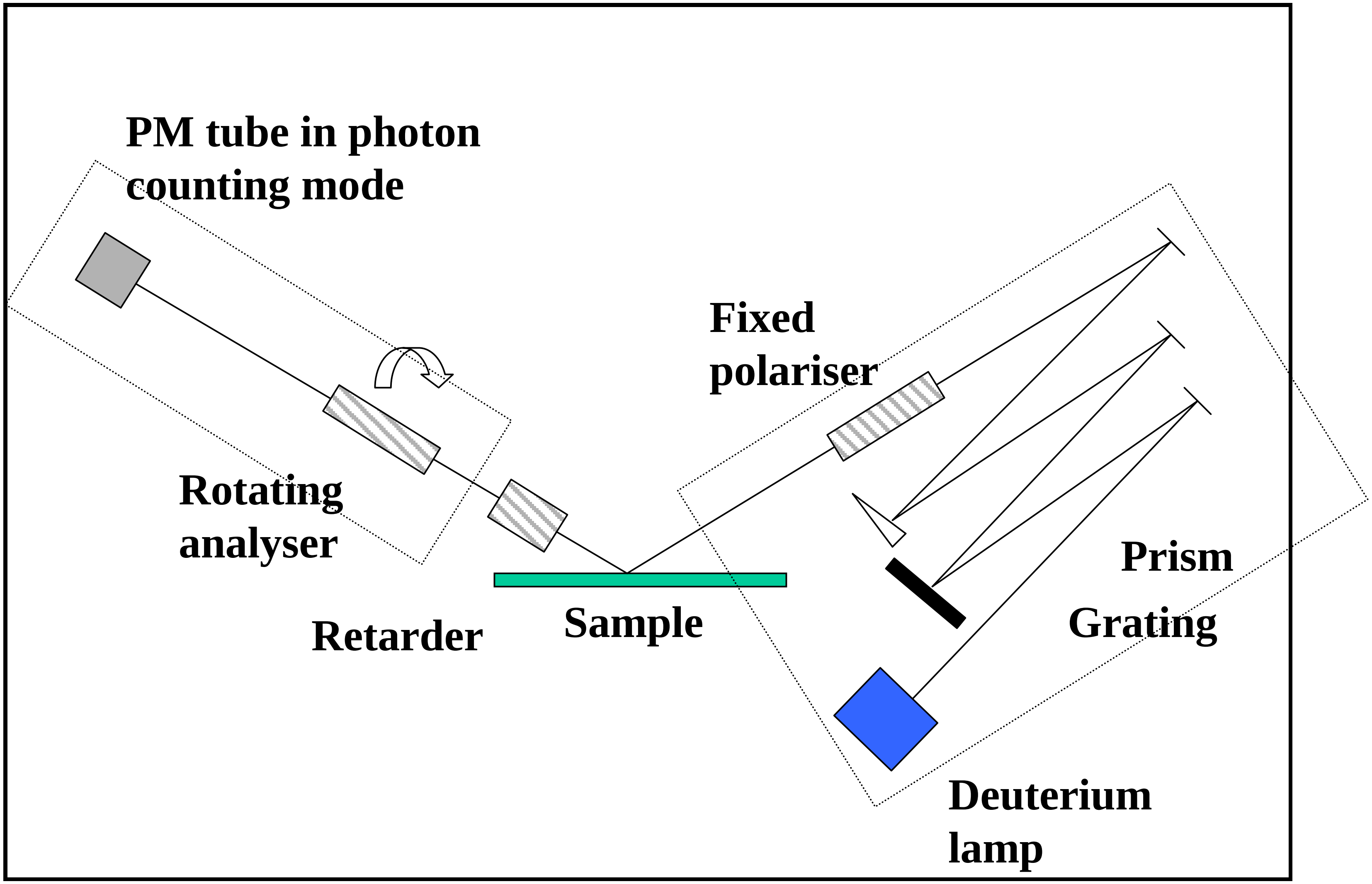
>*variable angle spectroscopic ellipsometry*

>*Photometry (reflectance or transmittance)*

>*Scatterometry*



Purged UV spectroscopic ellipsometer



Schematic view of the purged UV spectroscopic ellipsometer

SOPRA

Purged glove box

⇒SE system is installed inside a glove box with continuous H_2O and O_2 purification.

⇒Dry nitrogen is injected continuously with automatic pressure adjustment.

⇒Filters can be regenerated automatically every 3-month.

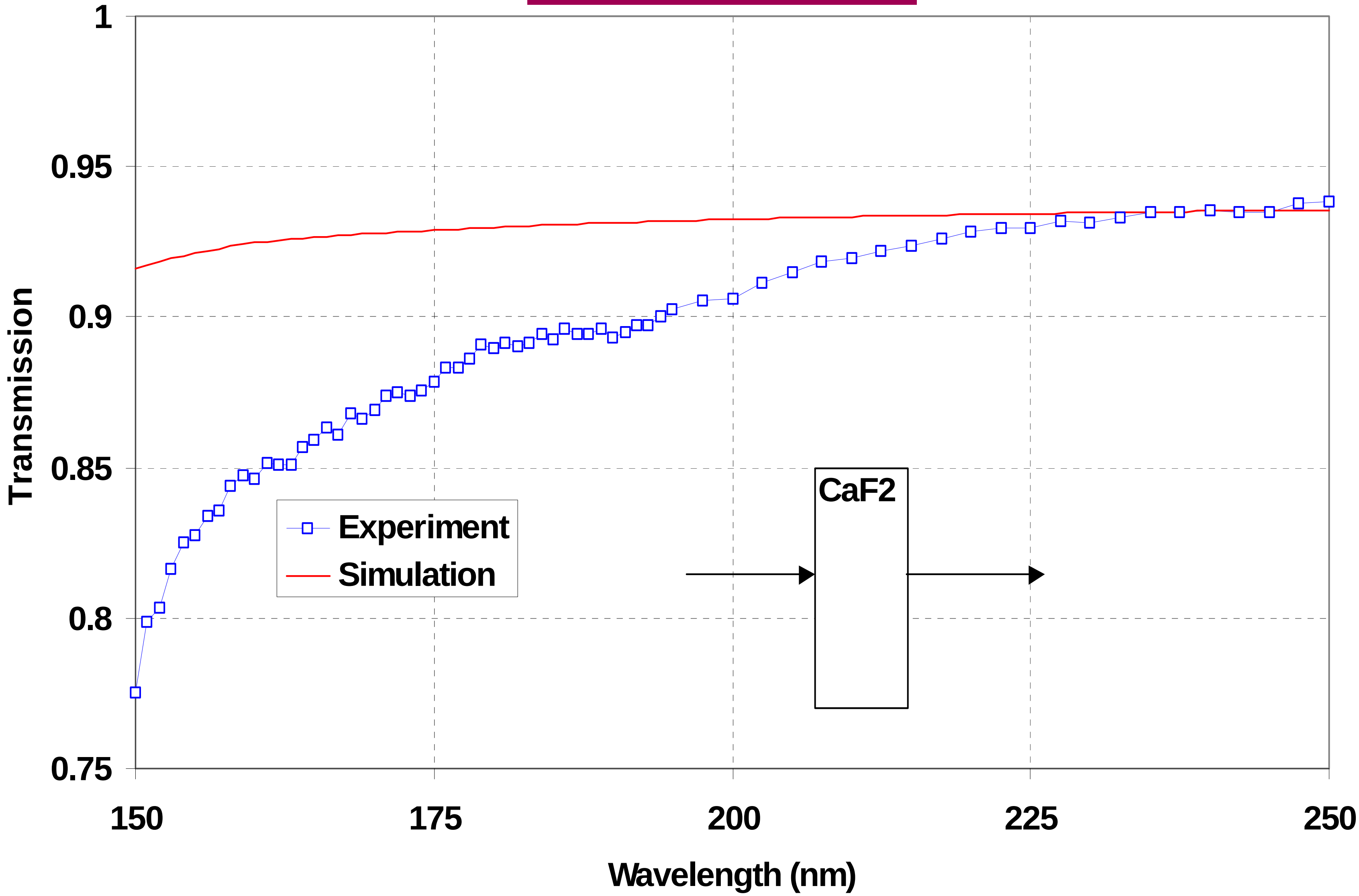
Purged glove box

⇒One working face with three gloves to adjust sample and replace deuterium lamp.

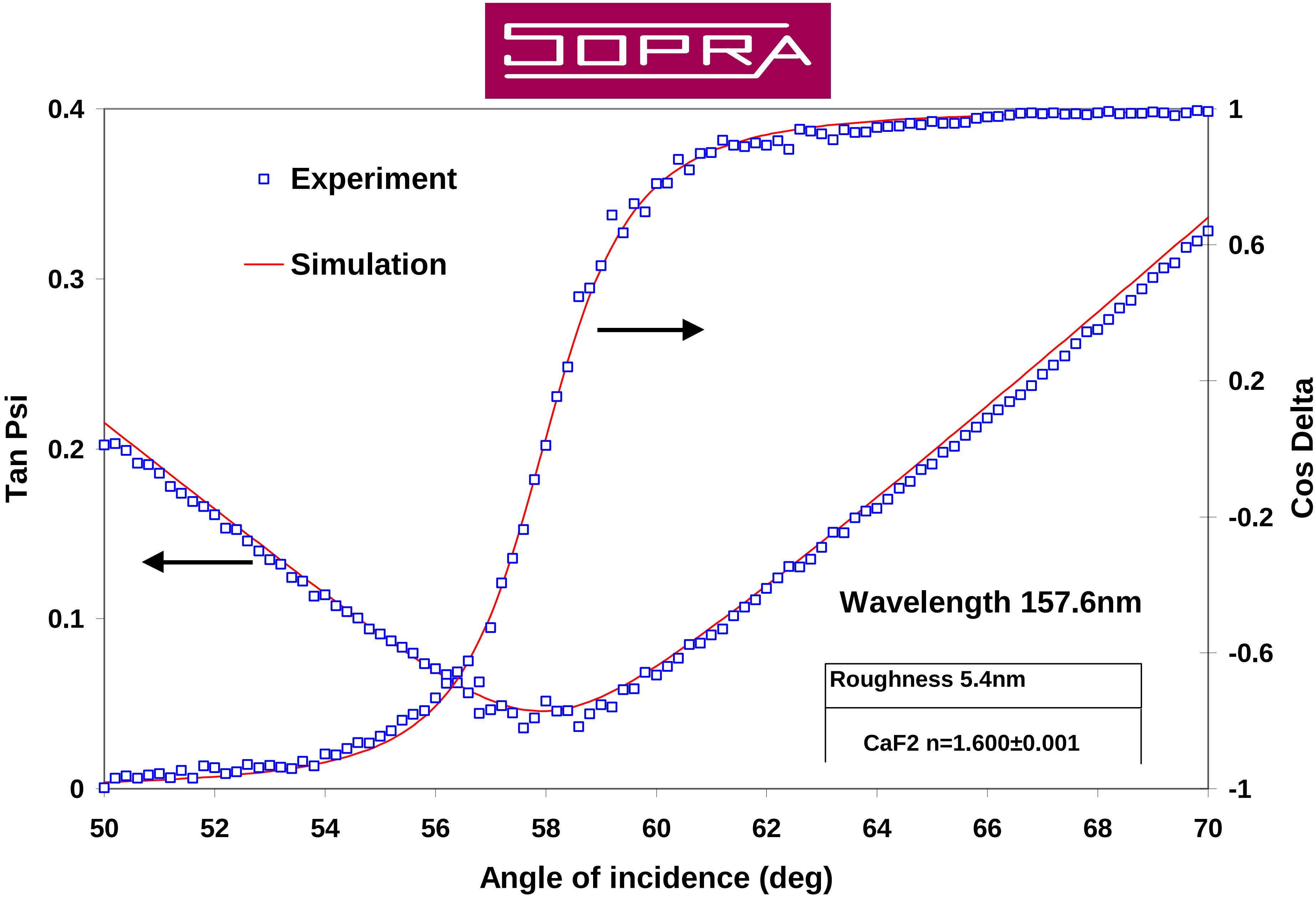
⇒Samples up to 200mm diameter introduced with load lock

