SE Repeatability and Hafnium Dielectric Characterization

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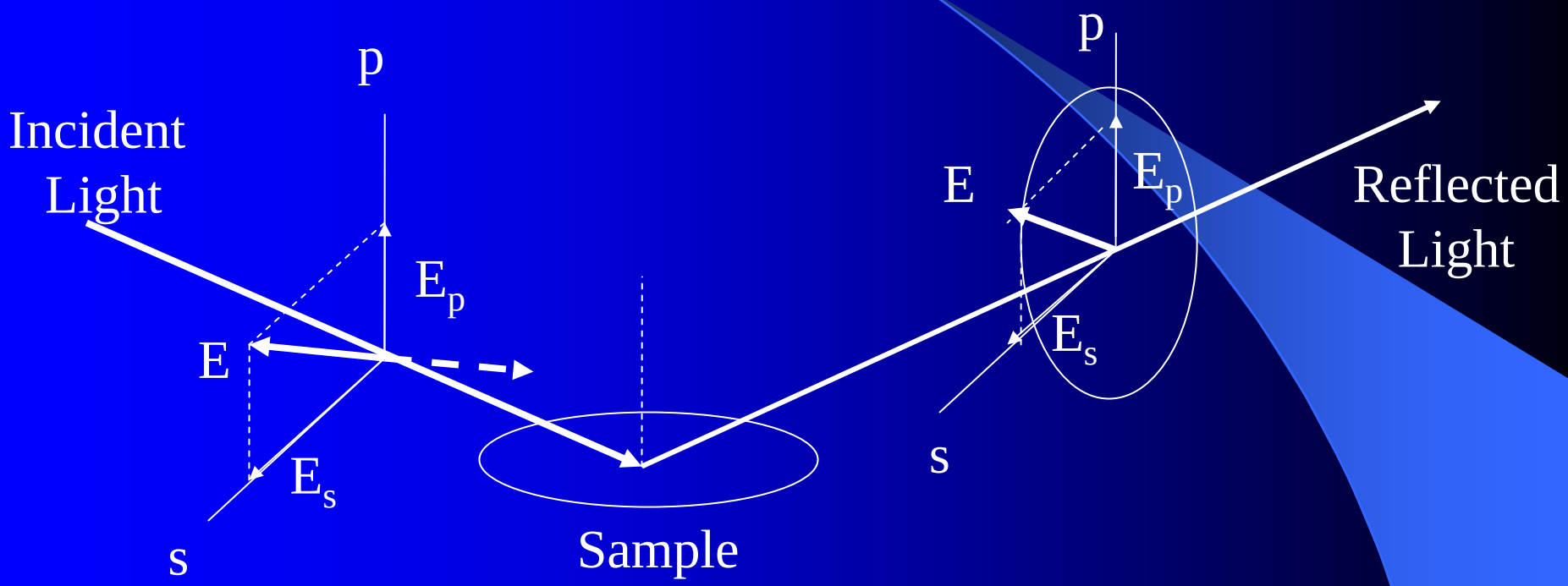
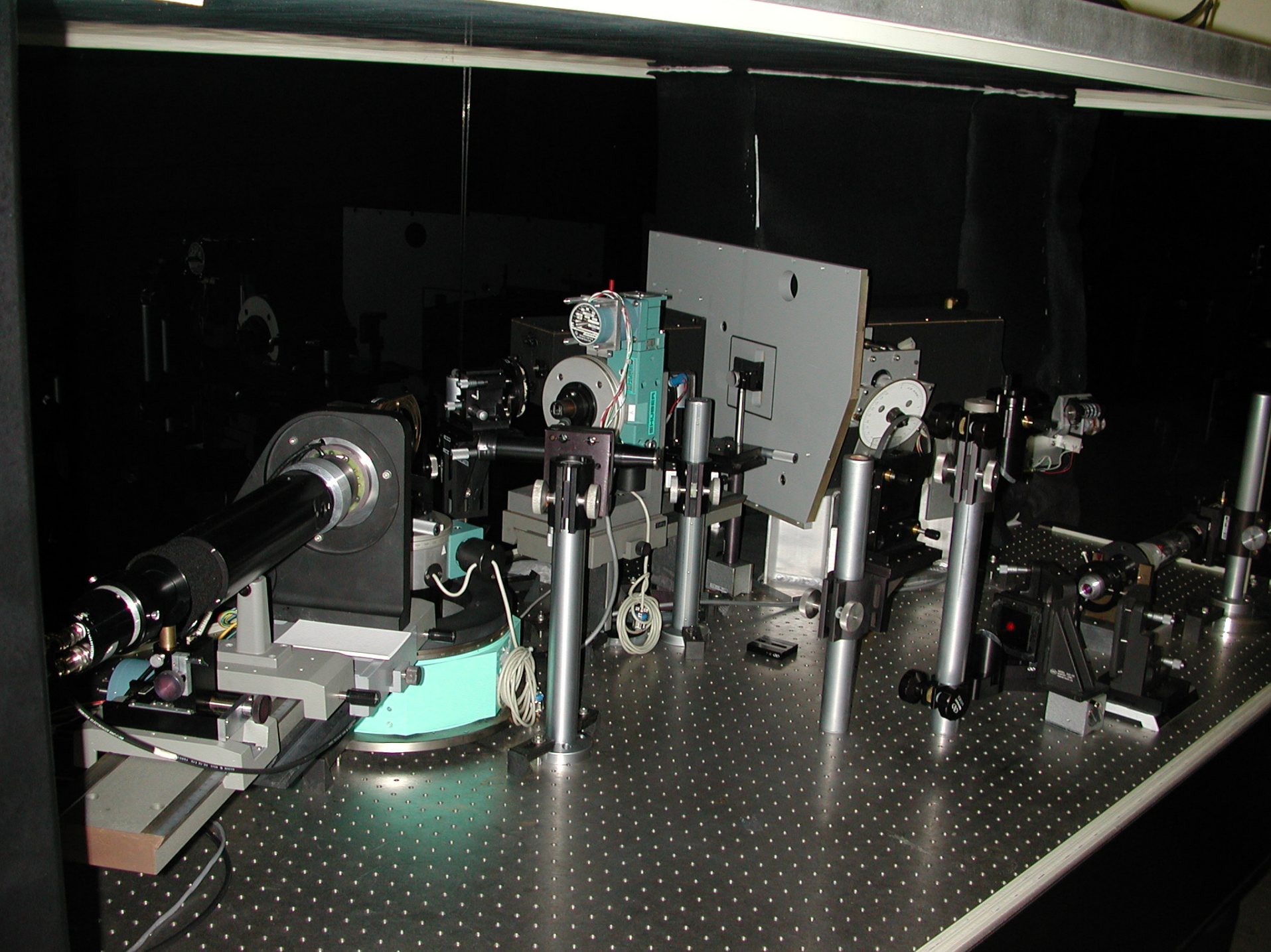
Outline

