Determination of Voigt Constant & Ellipsometry

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Xu Group Meeting

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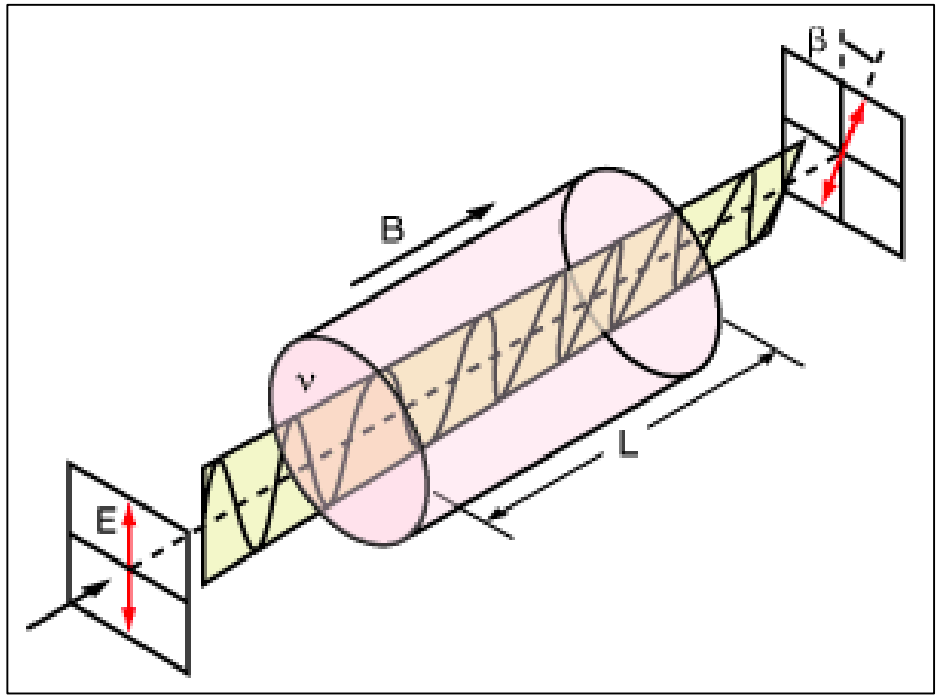
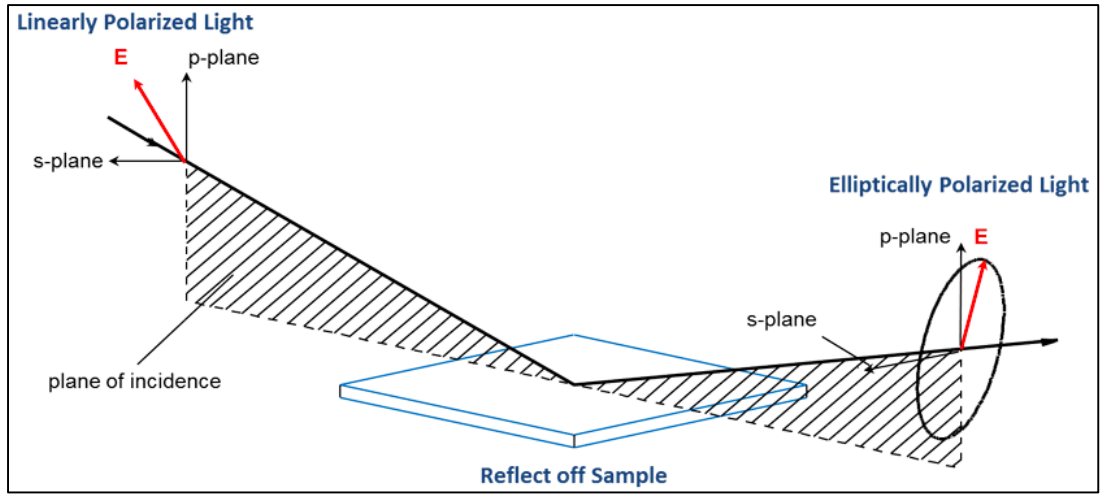
M. Fronk *et al.,* Phys Rev B, **79**, 235305 (2009)

Faraday Effect vs. Kerr Effect

Faraday: change in ellipticity of *transmitted* light



Kerr: change in ellipticity of *reflected* light



Voigt Parameter

- $\mathrm{Q} = \mathrm{Q}' + \mathrm{iQ}''$ is the (complex) Voigt parameter

- Enters the dielectric tensor on off-diagonals:

- $\overleftrightarrow{\epsilon} = \begin{pmatrix} \epsilon_1 & \mathrm{iQ}\epsilon_2 & 0 \\ -\mathrm{iQ}\epsilon_2 & \epsilon_1 & 0 \\ 0 & 0 & \epsilon_1 \end{pmatrix}$ (Polar MOKE configuration)

One Way to Determine…

- Complex Faraday rotation:
  - $\Theta_F = \theta_F + i\eta_F = \frac{\omega}{2c}\tilde{n}Qd$
  - $\Longrightarrow Q' = \frac{2c}{\omega nd}\theta_F$ & $Q'' = \frac{2c}{\omega kd}\eta_F$

- Excellent for (somewhat) transparent materials, but not much help for opaque films with substrates