⇒Residual H_2O and O_2 measured continuously (in the ppm range during normal working conditions).

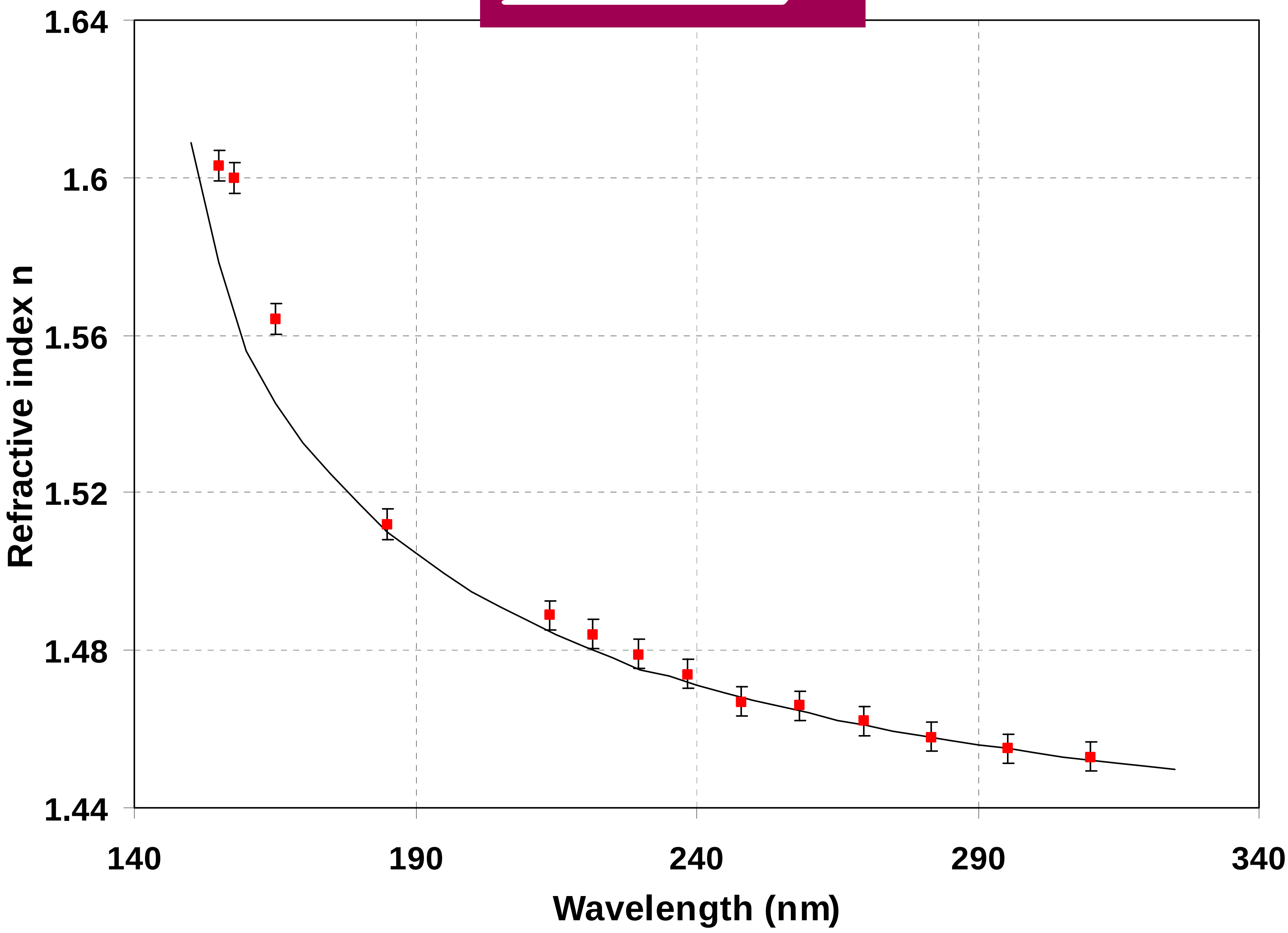

Purged Glove Box
SOPRA



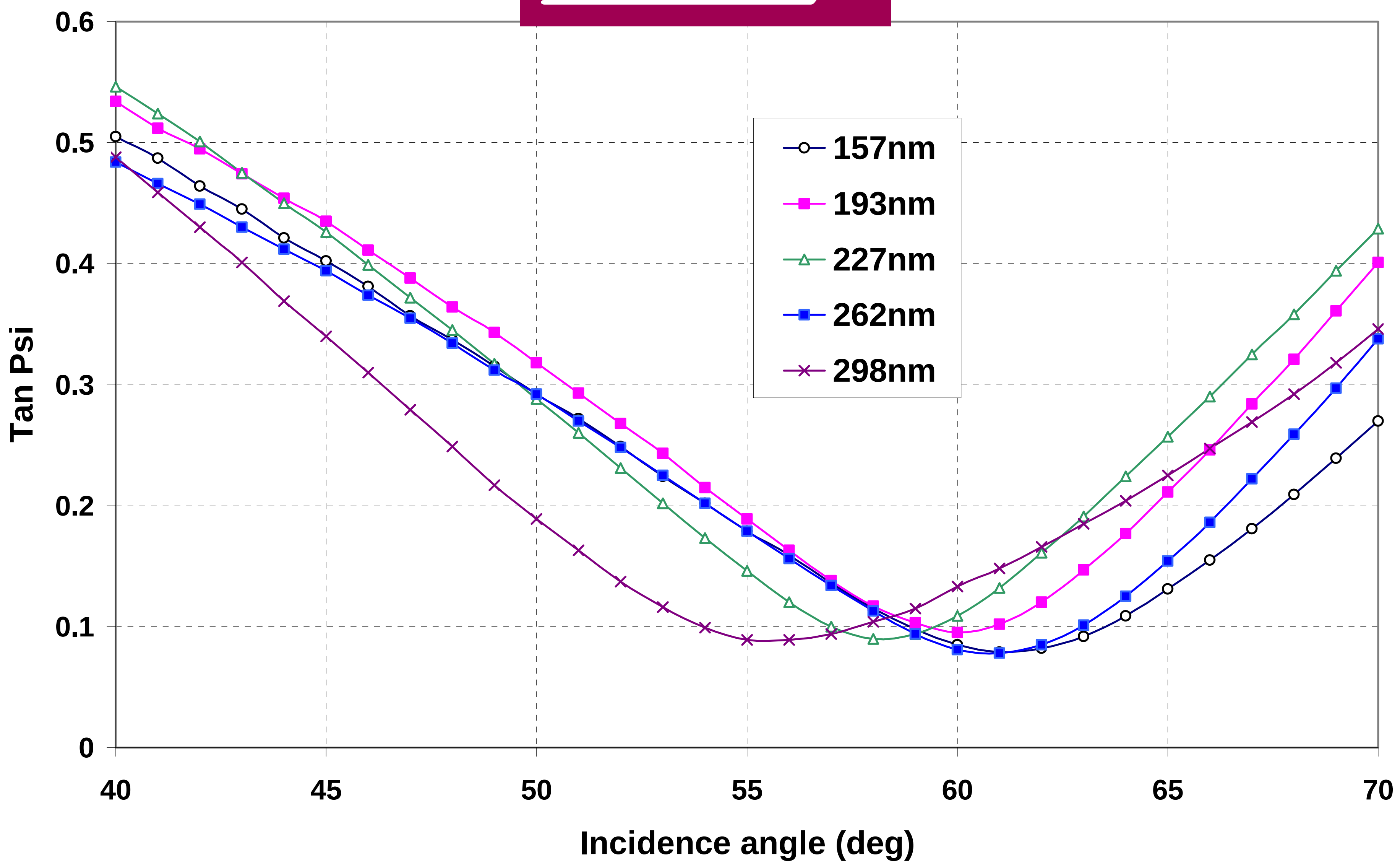
Transmittance measurement on a CaF_2 substrate