- Ellipsometry Introduction
- Repeatability Measurements
- Hafnium Data
- Data Analysis: Dielectric Functions
- Results
- Conclusions

Ellipsometry



Shift from linear to elliptical polarization upon reflection



Δ and Ψ

- Ellipsometric parameters measured directly
- Δ: phase shift difference (0 to 360°)
- Ψ: relative change in amplitude (0 to 90°)

$$\tan \Psi \, e^{(i \, \Delta)} = R_p / R_s$$

Functionality of SE

- Calculate film thickness, assess crystallinity
- Fit a dielectric function to the data: electron energy band properties
- Noncontact, noninvasive technique
- Volume fraction of composite materials
- Useful in: thin film technologies

  study and characterize new materials

Repeatability

- High precision and accuracy are necessary at NIST to provide standards
- Controls: temperature, humidity, sample loading, oxide removal by cleaning or baking

Repeatability Results

- Sample Stability: HeNe compared to Xe
- Mounting Repeatability
- Sample Cleaning
- Comparison of SE ellipsometer to VUV ellipsometer (about 0.5 Å)
- Error Studies

Hafnium Dioxide

- Candidate currently under extensive research to replace the traditional gate oxide SiO_2.
- Dielectric function with unstudied variations

$$\mathbf{n} = n + ik$$

Dielectric Function

- Dielectric constant also called relative permittivity: external polarization sensitivity

$$K_e = \varepsilon / \varepsilon_o$$

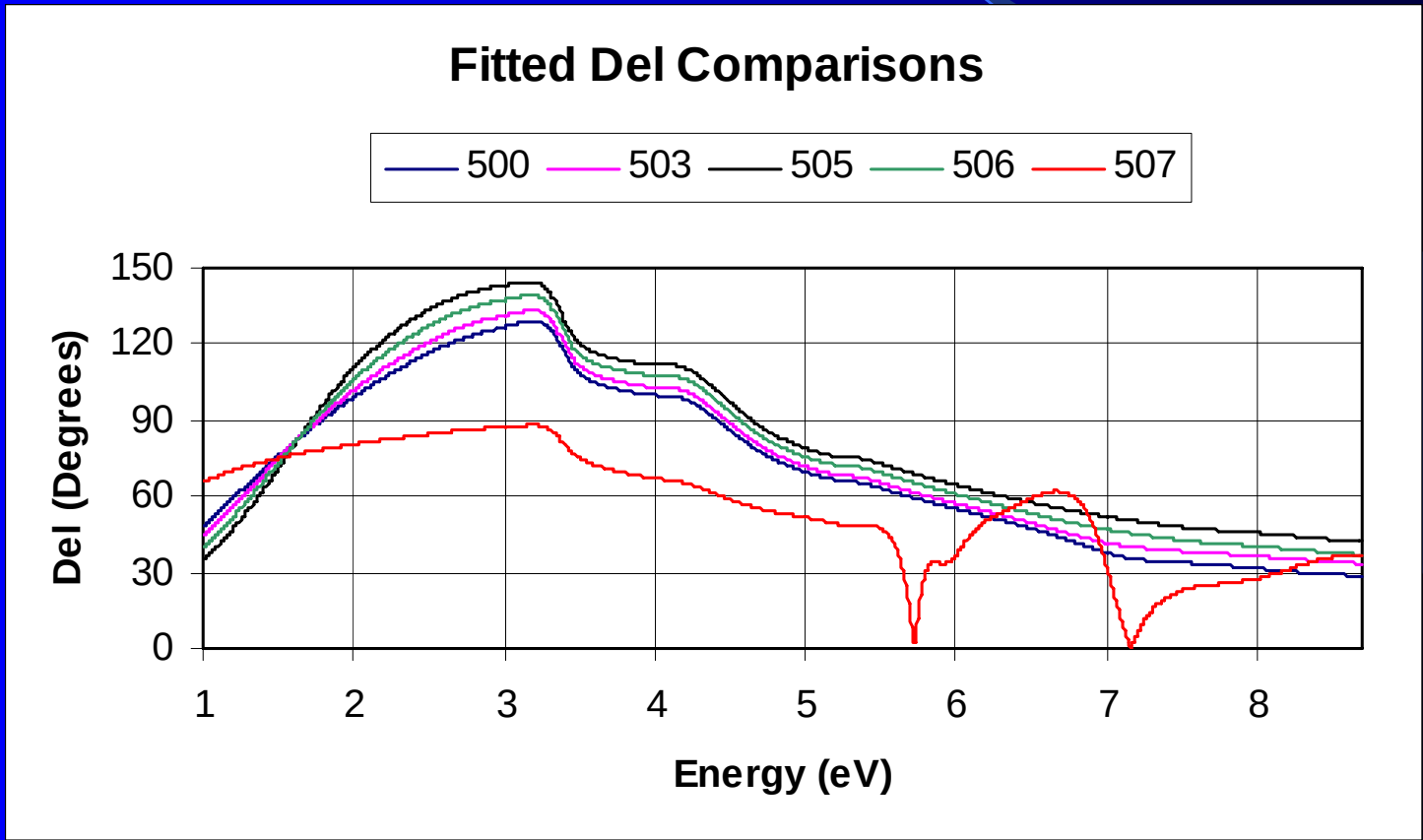
- Dielectric function is dependent on photon wavelength (energy).
- Is related to the complex index of refraction:

