

Study on Epitaxial Layer Thickness Measurement Based on Infrared Interferometry Combined with Machine Algorithm

Daitong Lin^{*,1}, Jiaru Zhang², Huanxi Wang¹

¹School of Finance & Investment, Guangdong University of Finance, Guangzhou 510521, China

²School of Computer Science, Guangdong University of Finance, Guangzhou 510521, China

* Corresponding author: Daitong Lin (Email: 231526142@m.gduf.edu.cn)

Abstract: This study focuses on accurate measurement of epitaxial layer thickness for silicon carbide (SiC) and silicon crystals using infrared interferometry combined with machine algorithms, while addressing beam interference effects. Theoretically, it builds a mathematical model based on optical interference theory, Snell's law, and Fresnel reflection formula, incorporating a half-wave loss correction to minimize phase difference errors. Reflection spectrum data are gathered via Fourier transform infrared spectrometry, and a linear fitting model is derived for calculations. Algorithmically, a two-step inversion method is developed: first, a simulated annealing-like algorithm optimizes wavenumber intervals with Monte Carlo sampling to enhance spectral data use; then, thickness and refractive index are calculated within a physically valid range. Results show low error and high robustness. Additionally, the study examines multi-beam interference, proposing a model with high-order reflections (Airy distribution) and spectral fitting to eliminate errors from multiple reflections in SiC wafers, achieving accurate thickness measurements.

Keywords: Thin film interference principle, Linear fitting model, Two-step inversion algorithm, Fabry-Perot interference model, Multi-beam interference model.

1. Introduction

As a highly concerned third-generation semiconductor material, the thickness of the silicon carbide (SiC) epitaxial layer is a key parameter determining the device performance, so it is crucial to establish a scientific and reliable thickness test standard. Infrared interferometry is an effective technique for non-destructive measurement of epitaxial layer thickness. Its physical basis lies in the difference in refractive index between the epitaxial layer and the substrate due to different doping concentrations. When infrared light irradiates the sample, the two beams of light reflected from the epitaxial layer surface and the substrate interface interfere. The thickness can be calculated by analyzing the interference fringes, but this process faces the challenge that the refractive index of the epitaxial layer changes with the doping concentration and the incident light wavelength. In order to systematically address this challenge, this paper is committed to accurately measuring the epitaxial layer thickness through theoretical modeling and algorithm design. Its core research includes: first, establishing an optical interference basic model that can accurately describe the epitaxial layer thickness, considering key parameters such as the incident angle of infrared light, the spectral wavelength and the refractive index of the epitaxial layer; second, designing a highly reliable thickness inversion algorithm and verifying the stability of the calculation results to ensure the accuracy and robustness of the measurement method[1]; finally, deeply analyzing and correcting the influence of multi-beam interference effect on the measurement accuracy, aiming to

eliminate the system error that may be introduced by this physical phenomenon. Therefore, the research scheme of this paper will be based on the optical interference theory, combined with Snell's law and Fresnel reflection formula[2], and innovatively introduce a half-wave loss correction term to construct a more complete linear fitting model of thin film interference. On this basis, a two-step inversion algorithm including simulated annealing-like global optimization and Monte Carlo random sampling will be designed to solve the thickness and refractive index simultaneously and strictly restrict their physical validity. For the problem of multi-beam interference, this paper will first derive its coherent conditions, and judge its existence by comparing the goodness of fit of different models. If it exists, the spectral fitting method based on the Airy distribution formula will be adopted[3], and nonlinear optimization algorithms such as Levenberg-Marquardt will be used to accurately correct the measurement results, and finally achieve high-precision thickness measurement. The model assumptions and symbol descriptions of this paper are as follows (see Table 1):

1.A Fourier transform infrared spectrometer is used for detection.

2.Equipped with a matching reflection accessory with an incident angle $< 30^\circ$ and a mask made of non-reflective material with a light-transmitting aperture $< 8\text{mm}$.

3.Infrared interferometry can measure the epitaxial layer thickness in a non-destructive way.

4.The same silicon carbide wafer with uniform material and no loss is used for all model tests.

