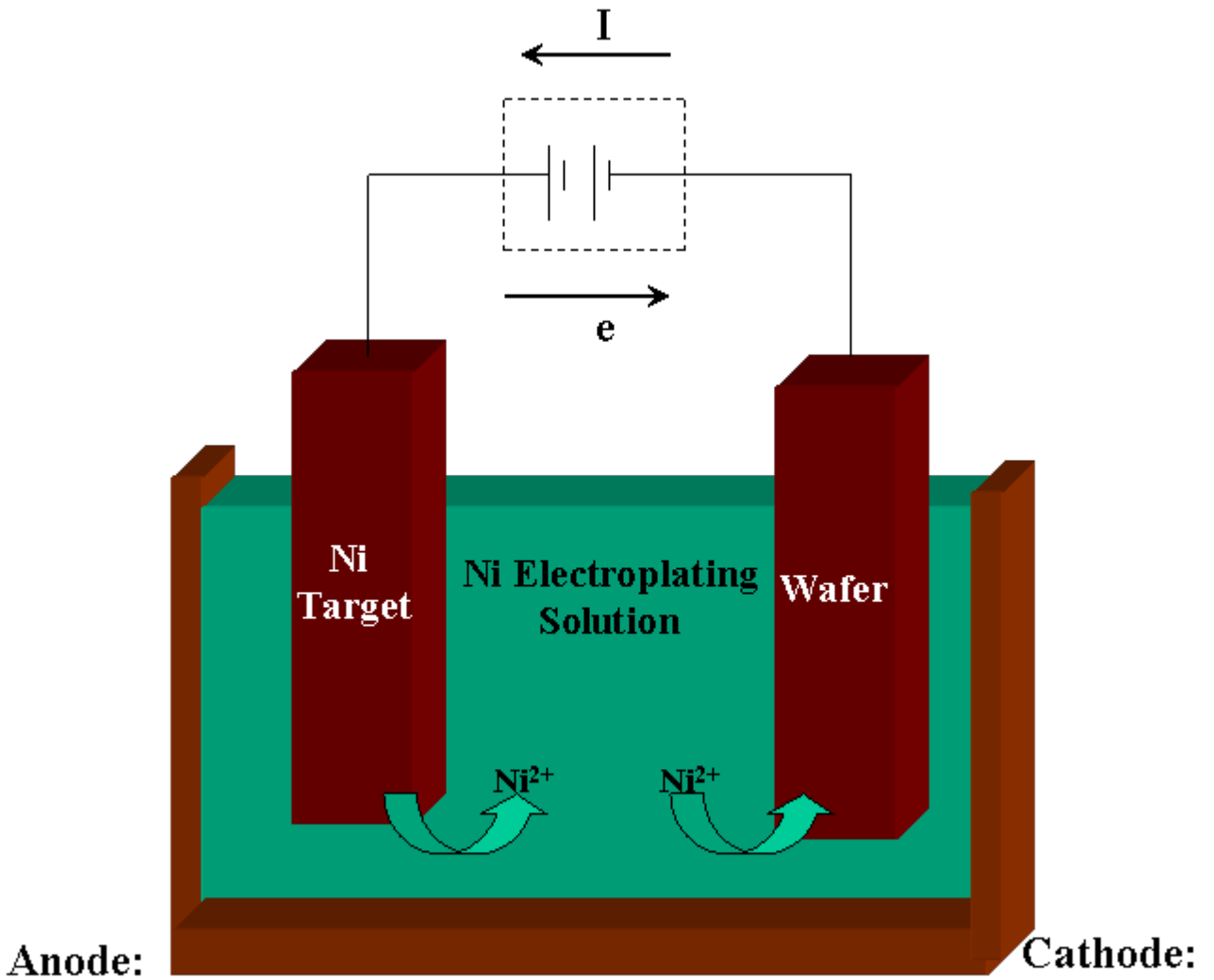
Ellipsometry of Electro-deposited magnetic thin films