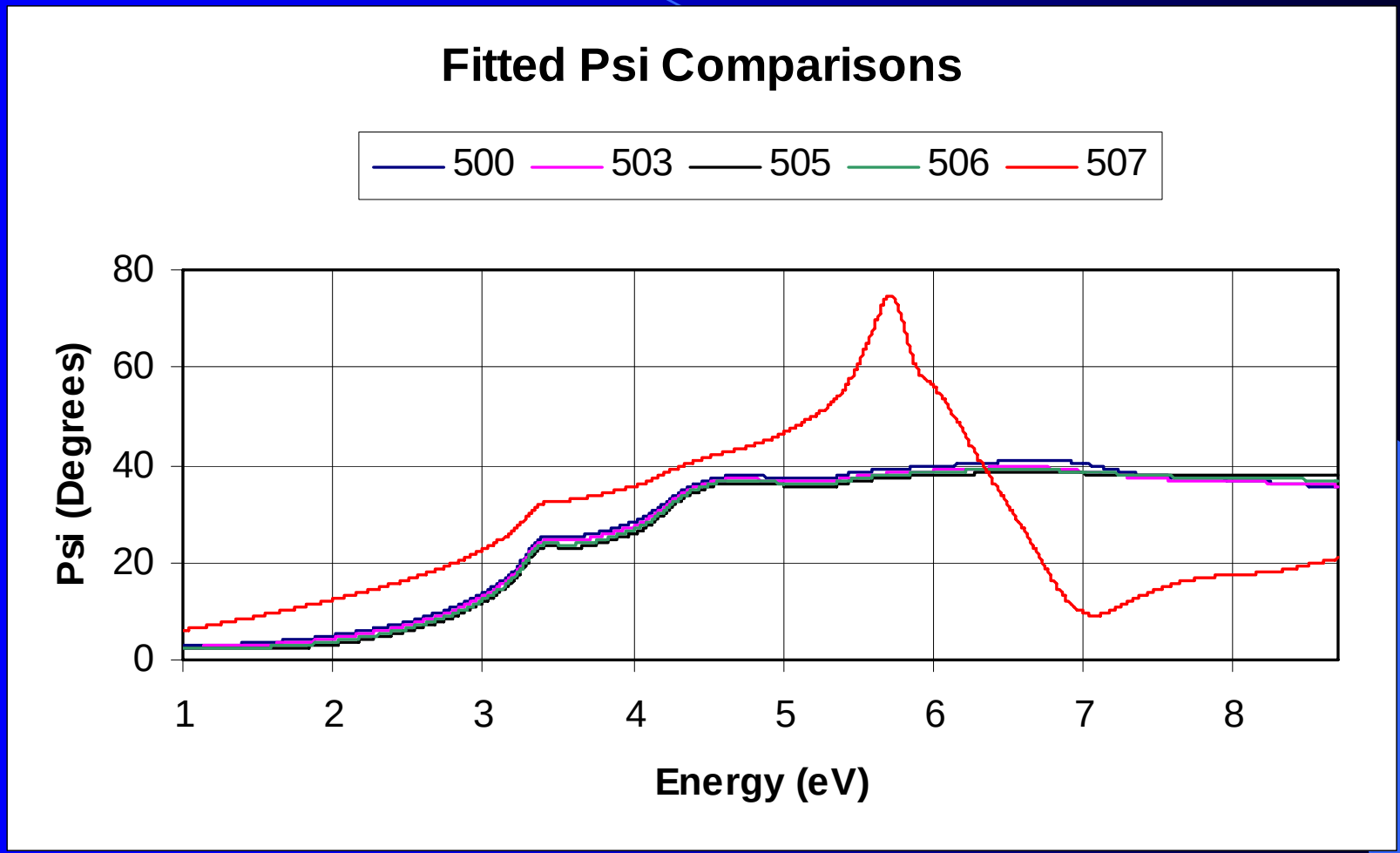
$$\boldsymbol{\varepsilon} = \mathbf{n}^2 = (n + i*k)^2$$