5.Small-probability events in daily life, such as damage, are excluded.

Table 1 Symbol Description

Symbol	Description	Unit
θ_0	Angle of light incident from air to the epitaxial layer	Degree
θ_1	Refraction angle when light is incident from air to the epitaxial layer	Degree
θ_{rad}	Incident angle in radian	rad
M	Number of weak learner trees	Piece
N	Total number of samples	Piece
η	Learning rate	%
n_0	Refractive index in air, $n_0 \approx 1$	-
n_1	Refractive index in the epitaxial layer	-
n_{Si}	Refractive index of silicon	-
R_1	Reflectivity of the upper interface (reflected only at the air-epitaxial layer interface)	%
R_2	Reflectivity of the lower interface (refracted into the substrate, then reflected back to the air layer at the epitaxial layer-substrate interface)	%
R_{theo}	Theoretical total reflectivity	%
R_{obs}	Actual total reflectivity	%
$R_{\text{hybrid}}(\lambda_i, d)$	Reflectivity predicted by the hybrid model	%
$R_{\text{ture}}(\lambda_i)$	Actual reflectivity measured in the experiment	%
r_{01}	Amplitude reflectivity at the air-epitaxial layer interface	-
r_{12}	Amplitude reflectivity at the epitaxial layer-substrate interface	-
Δ_{road}	Optical path difference	μm
$\Delta\phi$	Phase difference	rad
δ	Delay phase difference	rad
d	Thickness of the epitaxial layer	μm
λ	Wavelength	μm
$\tilde{\nu}$	Wavenumber	cm^{-1}
$\vec{E}$	Electric field intensity	(N/C)
$\vec{H}$	Magnetic field intensity	(A/m)
c	Speed of light in vacuum	$3 \times 10^8 \text{ m/s}$
$\vec{S}$	Poynting vector	(W/m ²)
ω	Angular frequency	(rad/s)
m	Order of interference fringes	/
ϵ_{∞}	High-frequency limit dielectric constant	/
K	Parameter related to carrier concentration and to be determined by fitting	/
y_j^{new}	Correction value	/
σ	Standard deviation of sample data	/
μ	Standard deviation of overall data	/
$\vec{k}$	Wave vector	/
$\vec{r}$	Spatial position vector	/
r	Amplitude reflection coefficient	/
I	Light beam	/
R	Reflectivity	/
T	Transmittance	/
A	Absorption loss	/
E_0	Incident light amplitude	/
ϑ	Amplitude transmission coefficient	/
A	Sellmeier coefficient	/
$h_m(x)$	Weak learner	/
r_{im}	Residual	/
ω_{mj}	Weight	/
R_{mj}	The j-th leaf node of the decision tree	/

Construction of Optical Interference Theoretical Model for Epitaxial Layer Thickness Measurement