BY HAMZA QURESHI

Overview

- Electrodeposition of Nickel
- Some properties of light
- Ellipsometry

Electrodeposition of Nickel

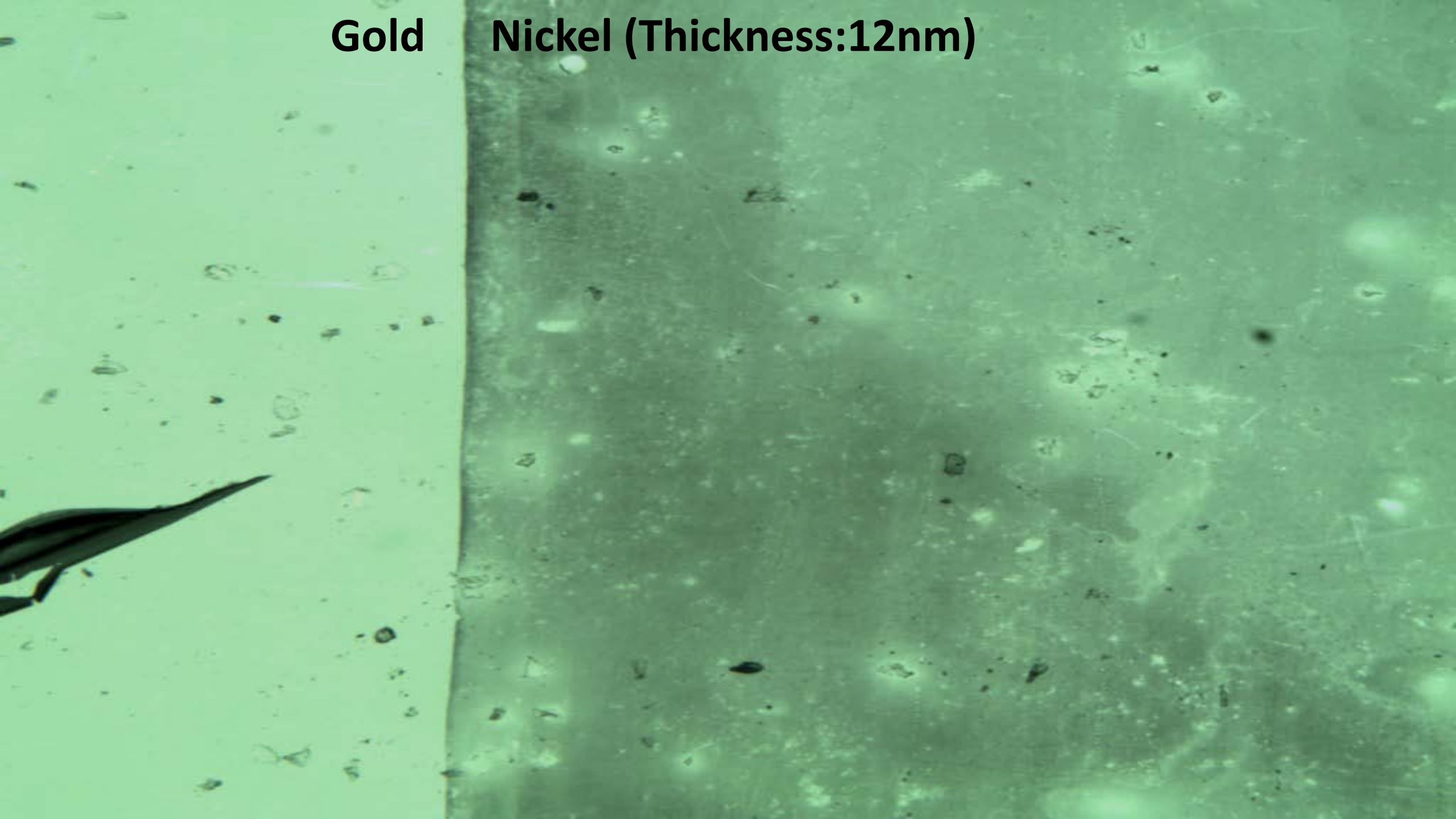

I
e
Ni
Target
Ni Electroplating
Solution
Wafer
Ni2+
Ni2+
Anode:
Cathode:

Recipe

	Electrolyte Composition[a] ($g L^{-1}$)		
	Watts Nickel	Nickel Sulfamate	Basic Semibright Bath[b]
Nickel sulfate, $NiSO_4 \cdot 6H_2O$	225–400		300
Nickel sulfamate, $Ni(SO_3NH_2)_2$		30–45	
Nickel chloride, $NiCl_2 \cdot 6H_2O$	30–60	300–450	35
Boric acid, H_3BO_3	30–45	0–30	45
		Operating Conditions	
Temperature (°C)	44–66	32–60	54
Agitation	Air or mechanical	Air or mechanical	Air or mechanical
Cathode current density ($A dm^{-2}$)	3–11	0.5–30	3–10
Anodes	Nickel	Nickel	Nickel
pH	2–4.5	3.5–5.0	3.5–4.5
		Mechanical Properties	
Tensile strength (MPa)	345–435	415–610	—
Elongation (%)	10–30	5–30	8–20
Vickers hardness (100 g load)	130–200	170–230	300–400
Internal stress (MPa)	125–185 (tensile)	0–55 (tensile)	35–150 (tensile)

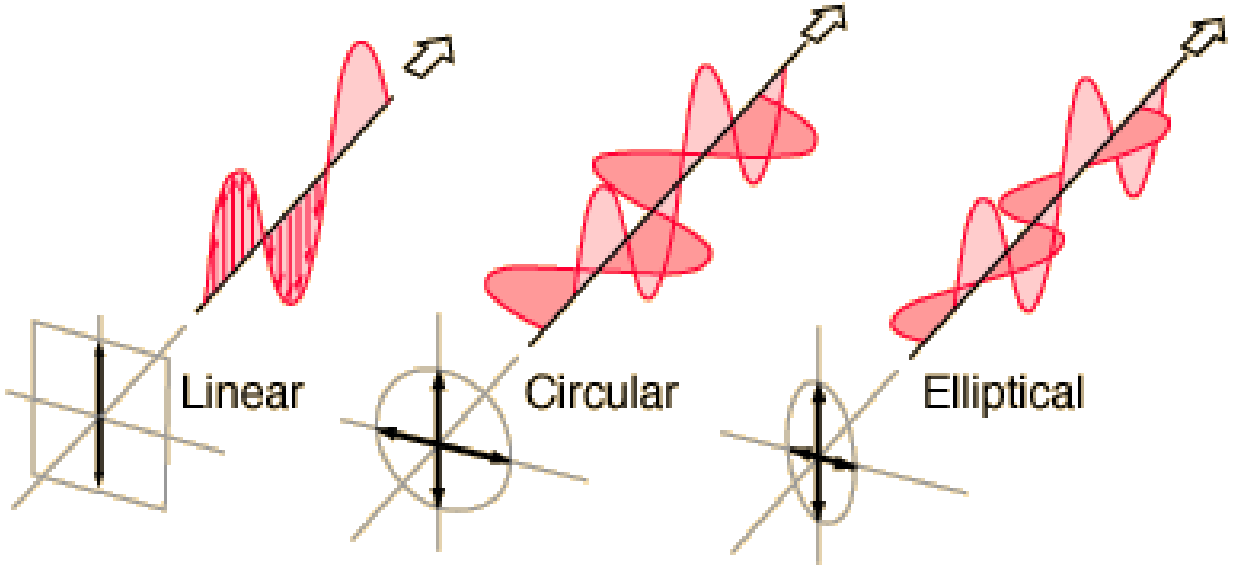
Magnetic assistance and current

- Distribution of dipoles in the absence of magnetic field
- External magnetic field is applied to orient these dipoles in the desired direction
- Effect on current


Gold
Nickel (Thickness:12nm)