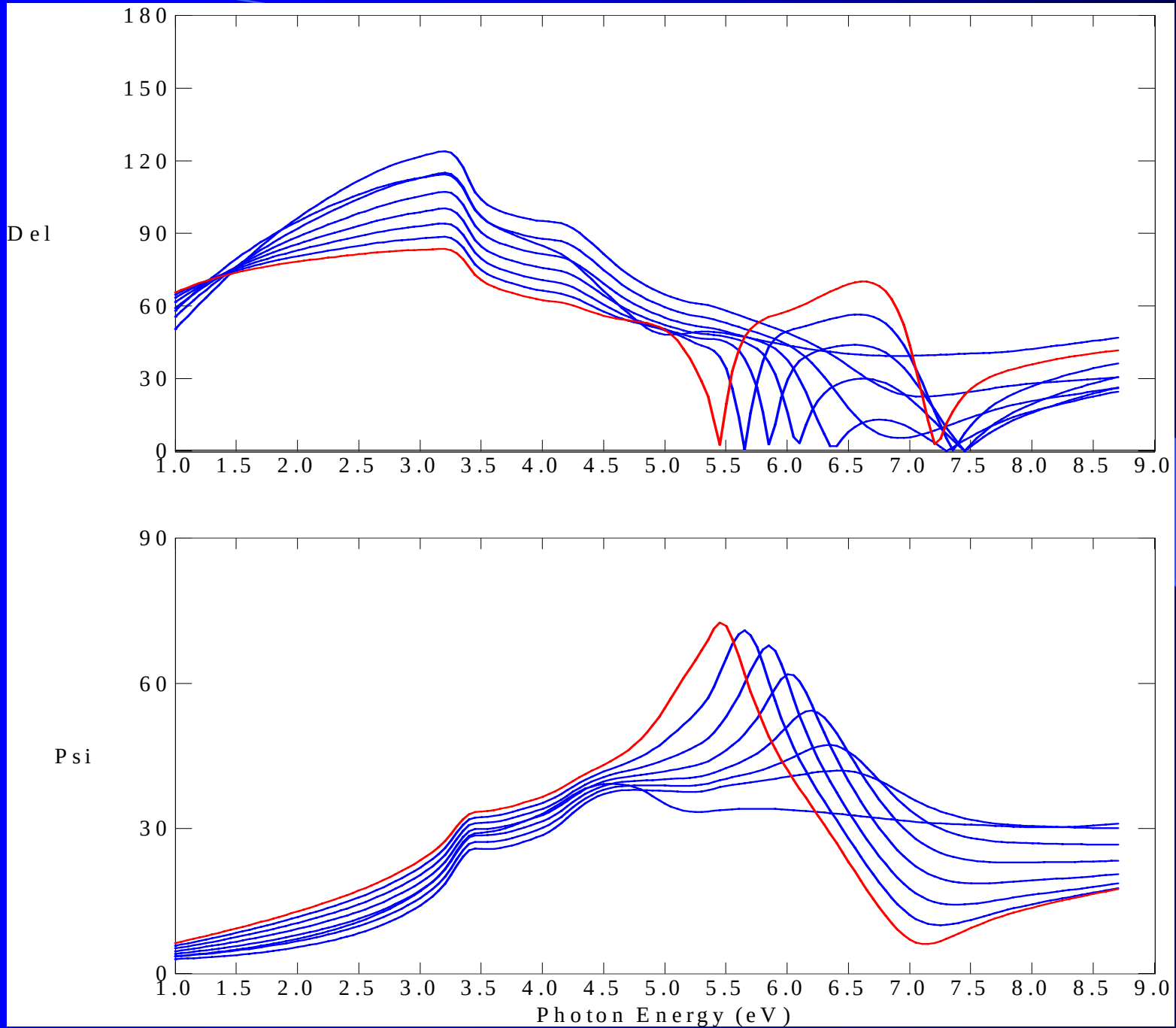
- Has both real and imaginary components:

$$\boldsymbol{\varepsilon} = \varepsilon_1 + i\,\varepsilon_2$$

Del and Psi for HfO_2

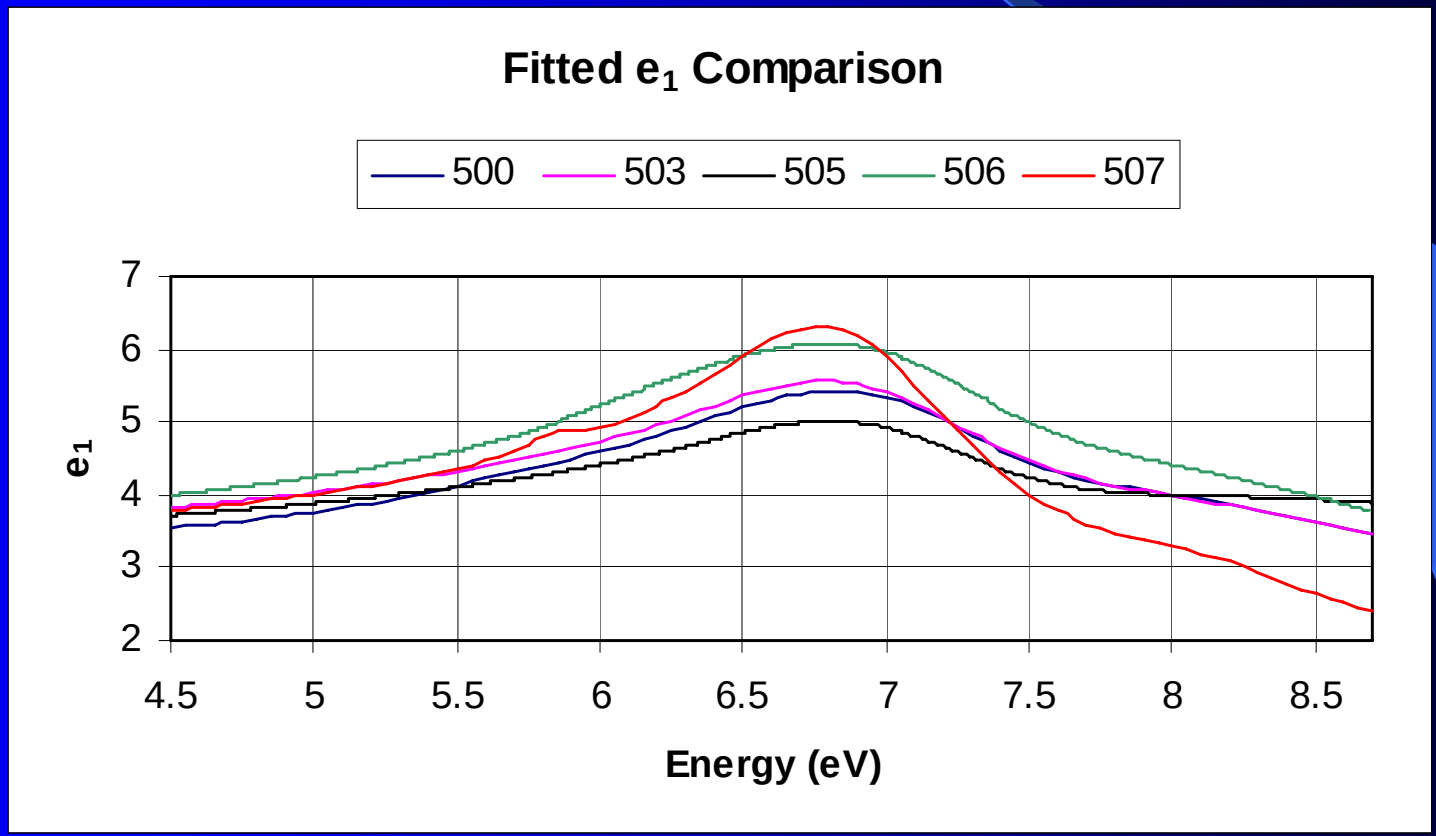


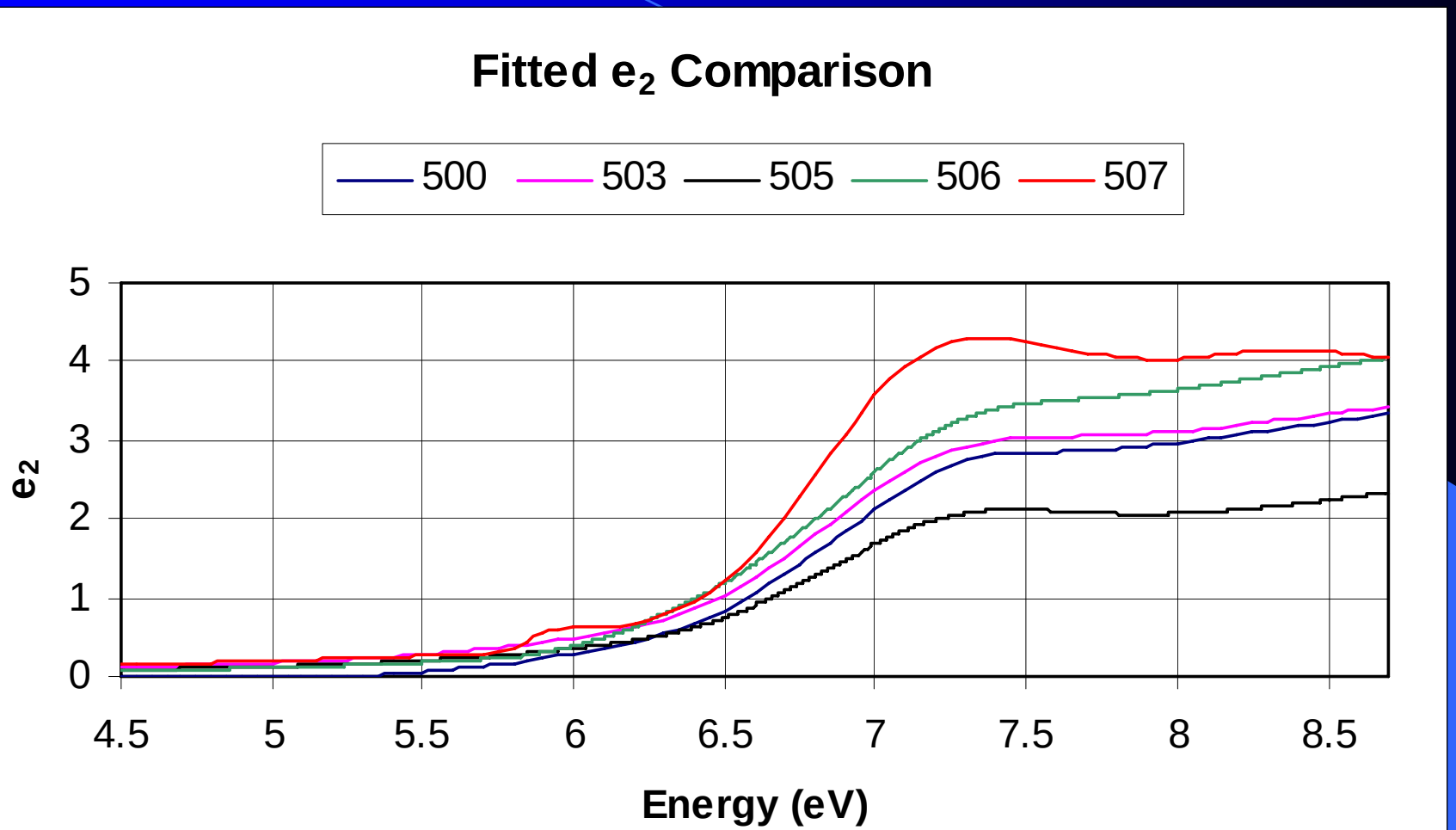

Fitted Psi Comparisons
500
503
505
506
507
80
60
40
20
0
Psi (Degrees)
1
2
3
4
5
6
7
8
Energy (eV)



Red line corresponds to 20 nm HfO_2 film, changing to 8 nm by steps of 2 nm.

Some Dielectric Functions for Hafnium




Fitted e2 Comparison
500
503
505
506
507
5
4
3
2
1
0
e2
4.5
5
5.5
6
6.5
7
7.5
8
8.5
Energy (eV)

Results and Conclusions

- Optical transitions sharpen with increasing temperature and thickness
- Annealing is not the sole factor: some thick samples (170 Å) have polycrystallinity from being deposited at 485°C. No thin samples (less than 75 Å) have defined optical transitions, they are amorphous.

Acknowledgements

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