Solid State Optics

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Versuchsdurchführung: ??. ?.????
Protokollabgabe: ?? ??

1 Introduction

Fourier Transform Infrared (FTIR) spectroscopy is a powerful method for determining the electronic properties of metals and semiconductors. The FTIR technique is based on the interaction of infrared light with the material. Reflection and transmission are used to determine important electronic properties. Especially for semiconductors, the FTIR method is particularly useful because it helps to adjust parameters such as the doping concentration or the bandgap. For building applications like LEDs, transistors, or solar cells, precise knowledge of the bandgap and doping concentrations is required. In contrast to other common methods, such as spectroscopy with a monochromator, the FTIR method is much faster and more precise. Instead of varying the wavelength through multiple measurements, the FTIR method can measure the entire spectrum at once due to the use of a Michelson interferometer, which enables the interference of light. After Fourier transformation, the complete spectrum is obtained in a single step.
Firstly, the theoretical basics of light-matter interaction and some important formulas regarding reflection and transmission will be discussed. Following this theoretical introduction, the experimental setup will be described. The final part of this paper will focus on data evaluation, starting with the gas absorption of air. The second part of the data evaluation will involve determining the signal-to-noise ratio. The last part will address the determination of several previously mentioned electronic and optical properties, such as the refractive index, extinction coefficient, absorption coefficient, bandgap, and pulse matrix element for all given semiconductor samples.

2 Theory

2.1 Plane parallel layer

The investigated semiconductor samples can in first approximation be described as a plane parallel layer 1 with a thickness d and refractive index N_2 which acts like a fabry-perot interferometer. Light is simpliefied

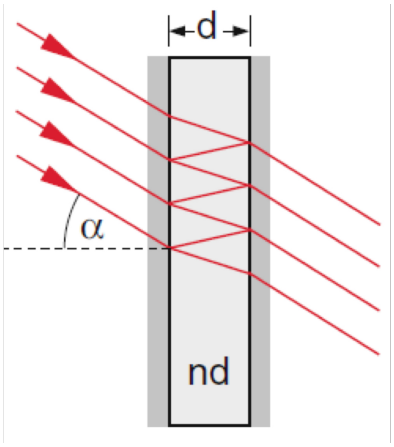

Abbildung 1: Simplified illustration of the measured samples as a plane parallel plate with thickness d and refractive index N_2. The surrounding air is described with a refractive indes $N_1 \approx 1$ [**?**]

as beams. Every incoming beam is partially reflected and partially transmittet at the first interface. The

total power reflectivity R_1 is described with:

$$R_1 = \left|\frac{1-N_2}{1+N_2}\right|^2 \tag{1}$$

without considering the phase shift of the reflected beam. Like shown in the illustration, the total power reflectivity of the second interface R_2 consists of the incoming beams and the beams reflected at the first interface within the material. Additionally, the absorption of the material is considered. Therefore, R_2 is described with:

$$R_2 = R_1(1-R_1)^2 \cdot e^{-2\beta d} \tag{2}$$

with the absorption coefficient β and the total power reflectivity R_1 of the first interface. The assumption that the reflection of the first interface is the same as the reflection of the second interface is in reality not correct. Disturbances like roughness of the interfaces or the absorption of the material lead to a different reflection coeffitients of the two interfaces.
Considering this and the phase of the light, the total power reflectivity R is described with:

$$R = \left|\frac{(e^{i\frac{2\omega}{c}N_2 d}-1)(1-N_2)}{e^{i\frac{2\omega}{c}N_2 d}(1-N_2)-(1+N_2)}\right|^2. \tag{3}$$

ω is the angular frequency of the light and c the speed of light. The phase shift of the light is described with $e^{i\frac{2\omega}{c}N_2 d}$. In contrast to 2, equation 3 shows a periodic modulation of the reflectivity because of interference. The difference between the maxima of the modulation can be calculated with:

$$\Delta\nu = \nu_{\mathrm{m}+1} - \nu_{\mathrm{m}} = \frac{1}{2dN_2} \tag{4}$$

The refractive index N_2 can be calculated either with equation 4 or with

$$N_2 = \sqrt{\epsilon} \tag{5}$$

using the square root of the dielectric function ϵ of the material. The dielectric function ϵ is described in the drude model as:

$$\epsilon = 1 - \frac{\omega_{\mathrm{p}}^2\tau^2}{1+\omega^2\tau^2} + i\frac{\omega_{\mathrm{p}}^2\tau}{\omega(1+\omega^2\tau^2)} \tag{6}$$

with ω_{p} as the plasma frequency:

$$\omega_{\mathrm{p}} = \sqrt{\frac{N_{\mathrm{e}}e^2}{\epsilon_0 m^*}} \tag{7}$$

and τ as the relaxation time of the electrons. m^* is the effective mass of the electrons and N_{e} the charge carrier density.
For semiconductors, ϵ_{sem} can be calculated as:

$$\epsilon_{\mathrm{sem}} = \epsilon_{\mathrm{LP}} + i\frac{\sigma}{\omega\epsilon_0} \tag{8}$$

with σ as the conductivity of the semiconductor:

$$\sigma = \frac{N_{\mathrm{e}}e^2\tau}{m^*}\frac{1}{1-i\omega\tau}. \tag{9}$$

The lattice contribution ϵ_{LP} is described as:

$$\epsilon_{\mathrm{LP}} = \epsilon_\infty(1 + \frac{\omega_{\mathrm{LO}}^2 - \omega_{\mathrm{TO}}^2}{\omega_{\mathrm{TO}}^2 - \omega^2 - i\Gamma\omega}) \tag{10}$$

with ϵ_∞ as the high frequency dielectric constant, ω_{LO} as the longitudinal optical phonon frequency, ω_{TO} as the transversal optical phonon frequency and Γ as the damping constant.

3 Set-Up

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4 Bibliography

Literatur

[1] Meschede D., *Gerthsen Physik*, Springer Verlag, 25th Edition, 2018. Modified by Lukas Hein and Elias Schwarzkopf.