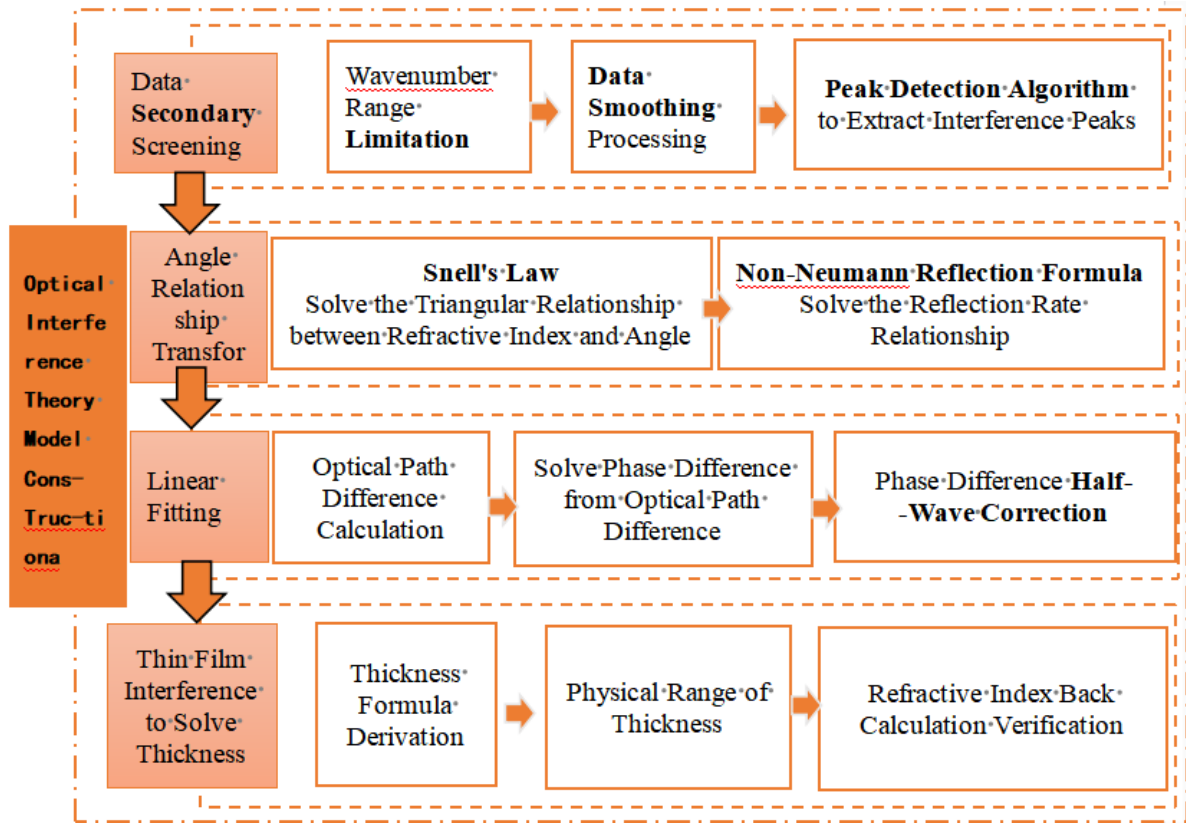


Figure 1: Logical Diagram of Optical Interference Theoretical Model Analysis for Epitaxial Layer Thickness Measurement

Figure 1 shows the logic diagram of the analysis of the optical interference theoretical model for epitaxial layer thickness measurement.

1.1. Model Establishment

1.1.1. Relationship between Refraction Angle and Incident Angle

According to Snell's law, the sine value of the refraction angle can be derived as follows:

$$\sin \theta_1 = \frac{\sin \theta_0}{n_1} \quad (1)$$

1.1.2. Fresnel Reflectivity and Linear Fitting of Reflectivity

After the light source is incident on the epitaxial layer, there are two reflection situations:

The first one is reflection only at the air-epitaxial layer interface (as shown in Figure 2). The second one is that the refracted light beam is incident into the substrate, reflected at the epitaxial layer-substrate interface, and then refracted back to the air layer (as shown in Figure 3).