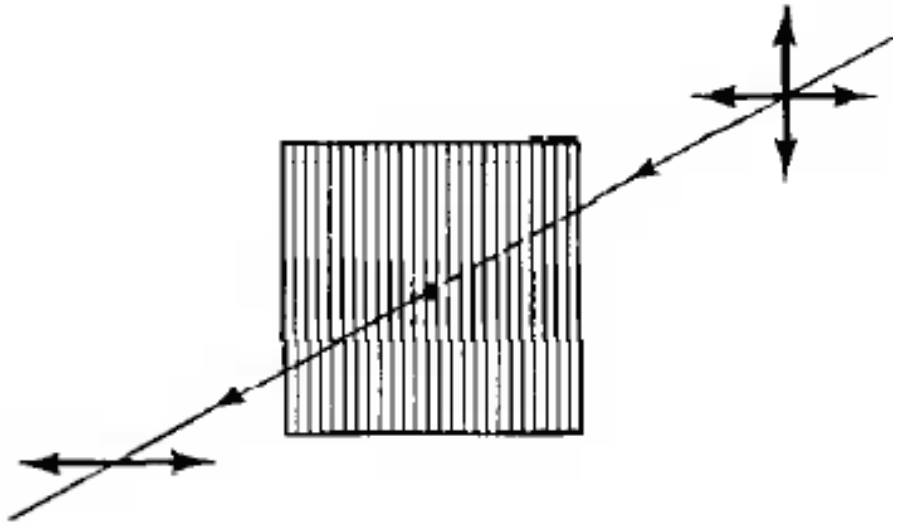
Properties of Light

- Propagation of light
- Classification of polarization of light

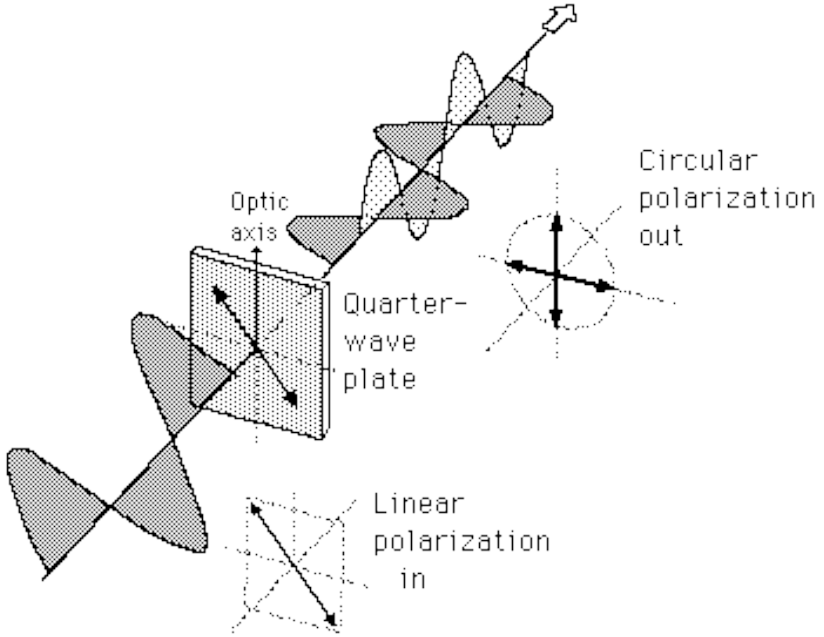


- $\boldsymbol{E = \hat{i}E_x e^{i(kz-wt)} + \hat{j}E_y e^{i(kz-wt+\Delta\emptyset)}}$

Changing Polarization



Linear polarization (wire grid)



Circular and Elliptical polarization (quarter wave plate)

Fresnel Equations

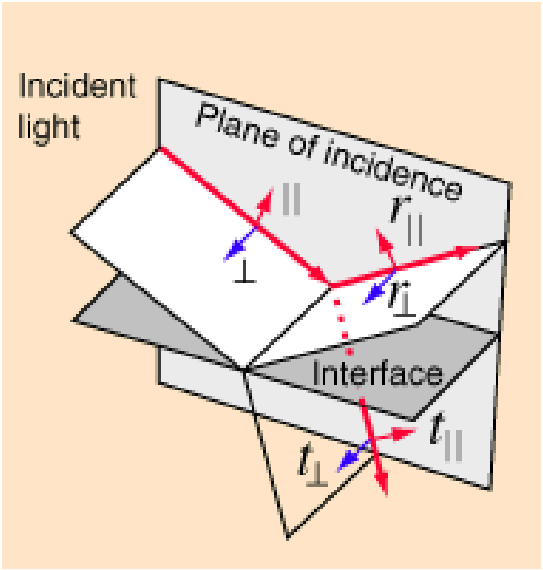
Fresnel equations describe the reflection and transmission of electromagnetic waves at an interface

$$r_s = \frac{n_1 \cos\theta_\mathrm{i} - n_2 \cos\theta_\mathrm{t}}{n_1 \cos\theta_\mathrm{i} + n_2 \cos\theta_\mathrm{t}}$$

$$t_s = \frac{2n_1 \cos\theta_\mathrm{i}}{n_1 \cos\theta_\mathrm{i} + n_2 \cos\theta_\mathrm{t}}$$