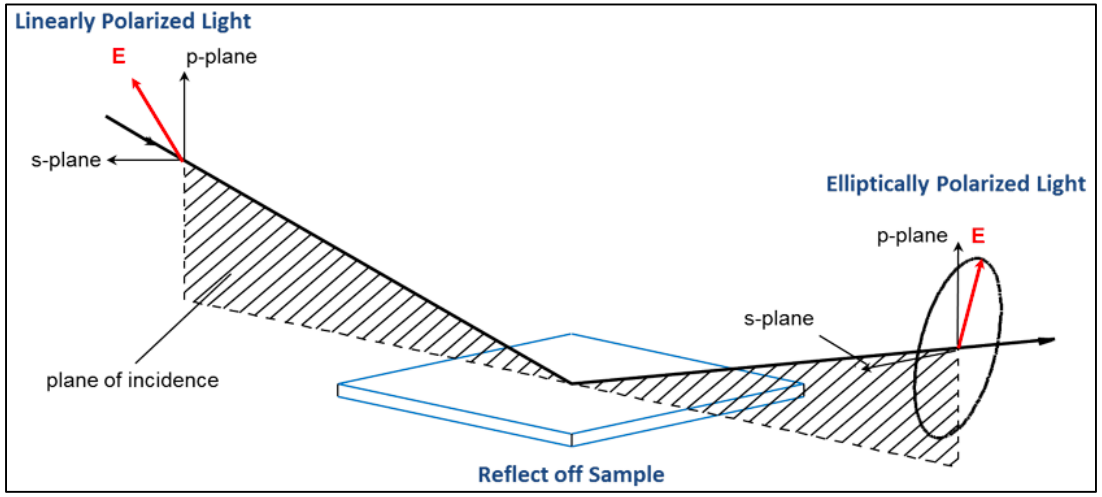
Dielectric Properties

- Complex refractive index: $\tilde{\mathrm{n}} = \mathrm{n}' + \mathrm{i}\mathrm{n}'' = \mathrm{n} + \mathrm{i}\mathrm{k}$
  - Describe transmittance and absorbance of light in material

- Relate to dielectric tensor: $\overleftrightarrow{\epsilon} = \tilde{\mathrm{n}}^2$
  - Determine refractive and absorptive information $\Longrightarrow$ Voigt parameter

Ellipsometry

- Very similar to type of measurement performed in MOKE
- Measure properties of elliptically polarized light from material reflection



Ellipsometry

- Quantities ψ, Δ determined by ratio of s- and p-polarization reflectivities:
  - $\frac{r_p}{r_s} = \rho = \tan(\psi)\, e^{i\Delta}$

- Parameters need to be fit using some kind of material modeling process (e.g. DFT in the paper)

- Effective information can be determined in some situations:
  - $< \tilde{\epsilon} > = \sin^2(\theta_i)\left\{1 + \tan^2(\theta_i)\left(\frac{1-\rho}{1+\rho}\right)^2\right\}$
  - (Effective dielectric value for bulk sample)

MOKE Spectroscopy

- Results presented give Voigt parameter Q as a function of photon energy in fixed magnetic field
  - Hence the *spectroscopy*

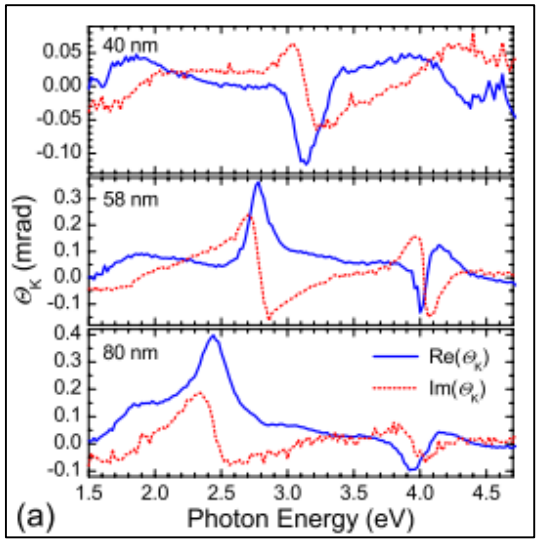
- Differs in our measurement (fixed photon energy & as a function of magnetic field

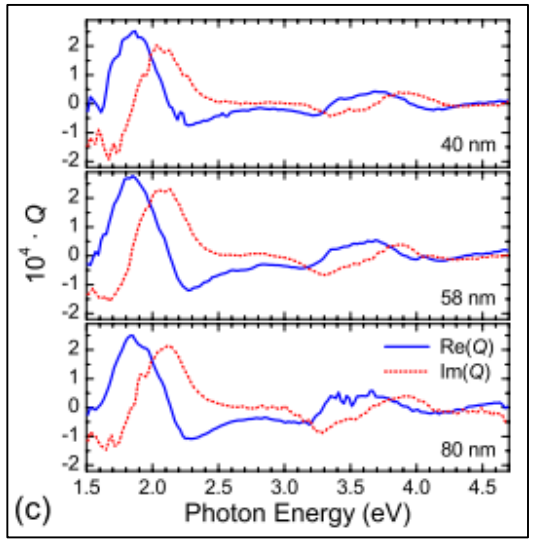
Example Results

- These dependences of Q on thickness and photon energies brings up questions:

- Why would Q depend on thickness?
  - More sample ⟹ more magnetization?

- If Q ∝ magnetization, why dependence on photon energy?





Takeaways

- Still no direct connection between magnetization and Q
- Q is determined based on the theoretical considerations of the matrix analysis technique previously discussed
  - No new information on how to determine
- How to relate Q to the material seems more unclear than ever