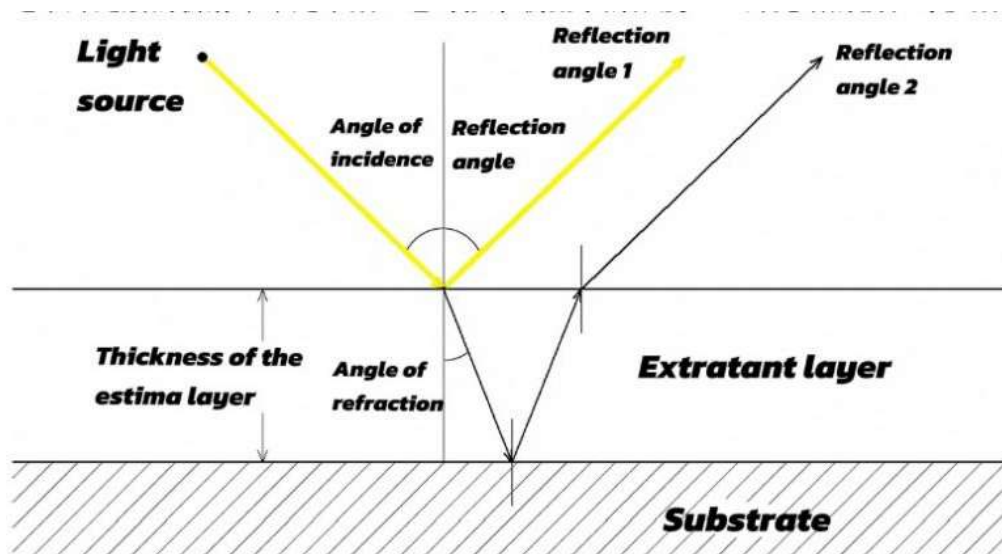


Figure 2 Reflection only at the air-epitaxial layer interface

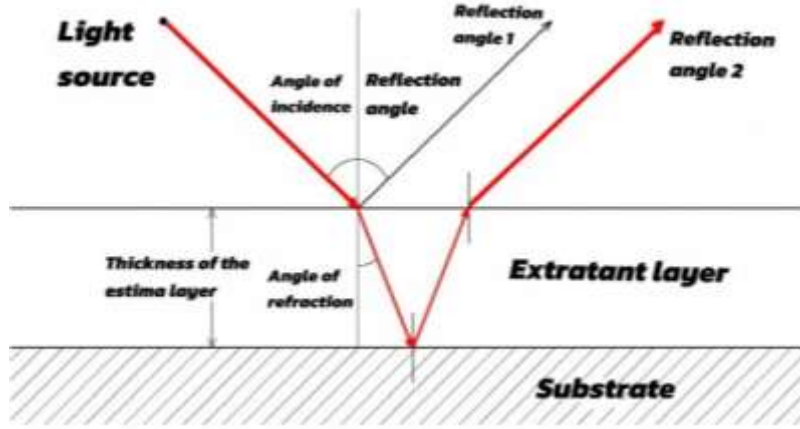


Figure 3 Schematic diagram of the propagation of light refracted into the substrate, then reflected back to the air layer at the epitaxial layer-substrate interface

According to Fresnel reflectivity, the reflectivity R_1 of the upper interface (Figure 2) is calculated as follows

$$R_1 = \left(\frac{n_0 \cos \theta_0 - n_1 \cos \theta_1}{n_0 \cos \theta_0 + n_1 \cos \theta_1} \right)^2 \quad (2)$$

n_0 is the refractive index of air, and n_1 is the refractive index of the epitaxial layer, which is also a fitting function of refractive index, carrier concentration and wavelength.

The reflectivity of the lower interface (Figure 3) is R_2 :

$$R_2 = \left(\frac{n_1 \cos \theta_1 - n_2 \cos \theta_2}{n_1 \cos \theta_1 + n_2 \cos \theta_2} \right)^2 \quad (3)$$

Among them, n_2 is the refractive index of the substrate.

Due to the high goodness of fit of the data, its variance is small, and it generally shows a linear relationship. Therefore, it is assumed that there is a linear relationship between reflectivity and wavelength, and the theoretical reflectivity is fitted by the least square method. The formula is:

$$R_{ols} = a\lambda + b \quad (4)$$

Among them, a and b are fitting coefficients.

1.1.3. Optical Path Difference and Phase Difference Correction for Half-Wave Loss

Based on the two situations and the fact that the extreme interval of interference fringes does not change with the infrared light frequency, the optical path difference comes from the propagation of the light beam in the epitaxial layer, that is, the trajectory in the epitaxial layer $\times$ the refractive index of the medium[4-5]. The optical path difference Δ_{road}

is defined as:

$$\Delta_{road} = 2dn_1(\lambda) \cos \theta_1 \quad (5)$$

According to the wave nature of light, the relationship between the optical path difference Δ_{road} and the phase difference $\Delta\phi$ is as follows:

$$\Delta\phi = \frac{2\pi}{\lambda} \cdot \Delta_{road} \quad (6)$$

Substituting the optical path difference formula into the above formula, the phase difference formula can be obtained:

$$\Delta\phi = \frac{4\pi n_1 d \cos \theta_1}{\lambda} \quad (7)$$

Since the formation of interference fringes needs to satisfy the phase difference of $2m\pi$ and $(2m+1)\pi$, that is:

$$\cos \Delta\phi^* = \begin{cases} 1 & \Delta\phi = 2m\pi \\ -1 & \Delta\phi = (2m+1)\pi \end{cases} \quad (8)$$

It represents the order of interference fringes, and its value is a natural number. Different m correspond to interference fringes of different orders, which can be determined by observing the distribution of interference fringes.