$$r_p = \frac{n_2 \cos\theta_\mathrm{i} - n_1 \cos\theta_\mathrm{t}}{n_1 \cos\theta_\mathrm{t} + n_2 \cos\theta_\mathrm{i}}$$

$$t_p = \frac{2n_1 \cos\theta_\mathrm{i}}{n_1 \cos\theta_\mathrm{t} + n_2 \cos\theta_\mathrm{i}}$$



s=perpendicular

p=parallel

n_1=incidence

n_2=transmission

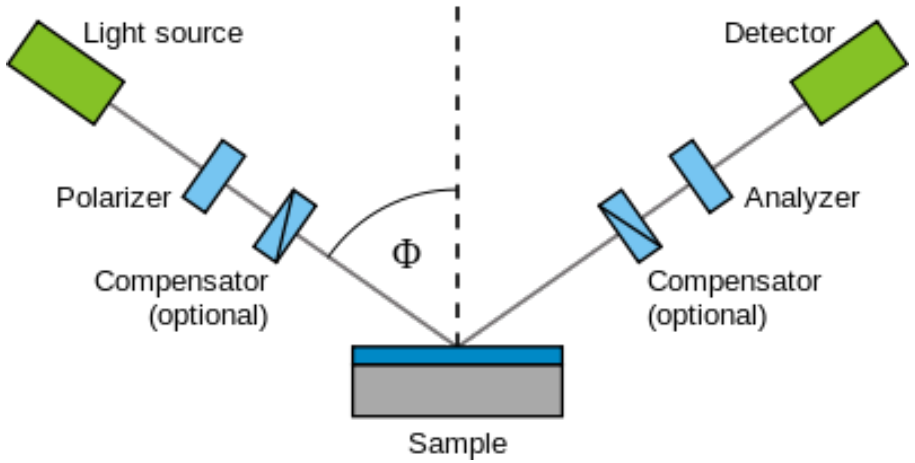
Fresnel Equations cont.

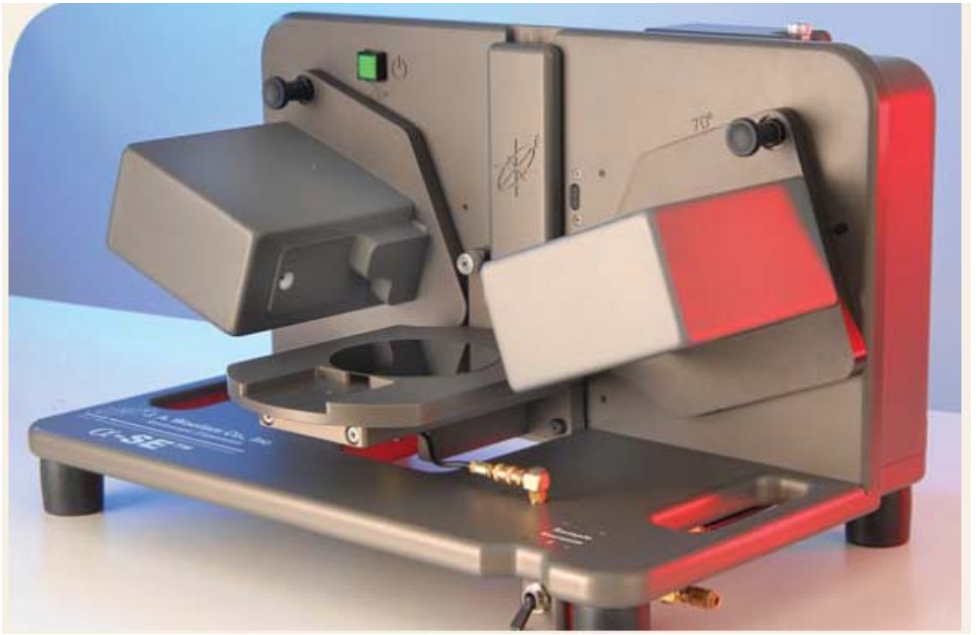
- Transmitted ray is never phase shifted
- For all angles ($n_i < n_t$), reflected wave is shifted by pi
- For all angles ($n_i > n_t$), reflected wave is not shifted

Refractive index and thickness

- Real and imaginary part of refractive index
- Consider the spatial part of $\boldsymbol{E = \hat{\imath}E_x e^{i(kz-wt)} + \hat{\jmath}E_y e^{i(kz-wt+\Delta\emptyset)}}$
- Effect on the propagation of light
- Measuring thickness
- Reduction in intensity

