

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.

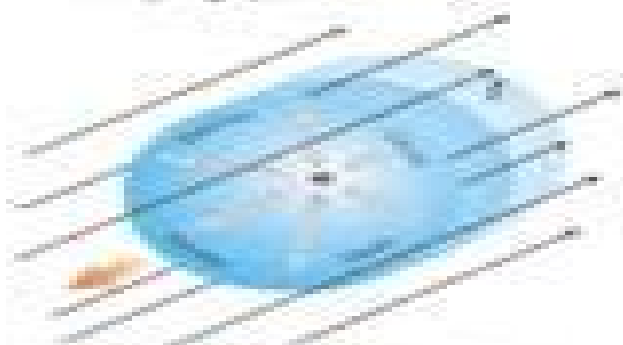


Fig. 1 Binding force between the polarization and the electron cloud (Ref. [1]).

Electrons react to an electron-magnetostatic field by vibrating like damped harmonic oscillators. The way the electric medium to a fluctuating 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 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 dispersion of frequency (Ref. [2]).

At low frequencies $\omega \ll \omega_0$, 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 .

At high frequencies $\omega \gg \omega_0$, the amplitude x vanishes.

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