As shown in Figure 4, when light is incident from an optically thinner medium to an optically denser medium interface, the reflected light produces a π phase mutation. When light is incident from an optically denser medium to an optically thinner medium interface, there is no phase mutation in the reflected light.

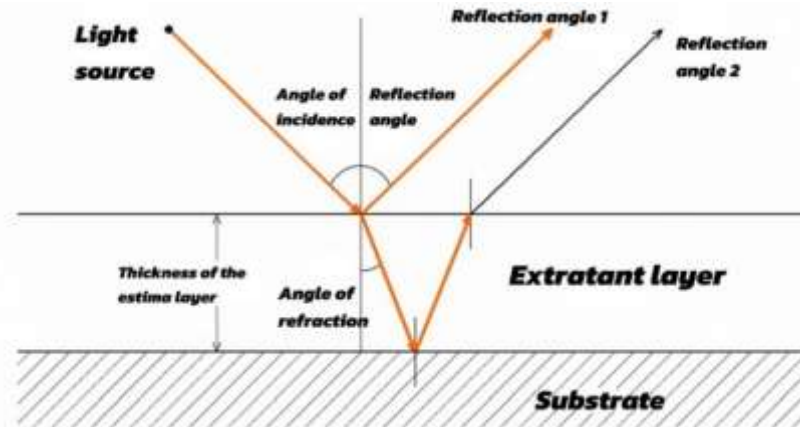


Figure 4 Schematic diagram of two reflections: air-epitaxial layer and epitaxial layer-substrate

In Figure 4, there are two reflections: from air (optically thinner) to the epitaxial layer (optically denser) and from the

epitaxial layer to the substrate. The optical path difference caused by the half-wave loss of the two reflected light beams

cancels each other out, so only the propagation optical path in the epitaxial layer needs to be considered.

1.1.4. Derivation of Thickness Formula Based on Thin Film Interference Principle

The phase difference between adjacent interference peaks is 2π , and the order difference $\Delta m = 1$. Let the wavelengths of adjacent peaks be λ_1 and λ_2 , and $\lambda_1 > \lambda_2$, then:

$$2n_1 d \cos \theta_0 = m\lambda_1 = (m + 1)\lambda_2 \quad (9)$$

By combining the extreme conditions and eliminating the interference order m , the thickness calculation formula is obtained:

$$d = \frac{\lambda_1 \lambda_2}{2n_1(\lambda_1 - \lambda_2) \cdot \cos \theta_0} \quad (10)$$

It is known that the physical range of thickness d is $[d_{min}, d_{max}] = [2.5, 579.6] \mu m$. The simulated value of thickness can be obtained through simulation calculation. The average value is defined as the actual thickness, and the refractive index can be inversely derived. According to the literature, the refractive index should be in $[2.0, 3.5]$.