Ellipsometry

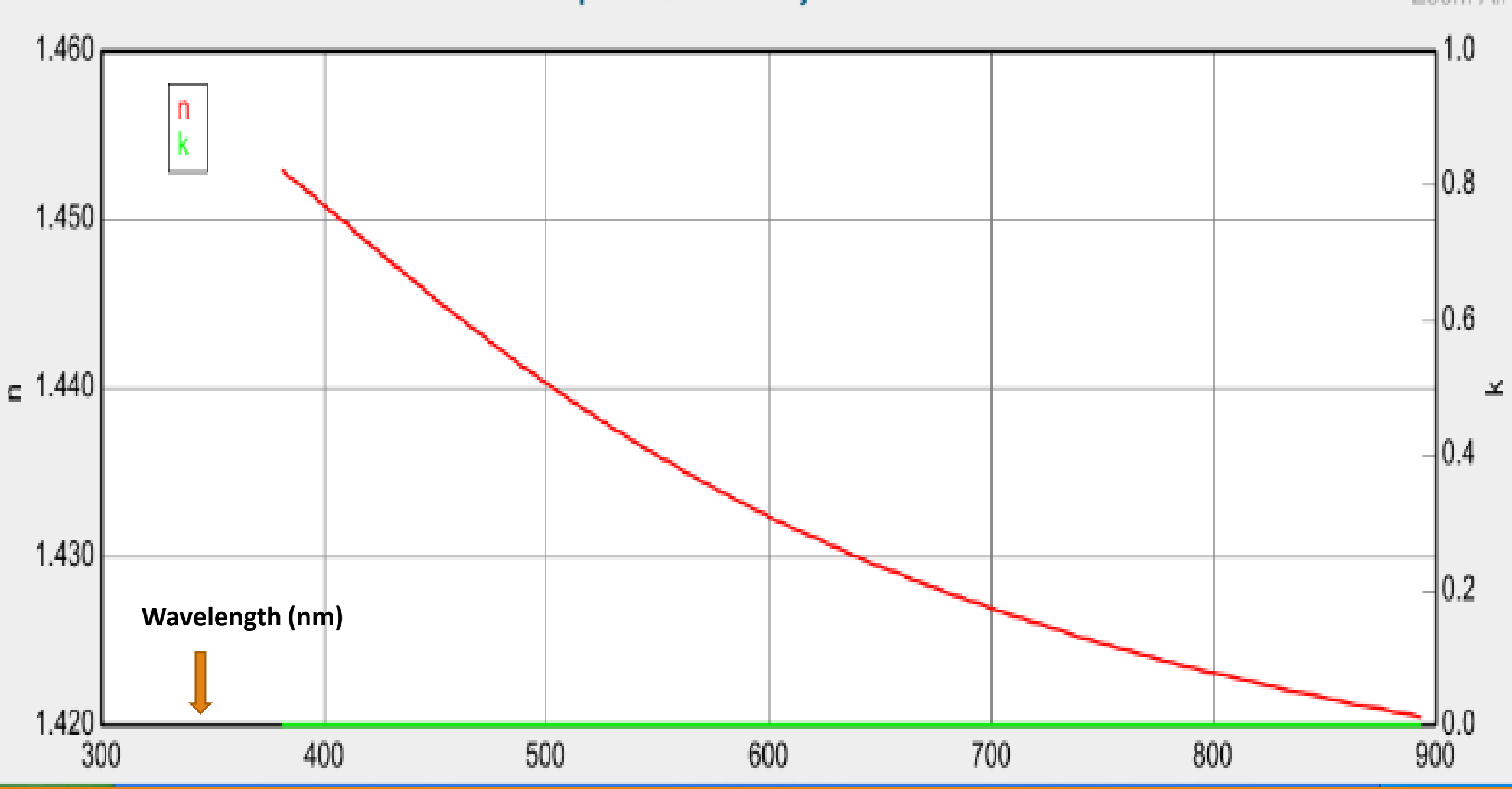


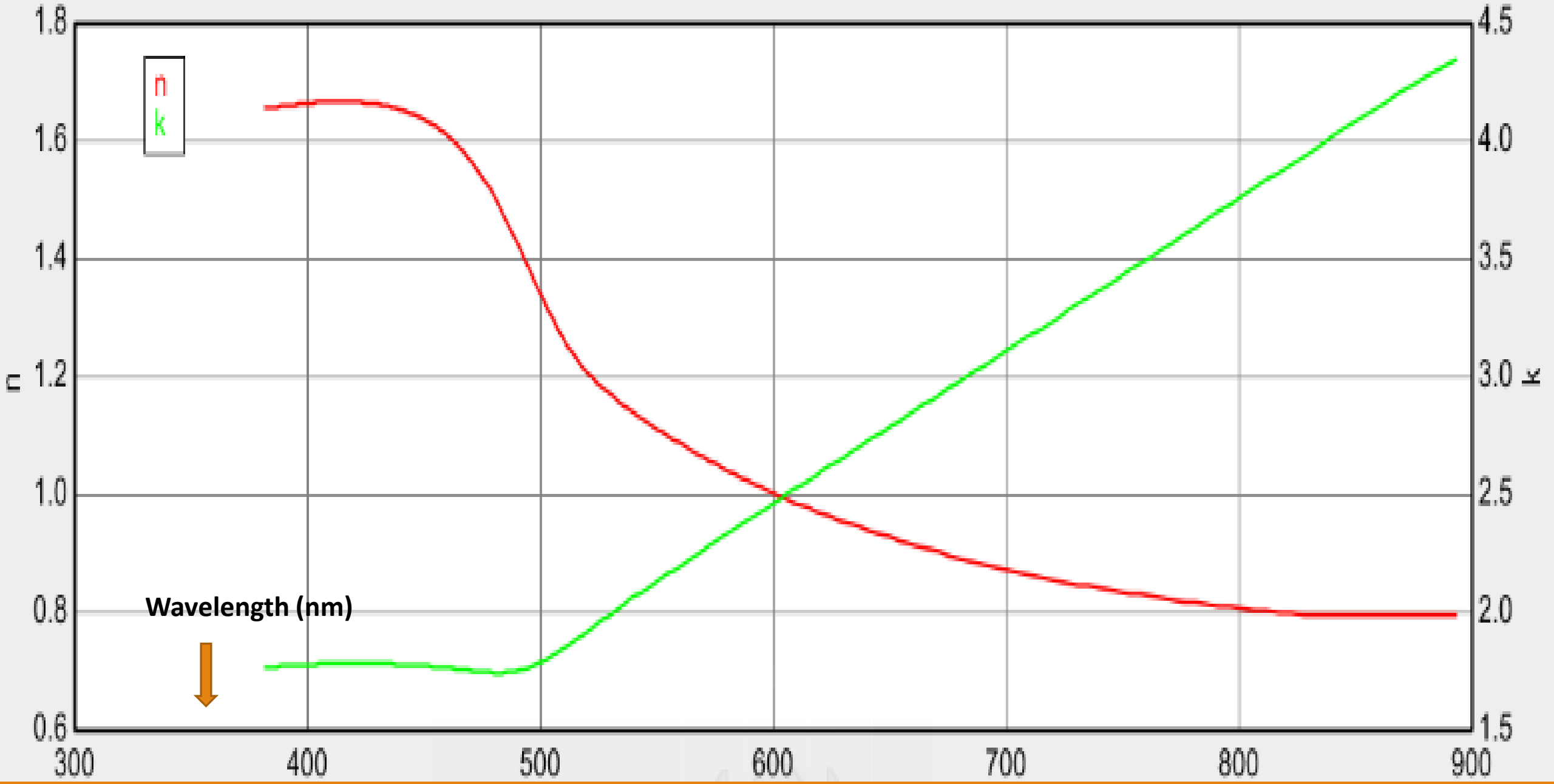


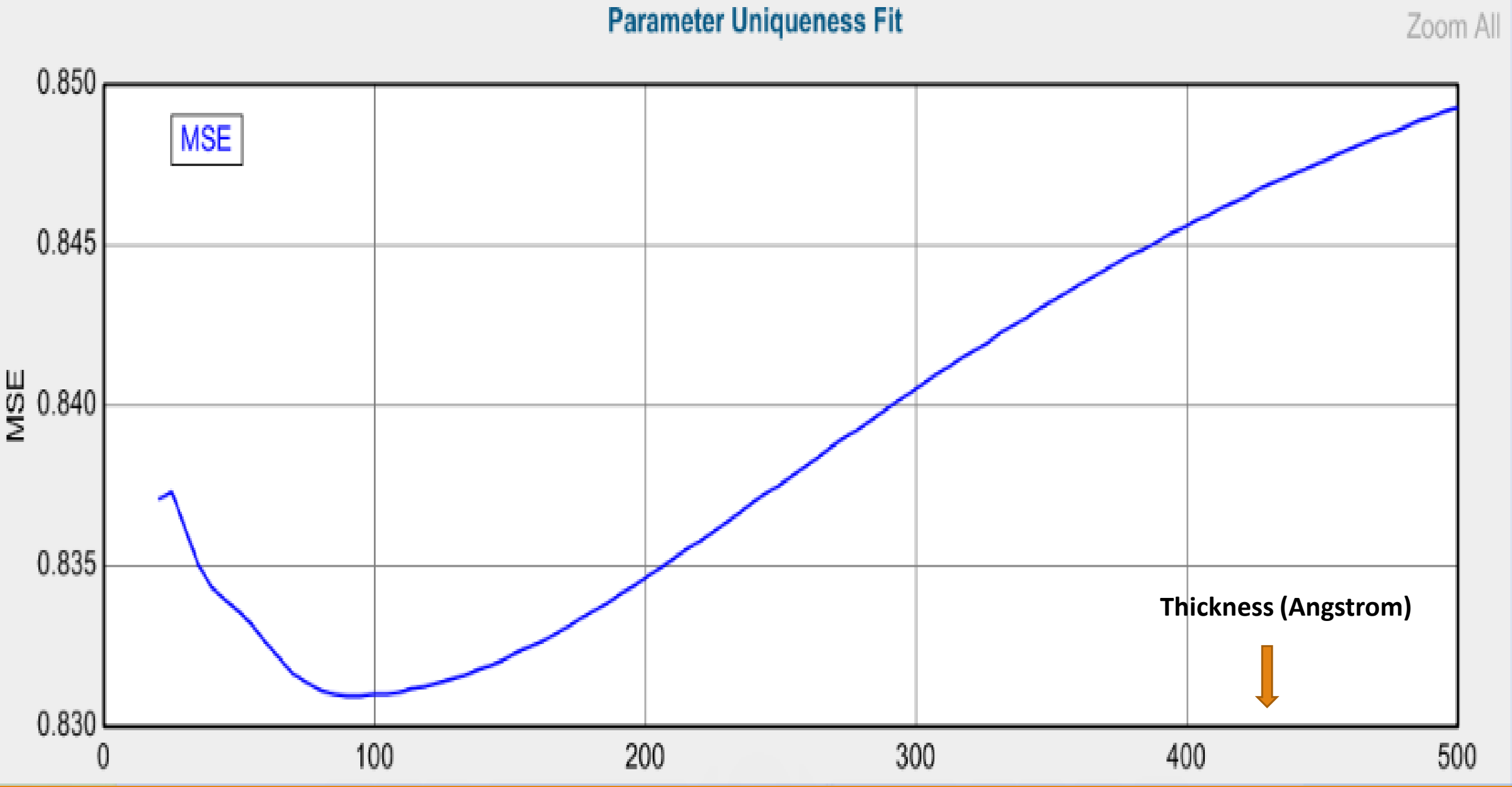
Uses: Absorbing coatings on glass, transparent coatings on glass, oxide coatings, etc.

Mode of operation

- Measures delta and psi
- Uses transmission and reflection data
- Fits the observed data using numerical analysis
- Calculates optical constants and thickness
- Calculates MSE
- Parameter Uniqueness Fit


n
k
1.460
1.450
1.440
1.430
1.420
n
1.0
0.8
0.6
0.4
0.2
0.0
k
300
400
500
600
700
800
900
Wavelength (nm)


n
k
1.8
1.6
1.4
1.2
1.0
0.8
0.6
4.5
4.0
3.5
3.0
2.5
2.0
1.5
k
300
400
500
600
700
800
900
Wavelength (nm)


Parameter Uniqueness Fit
Zoom All
MSE
0.850
0.845
0.840
0.835
0.830
MSE
0
100
200
300
400
500
Thickness (Angstrom)

Thank You