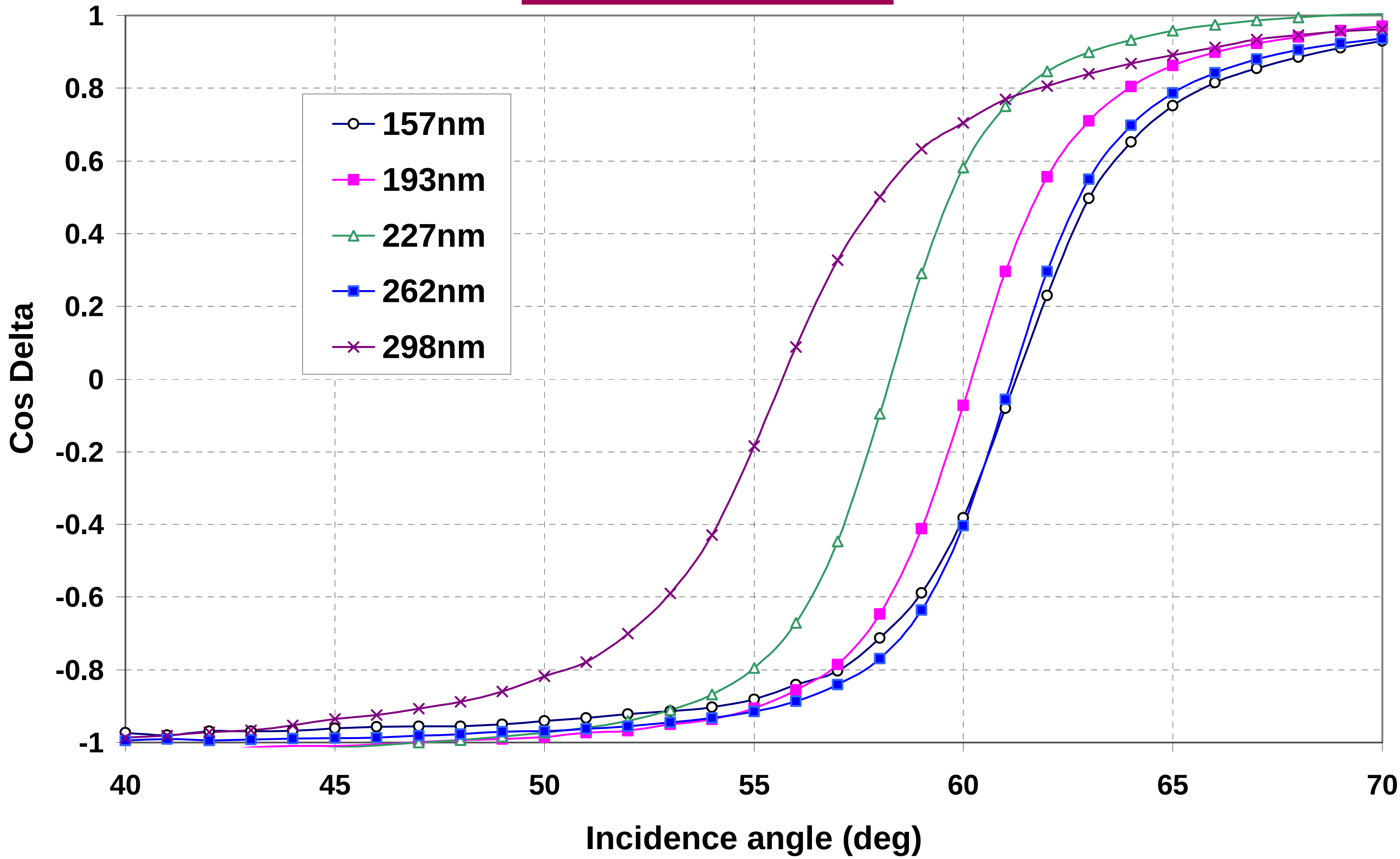
Analysis of the SE measurement at 157.6nm on the CaF_2 substrate[14]



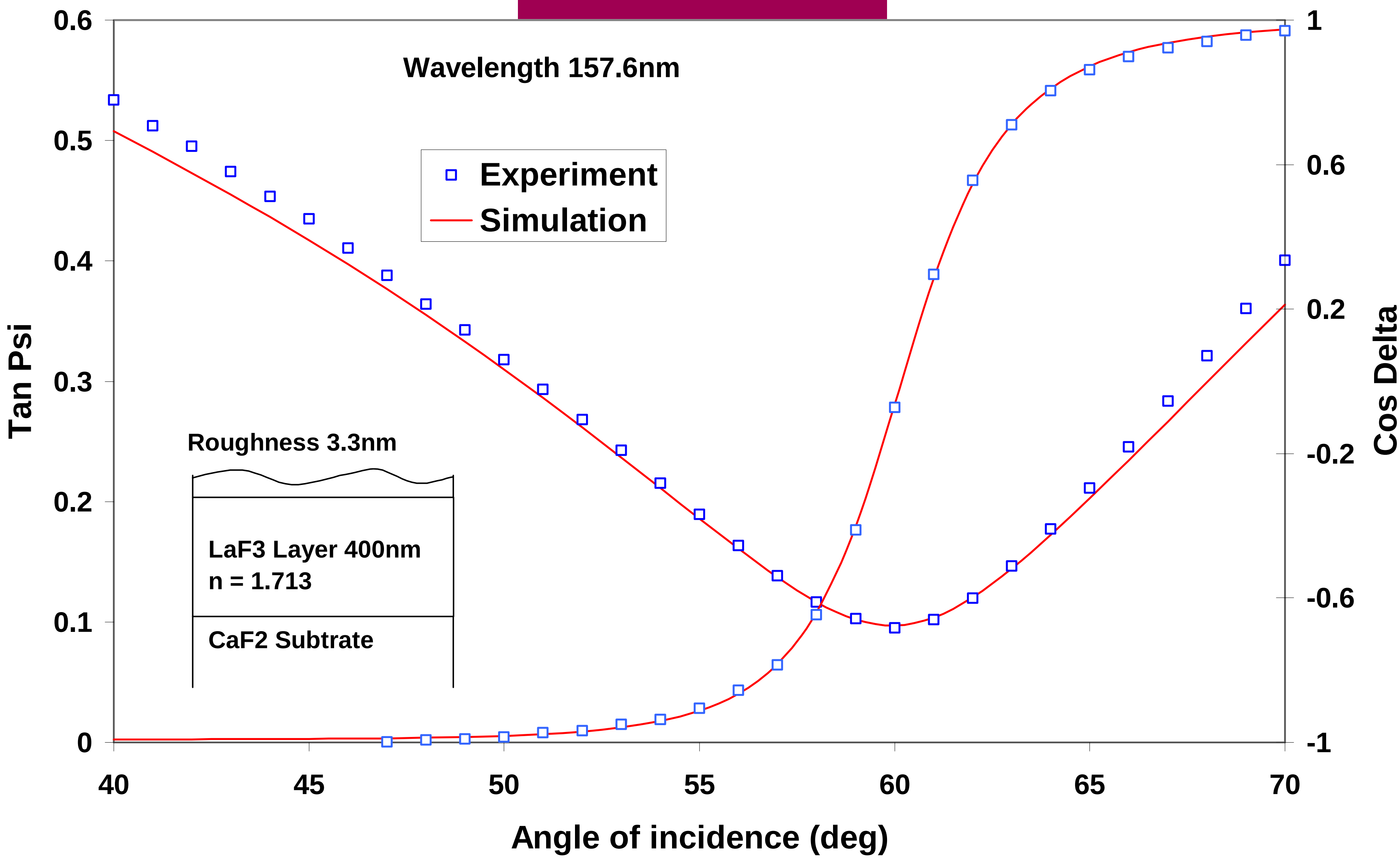
Refractive index of the CaF_2 substrate compared to the literature