2. Thickness Calculation and Reliability Analysis Based on Two-Step Inversion Algorithm

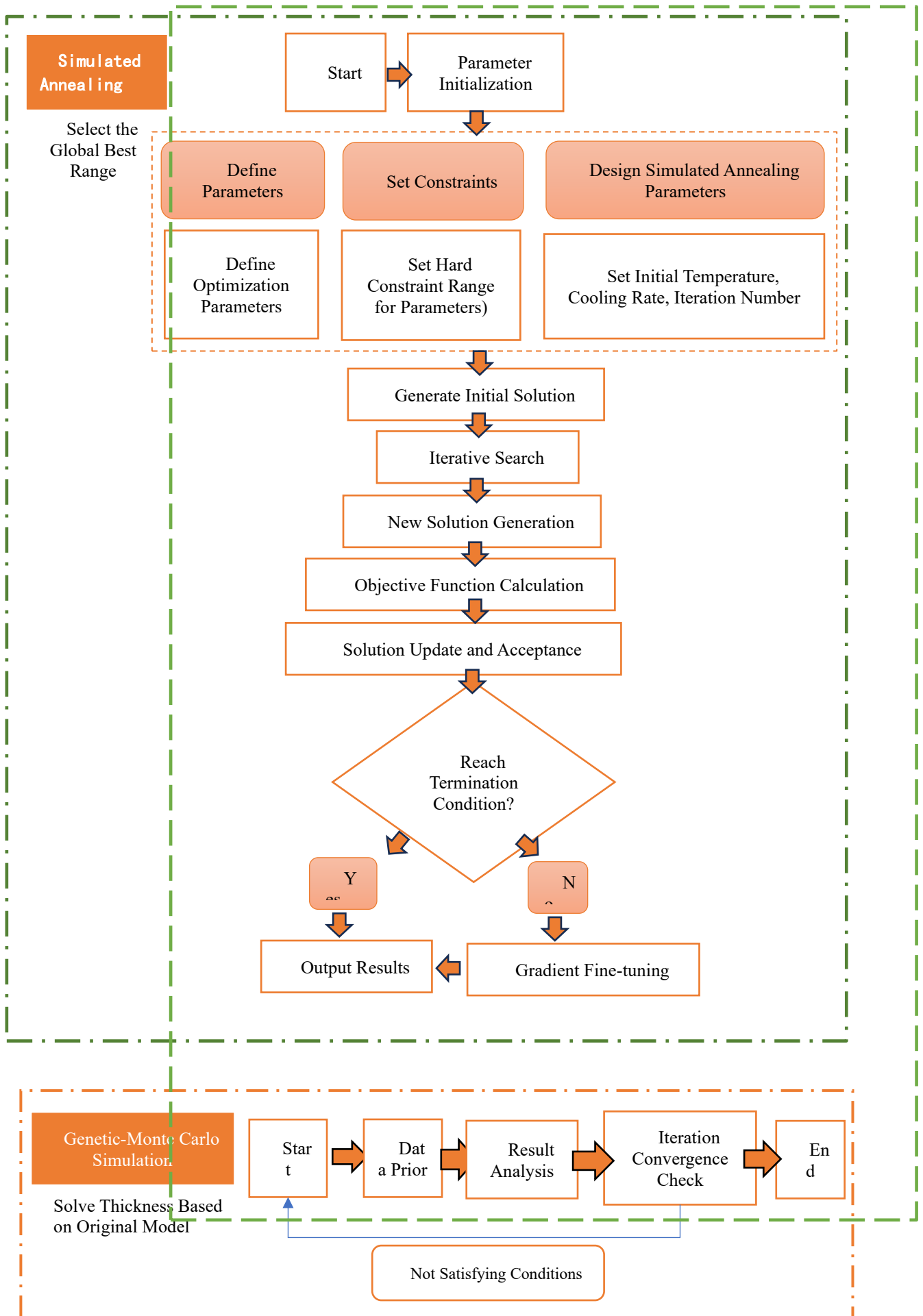


Figure 5 logic diagram

Figure 5 shows the logic diagram of thickness calculation and reliability analysis. Silicon carbide (SiC) has three

material forms: single crystal, polycrystal and amorphous. This study clearly takes the same silicon carbide wafer as the experimental material, so it can be directly determined that it has a crystalline structure[6-7]. Combined with the conclusions of relevant literature, the silicon carbide used in the semiconductor field is mainly single crystal. Therefore, in

the subsequent data screening process, the wavenumber parameter of single crystal characteristic $[963.5, 3950]cm^{-1}$ is selected as the constraint condition for calculation.

