

## 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.

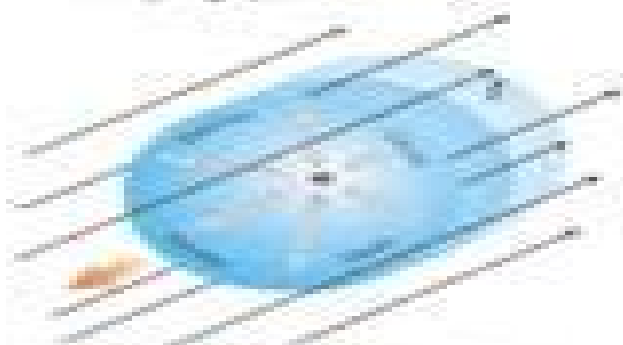


Fig. 1 Binding force between the polarization and the external wave (Ref. [1]).

Electrons react to an electron-magnetostatic 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;
- $\gamma$  or  $\gamma_0$  is the damping factor,  $E_0$  is the electric field.

- $m_0 \omega_0^2$  is the Hooke's force,  $\omega_0$  is the resonant mass and  $\omega_0$  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  $E_{\text{ext}}$  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  $\omega$ :

$$x(\omega) = \frac{1}{m} \frac{E_0}{\omega_0^2 - \omega^2 + i \gamma \omega} \quad (2)$$



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  $90^\circ$  phase shift between  $E$  and  $x$ .

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

# Lorentz Dispersion Model Horiba

**Nihon Kagakkai**

A red circular graphic with a gradient, appearing as a semi-circle or a partial circle, located to the right of the Nihon Kagakkai text.

## **Lorentz Dispersion Model Horiba:**

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    - Chapter 1: Introduction to Lorentz Dispersion Model Horiba
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## **Table of Contents Lorentz Dispersion Model Horiba**

1. Understanding the eBook Lorentz Dispersion Model Horiba
  - The Rise of Digital Reading Lorentz Dispersion Model Horiba
  - Advantages of eBooks Over Traditional Books
2. Identifying Lorentz Dispersion Model Horiba
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Lorentz Dispersion Model Horiba
  - User-Friendly Interface
4. Exploring eBook Recommendations from Lorentz Dispersion Model Horiba
  - Personalized Recommendations
  - Lorentz Dispersion Model Horiba User Reviews and Ratings
  - Lorentz Dispersion Model Horiba and Bestseller Lists
5. Accessing Lorentz Dispersion Model Horiba Free and Paid eBooks
  - Lorentz Dispersion Model Horiba Public Domain eBooks
  - Lorentz Dispersion Model Horiba eBook Subscription Services
  - Lorentz Dispersion Model Horiba Budget-Friendly Options
6. Navigating Lorentz Dispersion Model Horiba eBook Formats
  - ePub, PDF, MOBI, and More
  - Lorentz Dispersion Model Horiba Compatibility with Devices
  - Lorentz Dispersion Model Horiba Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Lorentz Dispersion Model Horiba
  - Highlighting and Note-Taking Lorentz Dispersion Model Horiba
  - Interactive Elements Lorentz Dispersion Model Horiba
8. Staying Engaged with Lorentz Dispersion Model Horiba

- Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Lorentz Dispersion Model Horiba
9. Balancing eBooks and Physical Books Lorentz Dispersion Model Horiba
- Benefits of a Digital Library
  - Creating a Diverse Reading Collection Lorentz Dispersion Model Horiba
10. Overcoming Reading Challenges
- Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Lorentz Dispersion Model Horiba
- Setting Reading Goals Lorentz Dispersion Model Horiba
  - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Lorentz Dispersion Model Horiba
- Fact-Checking eBook Content of Lorentz Dispersion Model Horiba
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning
- Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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