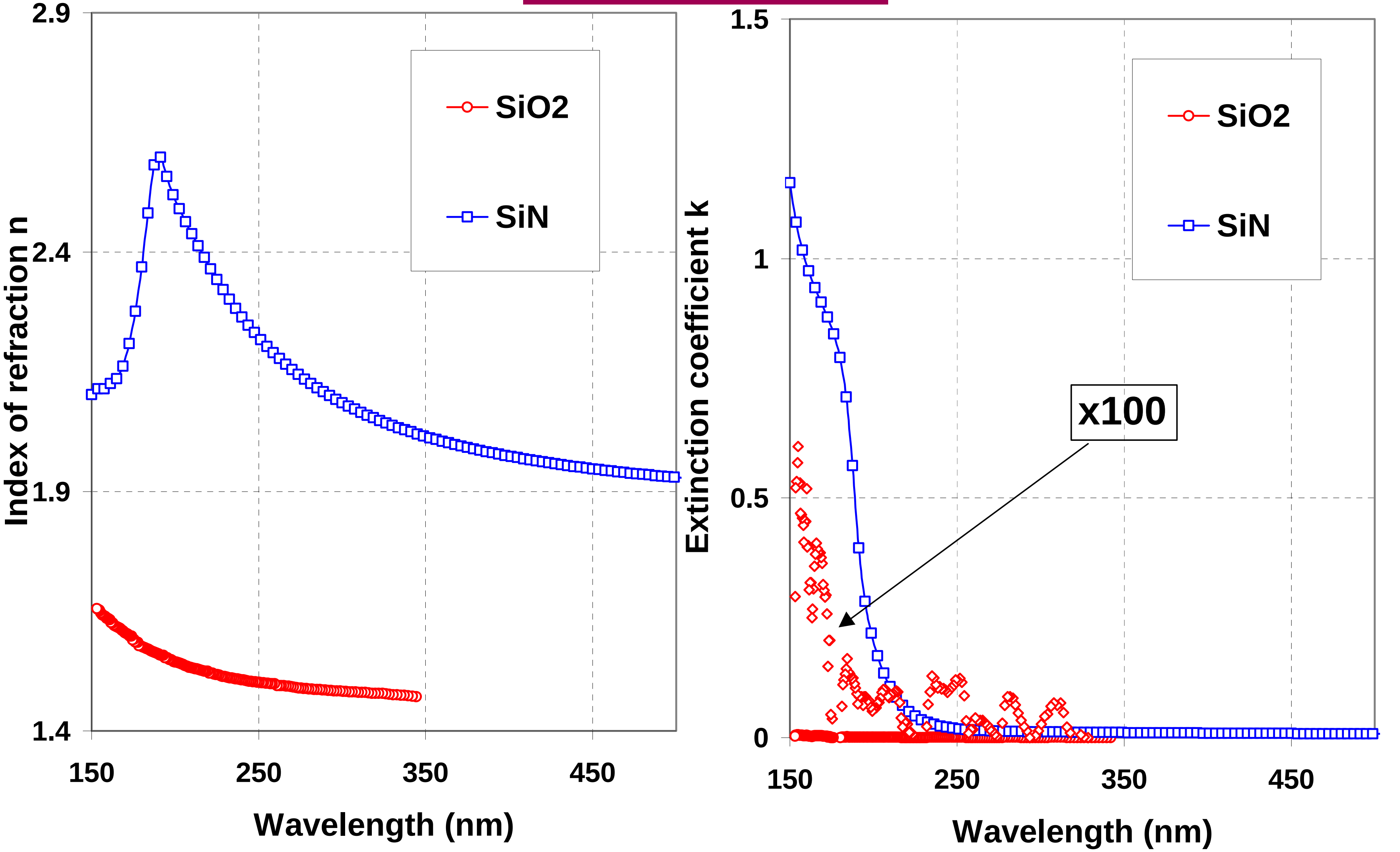
SE measurements on LaF3/CaF2 sample



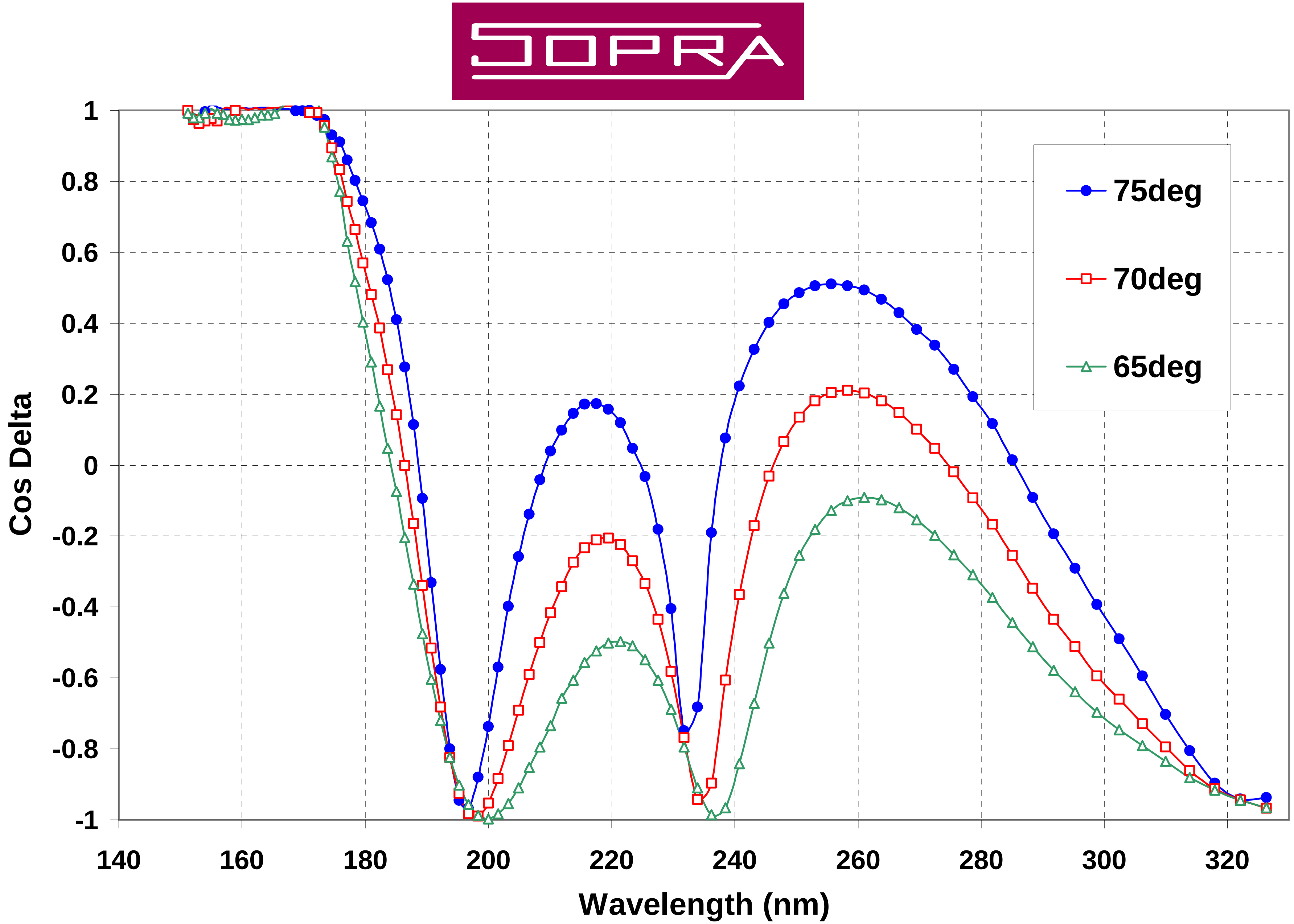
SE measurements on LaF3/CaF2 sample



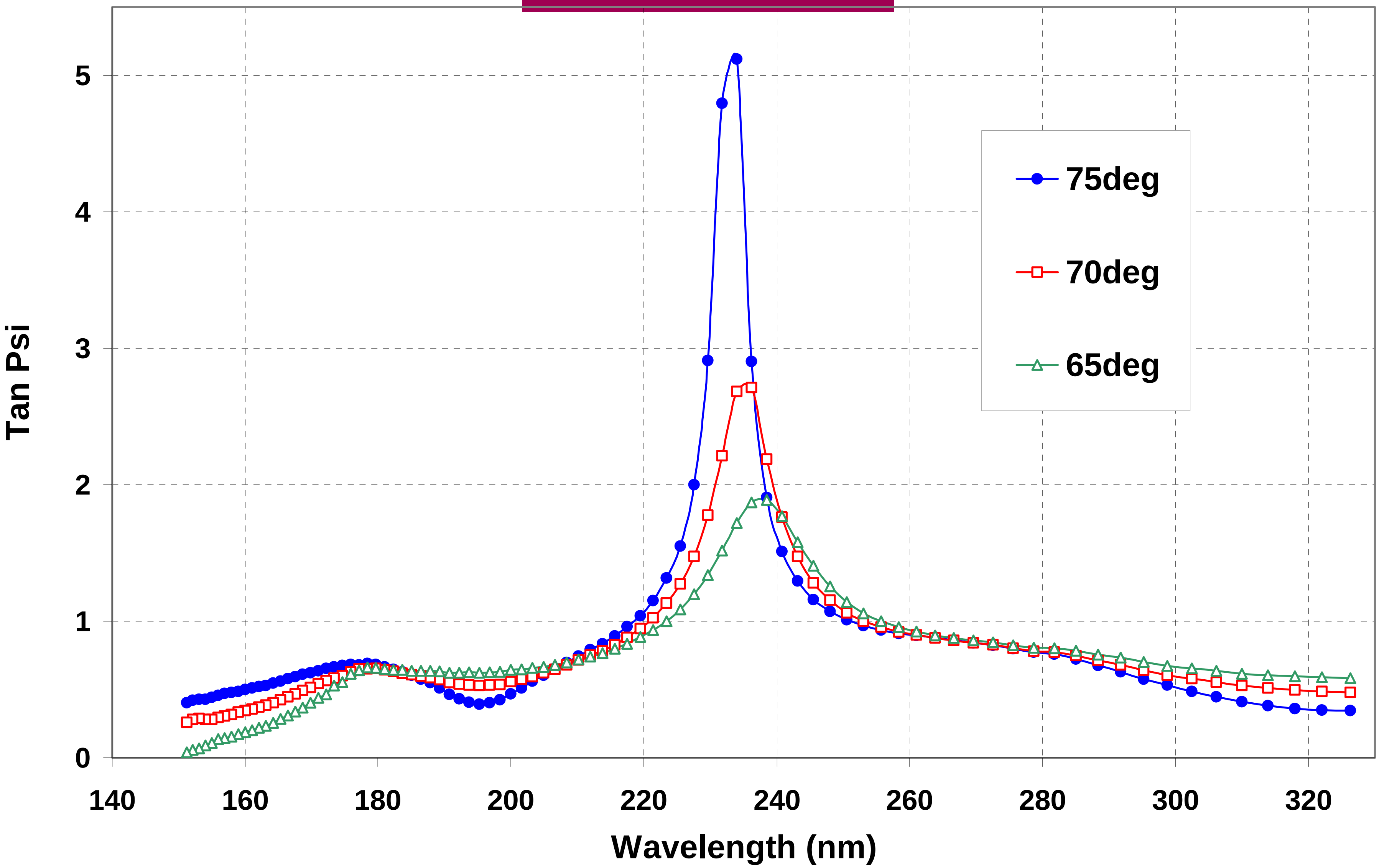
Analysis of the SE measurement at 157.6nm on the LaF_3/CaF_2 sample



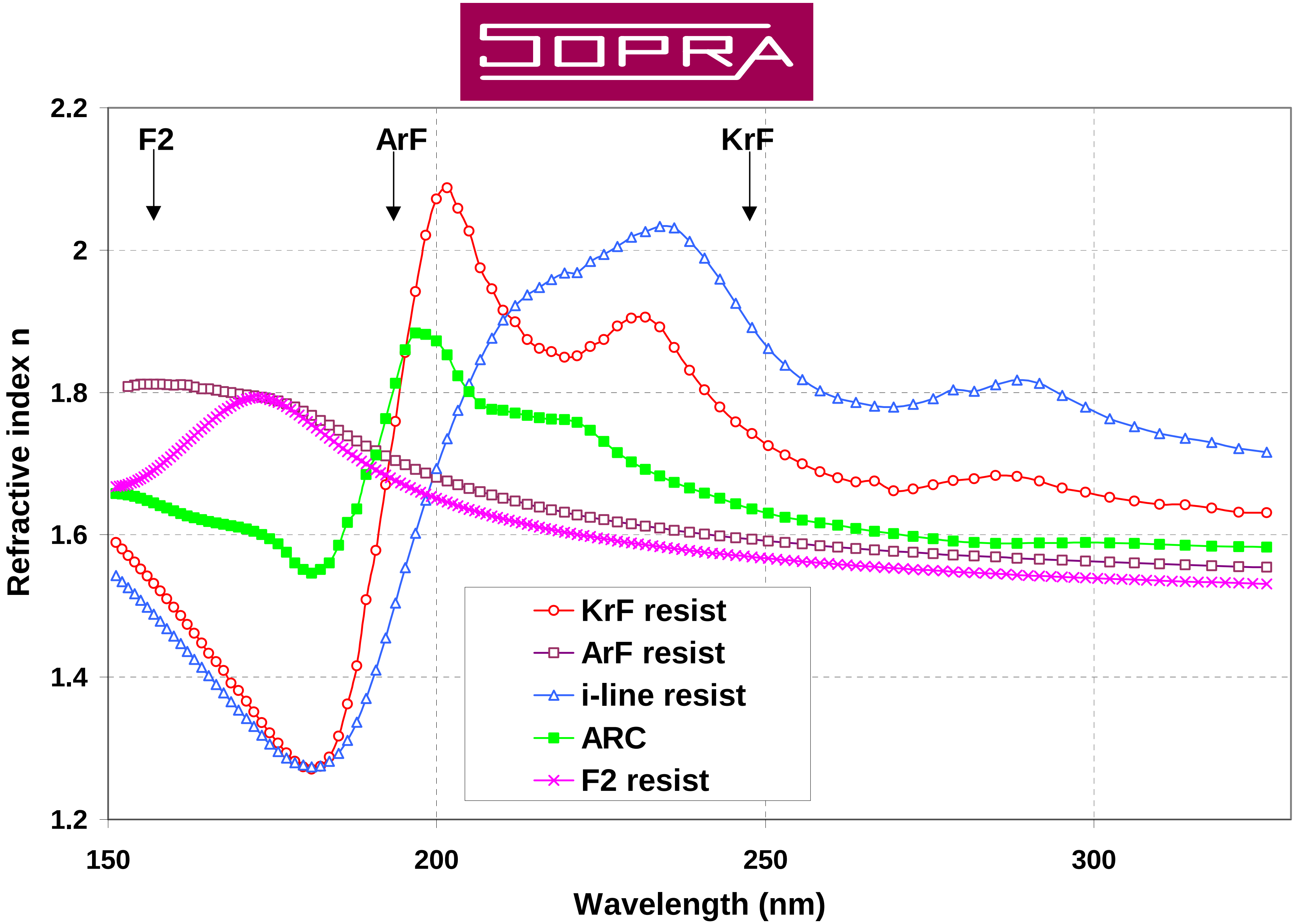
Measured dielectric constants of SiO_2 and SiN layers