The following data are obtained based on simulated annealing-like and Monte Carlo simulation (Table 2):

Table 2 Calculation Data

Index	Data File 1	Data File 2	Difference
Incident Angle	10.0 Degree	15.0 Degree	5.0 Degree
Reflectivity Goodness of Fit	$R^2=0.815268$	0.829025	0.013757
Thickness Goodness of Fit R^2	1	1	0
Average Thickness (μm)	6.9906	7.2236	0.233
Thickness Standard Deviation (μm)	0.0403	0.0375	0.0028
Optimal Wavenumber Lower Limit (cm^{-1})	1063.5	1063.5	0
Number of Valid Data Points	5988	5988	0
Number of Detected Interference Peaks	9	8	1
Average Refractive Index	2.6271	2.6269	0.0002
Refractive Index Standard Deviation	0.0141	0.0113	0.0028

Based on the experimental data of incident angles of 10.0° and 15.0° , the measured results of epitaxial layer thickness are $6.9906\mu m$ and $7.2236\mu m$ respectively, with a difference of $0.233\mu m$. The average refractive indices are 2.6271 and 2.6269 respectively, showing high consistency.

Since the goodness of fit of reflectivity is greater than 0.8, and the spectral data of Data File 1 is more consistent with the model. The overall results show that the refractive index

results are robust, and the model has good repeatability and reliability.

