

Lorentz Dispersion Model

Spectroscopic ellipsometry (SE) is a technique based on the measurement of the relative phase change of reflected and polarized light in order to characterize thin film optical functions and other properties. The measured data are used to describe a model where each layer refers to a given material. The model uses mathematical relations called dispersion formulas that help to evaluate the thickness and optical properties of the material by adjusting specific fit parameters. This application note deals with the Lorentzian dispersion formula.

Note that the technical notes «Classical dispersion models» and «Drude dispersion models» are complementary to this one.

Theoretical model

The Lorentz Dispersion theory [1870] is based on the classical theory of interaction between light and matter and is used to describe frequency-dependent polarization due to bound charges. The binding between electrons and nucleus are considered to be similar to the that of a mass-spring system.

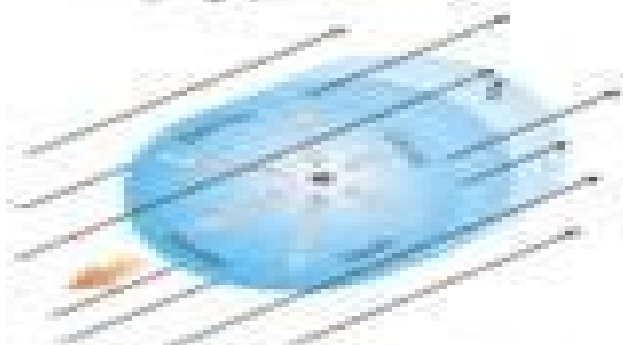


Fig. 1 Binding force between the polarization and the external wave (Ref. [1]).

Electrons react to an electron-magnetic field by vibrating like damped harmonic oscillators. The way the electric nucleus of a polarized electron field is given by the following equation of motion of a bound electron:

$$m \frac{d^2x}{dt^2} + m \gamma \frac{dx}{dt} + m \omega_0^2 x = -e E_{\text{ext}} \quad (1)$$

where:

- m or m_0 is the mass of the electron;
- γ or γ_0 is the damping factor, E_0 is the electric field.

- $m_0 \omega_0^2$ is the Hooke's force, ω_0 is the resonant mass and ω_0 is the resonant frequency of the oscillator;
- $-e E_{\text{ext}}$ is the total electric field driving force, e is the magnitude of the electronic charge and E_{ext} is the total electric field acting on the electron. The assumption is made that the macroscopic and local electric fields are equal and only a term ex is added.

The solution to the previous equation yields the expression for the magnitude of oscillation x depending on the photon energy ω :

$$x(\omega) = \frac{1}{m} \frac{E_{\text{ext}}}{\omega_0^2 - \omega^2 + i \gamma \omega} \quad (2)$$



Fig. 2 The electron oscillation and function of frequency (Ref. [2]).

At low frequencies $\omega < \omega_0$, the amplitude x has a maximum value and is in phase with E . At the resonance frequency $\omega = \omega_0$, the amplitude is imaginary and maximum when dissipation is maximum. After $\omega > \omega_0$, there is a 90° phase shift between E and x .

In high frequencies $\omega > \omega_0$, the amplitude x vanishes.

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Maria Losurdo, Kurt Hingerl



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Ellipsometry at the Nanoscale Maria Losurdo, Kurt Hingerl, 2013-03-12 This book presents and introduces ellipsometry in nanoscience and nanotechnology making a bridge between the classical and nanoscale optical behaviour of materials It delineates the role of the non destructive and non invasive optical diagnostics of ellipsometry in improving science and technology of nanomaterials and related processes by illustrating its exploitation ranging from fundamental studies of the physics and chemistry of nanostructures to the ultimate goal of turnkey manufacturing control This book is written for a broad readership materials scientists researchers engineers as well as students and nanotechnology operators who want to deepen their knowledge about both basics and applications of ellipsometry to nanoscale phenomena It starts as a general introduction for people curious to enter the fields of ellipsometry and polarimetry applied to nanomaterials and progresses to articles by experts on specific fields that span from plasmonics optics to semiconductors and flexible electronics The core belief reflected in this book is that ellipsometry applied at the nanoscale offers new ways of addressing many current needs The book also explores forward looking potential applications

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