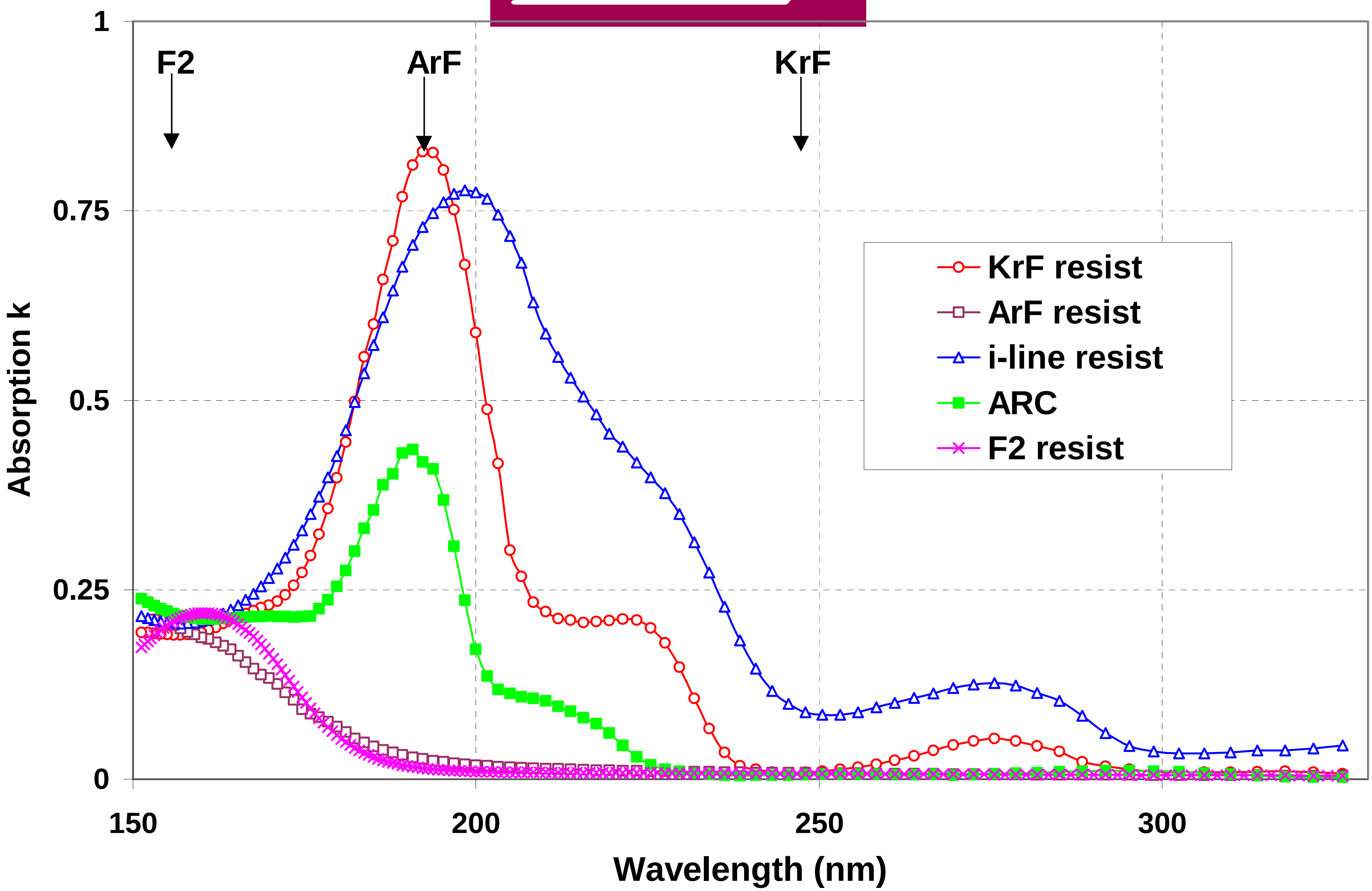
Variable angle measurement on a photoresist film



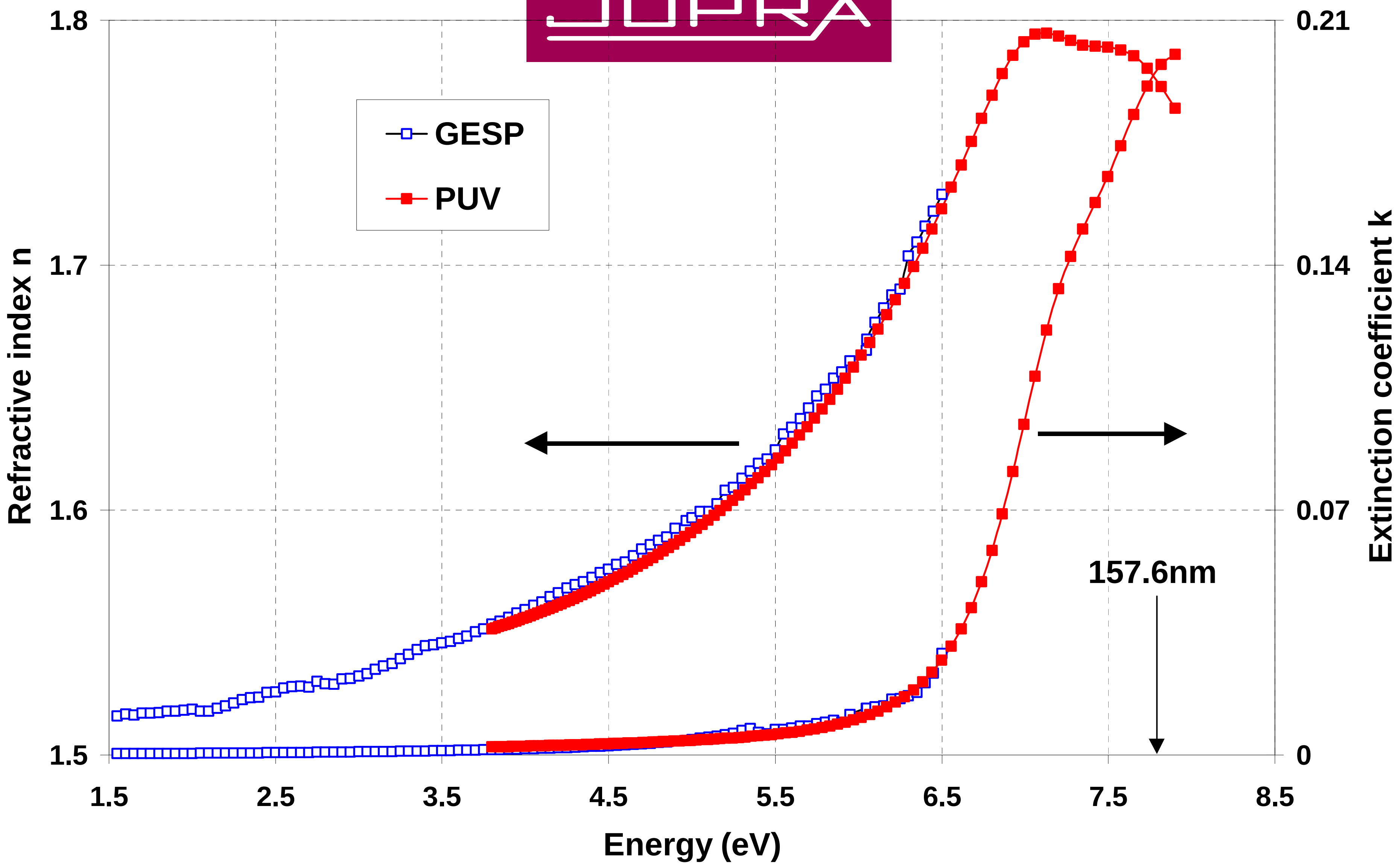
Variable angle measurement on a photoresist film



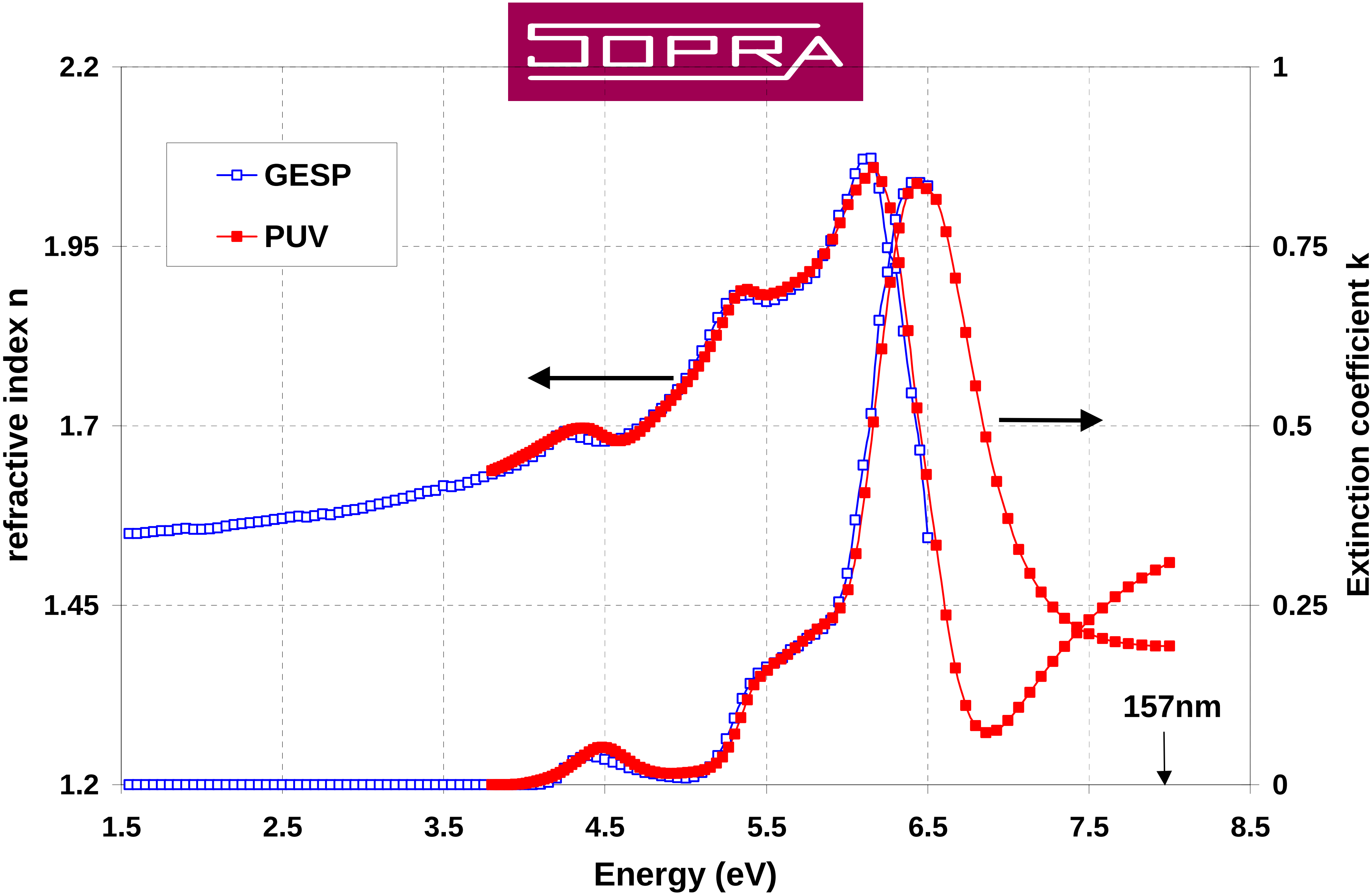
Refractive index of different resists and antireflective coatings



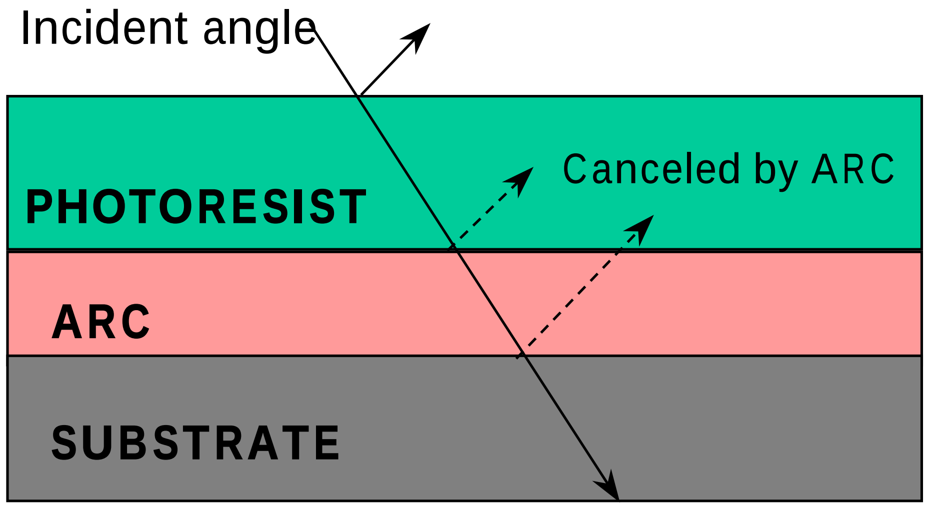
Extension coefficients of different resists and antireflective coatings

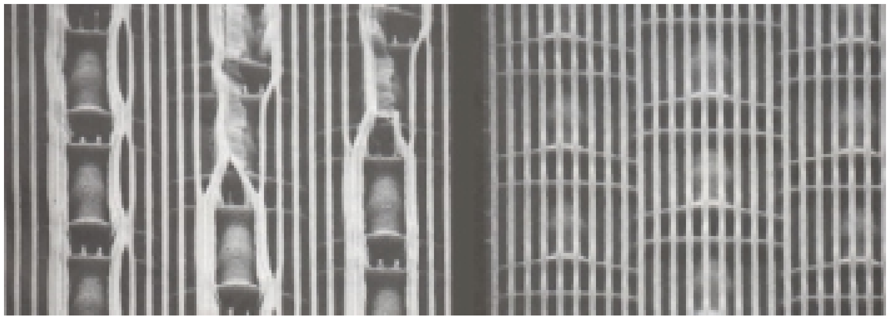


Dielectric constants of photoresist 1 measured with the GESP and PUV instruments



Dielectric constants of photoresist 2 measured with the GESP and PUV instruments



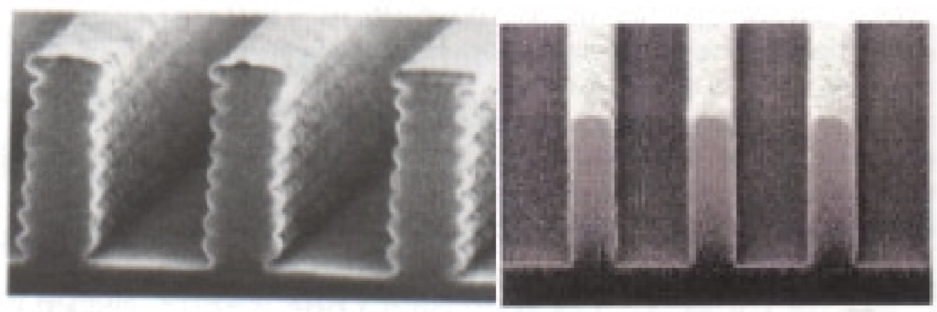


* Reduction of the notching effect

---> lower line width fluctations

* Reduction of the « swing » effect

---> periodic behaviour of the reflectivity



* Spectroscopic Ellipsometry provides :

- Thickness : T
- Refractive index : $n(\lambda)$
- Extinction coefficient : $k(\lambda)$

* The index profile : quality of the material

* The knowledge of N and K allows to simulate the REFLECTIVITY of the material for any thicknesses, any angles of incidence and at any photolithographic wavelengths.

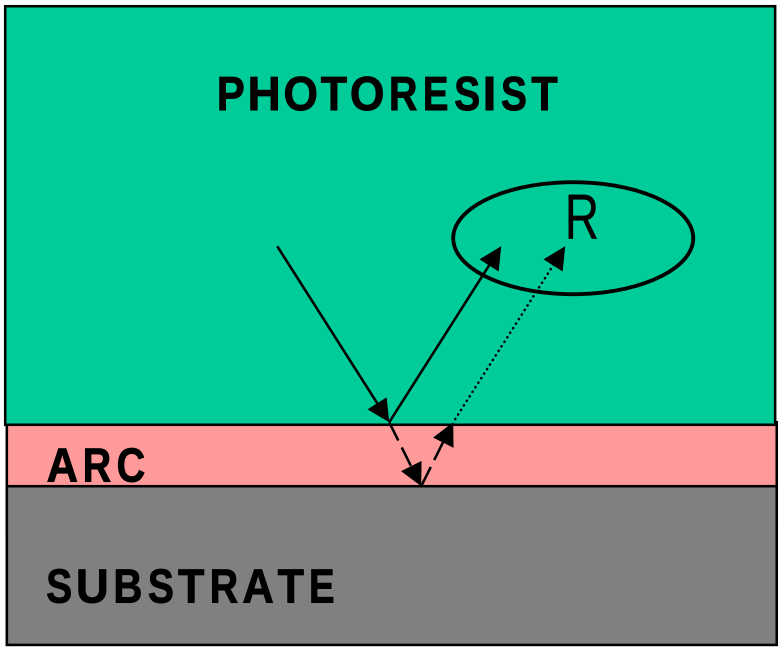
→The best conditions for the deposition process can be predicted

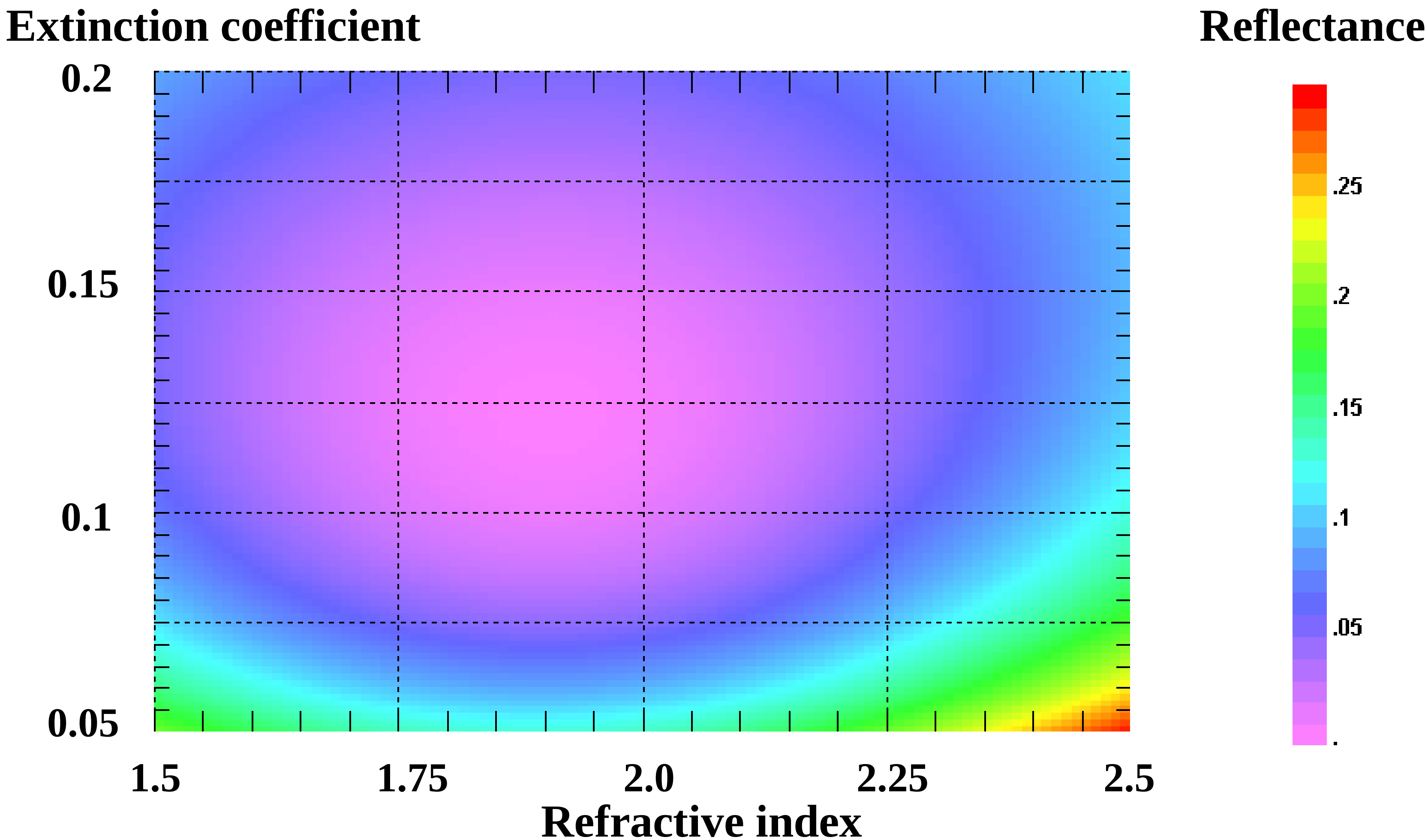
REFLECTIVITY SIMULATIONS

Normal incidence

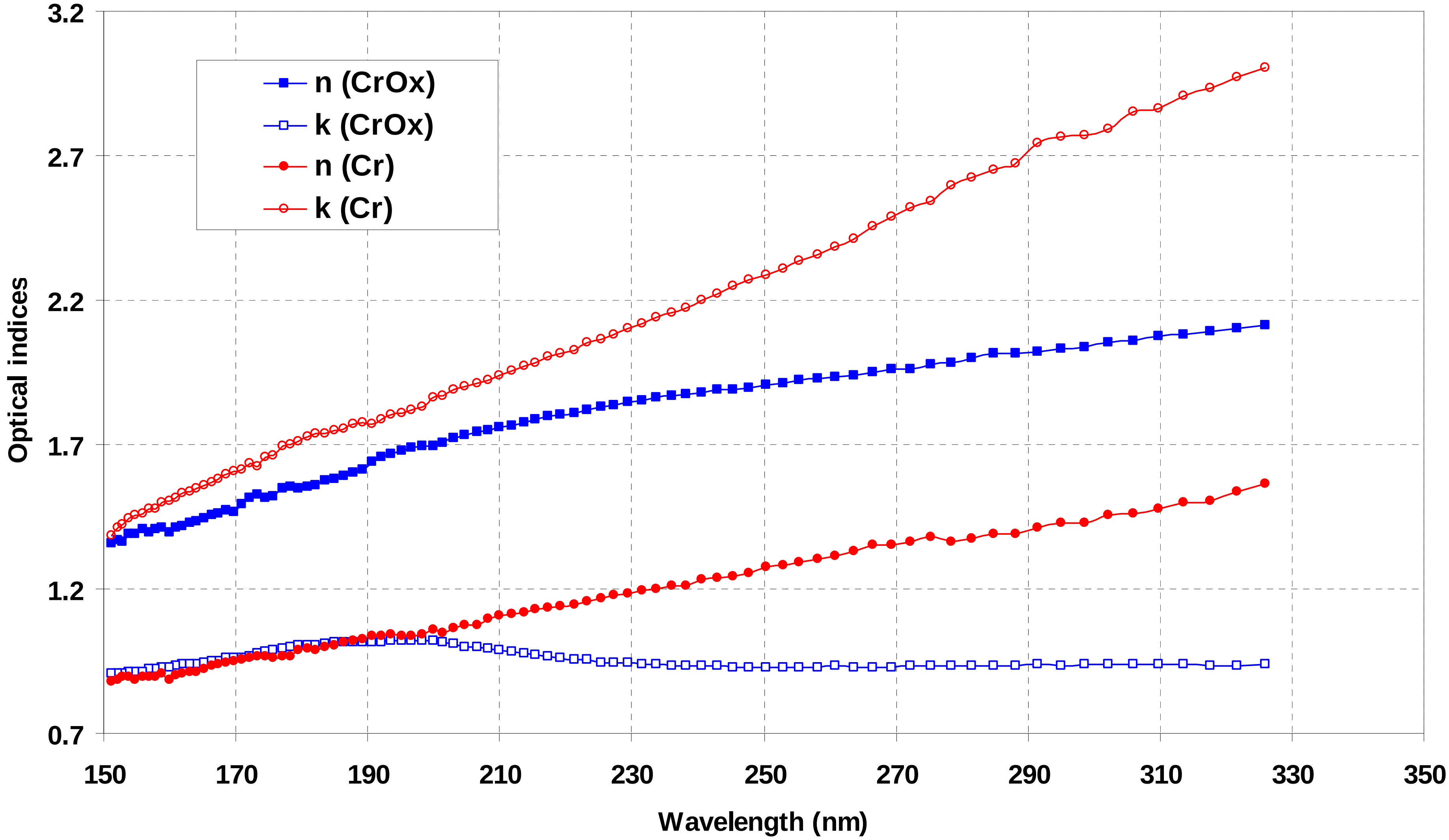
Wavelength : 157.6 nm

Ambient : Photoresist

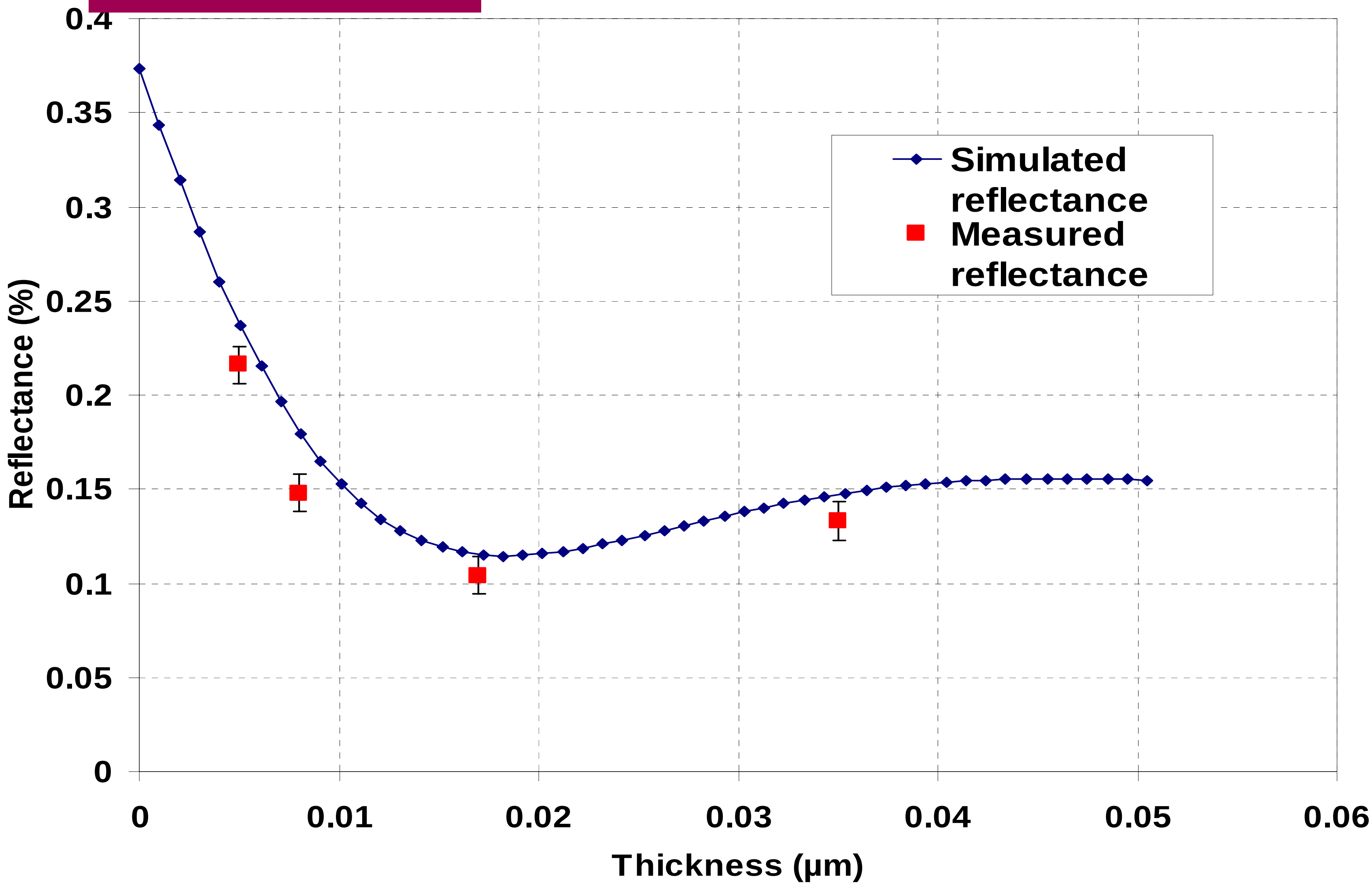




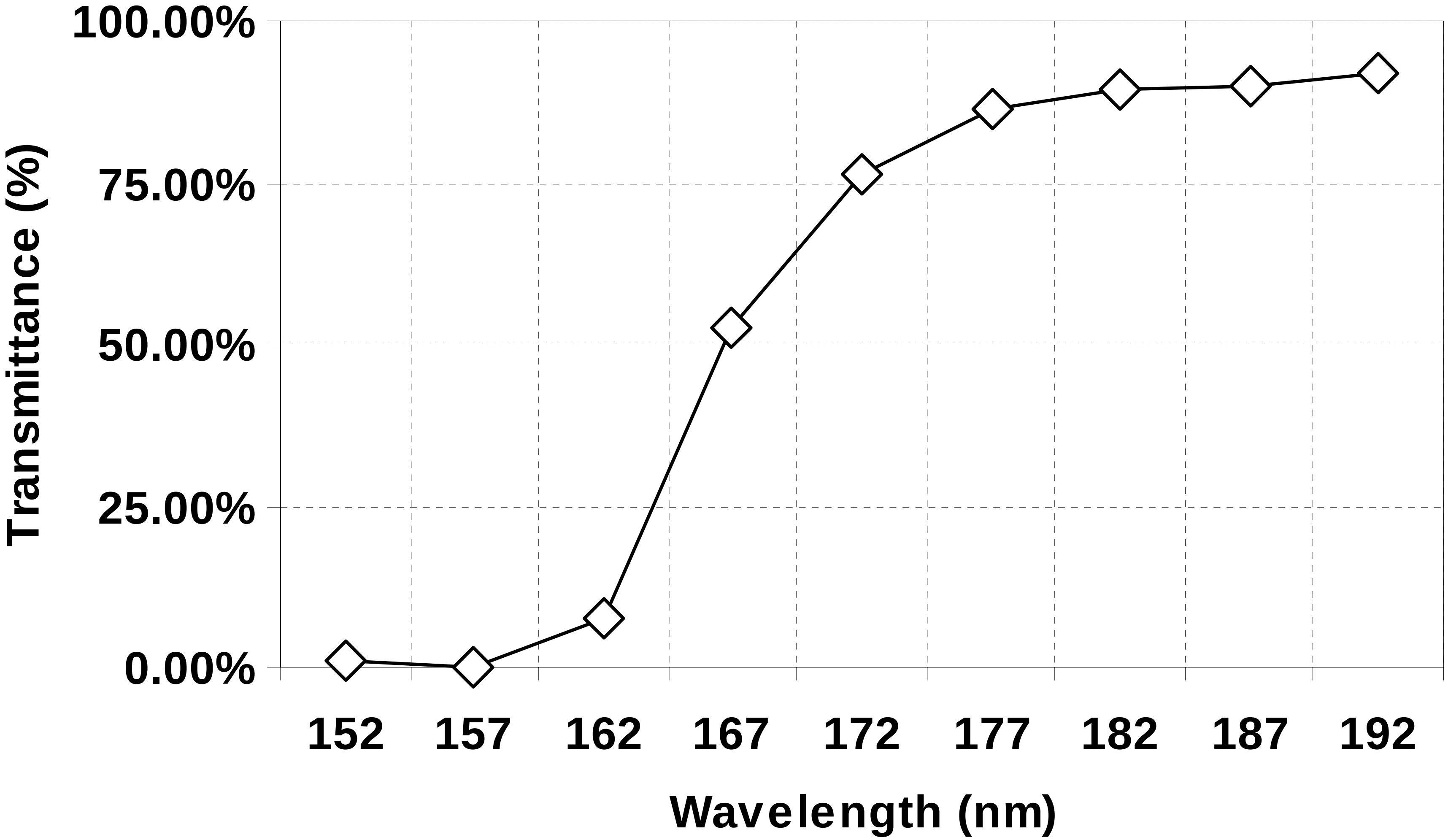
Reflectivity at 157.6 nm versus n & k using photoresist 1
Thickness=150 Å



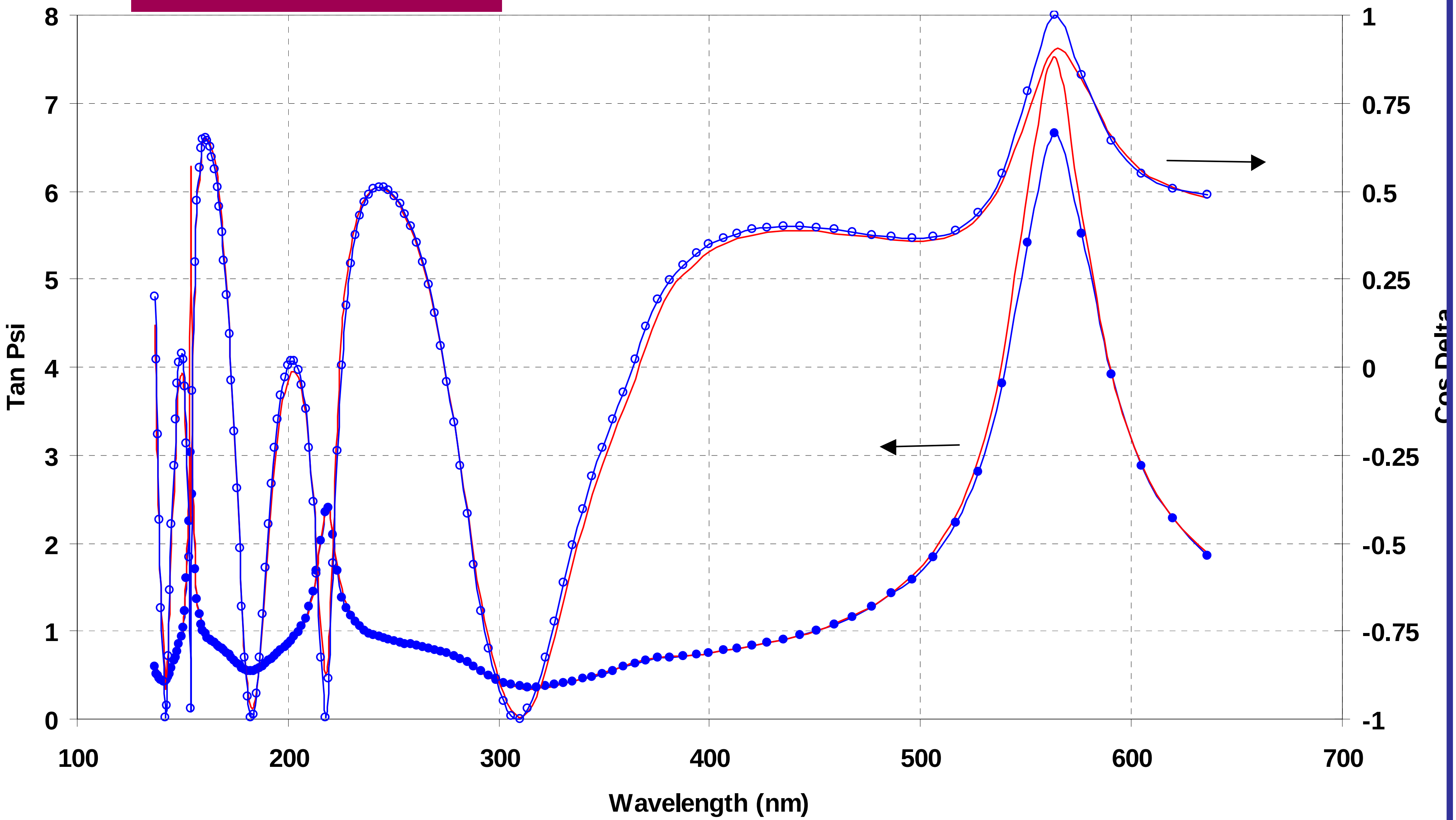
Measured Refractive Indices of Cr oxide and Cr versus Wavelength.



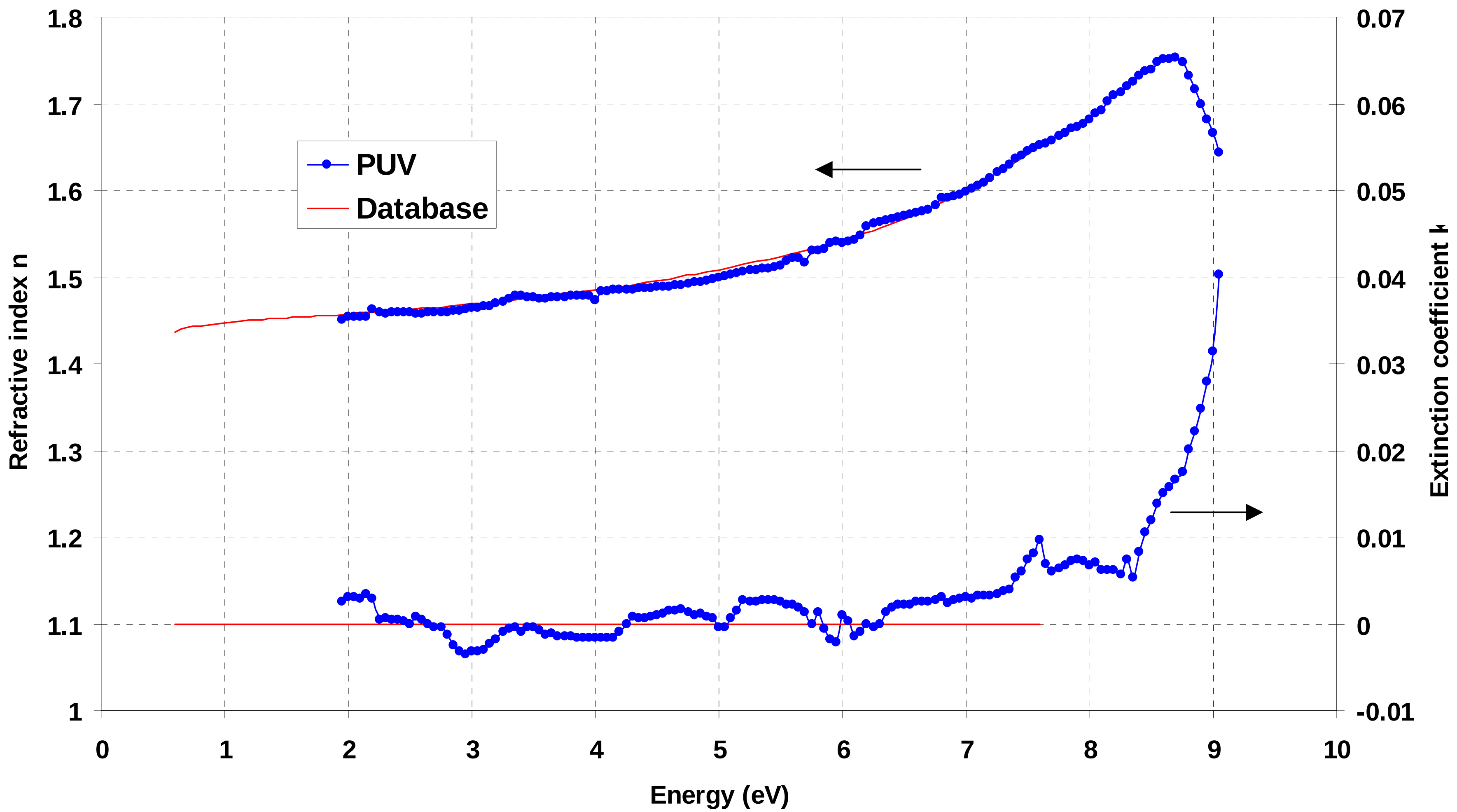
Measured and Simulation of reflectance of Cr Oxide on Cr on Glass at 157.6 nm.



Transmission of SiOF versus wavelength.



SE on $SiO_{2/}$ Si samples using extended PUV range



Optical indices of SiO_2 compared to litterature using extended PUV range

Conclusion:

•A new purged UV spectroscopic ellipsometer has been presented.

•Experimental results on:

- *–CaF_2 substrate.*
- *–LaF_3 layer on CaF_2 substrate*
- *–CrOx/Cr/glass structures.*
- *–Photoresists and antireflective coatings*
- *–SiOF transmittance*

- *–Now the range is extended to 145-630nm*