3. Analysis of Multi-Beam Interference Effect and Measurement Correction

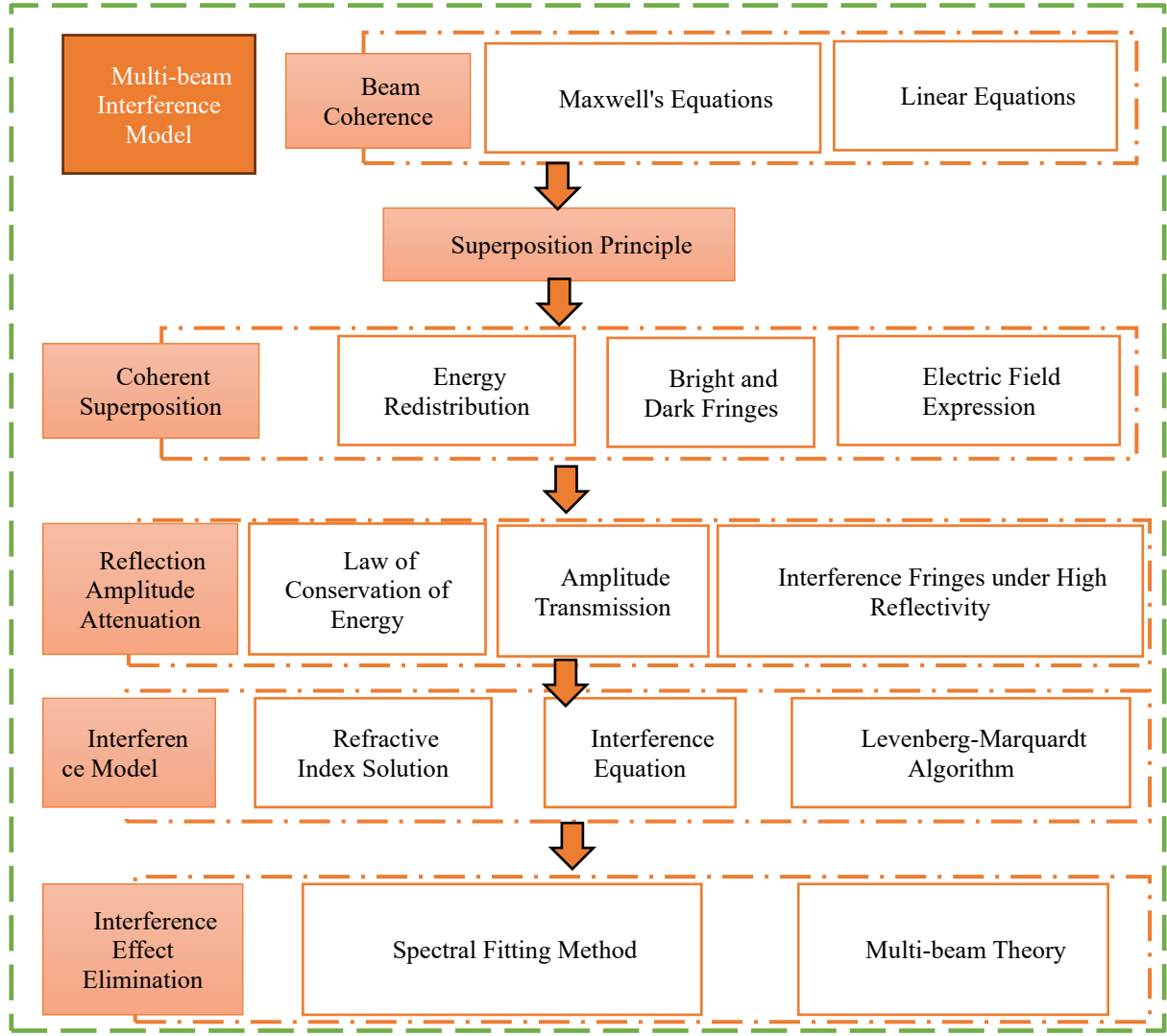


Figure 6. Analysis and Measurement Correction Logic Diagram of Multi-Beam Interference Effects

Figure 6 shows the logic diagram of the analysis and measurement correction of multi-beam interference effect.

3.1. Necessary Conditions and Their Derivation

3.1.1. Three Coherence Conditions of Light Beams

According to the superposition principle of solutions of linear equations, the linear differential equations of Maxwell's equations, and coherent superposition, it can be derived that:

$$\begin{cases} \omega_1 = \omega_2 \\ \vec{E}_1 \cdot \vec{E}_2 \neq 0 \text{ or } \vec{E}_1 \parallel \vec{E}_2 \\ \varphi_1 - \varphi_2 = C \end{cases} \quad (11)$$

The frequencies are the same, and the interference term will not become zero after time averaging, thus forming stable interference fringes. Since light is a transverse wave, the vibrations need to be in the same direction or have parallel components to cause the redistribution of energy, and the interference term exists. The constant phase difference enables the interference term to fluctuate regularly within a certain range. Methods such as wavefront division, amplitude division and $F-P$ mirror can be used to make the two beams of light come from the same light source, thereby ensuring that the phase difference remains constant.

3.1.2. Condition for Slow Attenuation of Reflected Light Amplitude

According to the law of conservation of energy, light needs to satisfy the following in the process of reflection and

transmission at the mirror surface:

$$R + T + A = 1 \quad (12)$$

Among them, R is the reflectivity, T is the transmittance, and A is the absorption loss. To reduce the loss, $A \ll 1$. Among them:

$$\begin{cases} R = r^2 \\ T = \vartheta^2 \end{cases} \quad (13)$$

r is the amplitude reflection coefficient, and ϑ is the amplitude transmission coefficient.

The $F-P$ mirror needs to be coated with a high-reflection film to improve the reflectivity R . Assuming that the incident light amplitude is E_0 , the amplitude after transmission through the first mirror is $E_0\vartheta r$. After reaching the second mirror, the amplitude of the reflected light is $E_0\vartheta^2 r$, and the amplitude after transmission through the first mirror again is $\vec{E}_1$ (i.e., $E_0\vartheta^2 r$). The amplitude attenuation per round trip is $r^2 = R$ of the original. Thus, the amplitude of the k -th outgoing light beam can be derived as:

$$E_k = E_0\vartheta^2 r^{k-1} \quad (14)$$

The amplitude attenuates in a geometric sequence, with an attenuation coefficient of R . Under the condition of low reflectivity ($R < 10\%$), when the reflected light intensity is weak, it means that the high-order light beams can be ignored, so it can be approximated as double-beam interference, which has the characteristics of wide fringes and low contrast. In the case of high reflectivity ($R > 90\%$), a large number of light beams participate in the interference, which will form sharp

and fine fringes accordingly, and the fringe sharpness is quantified by the finesse, which can be defined as the ratio of the interval between adjacent fringes to the half-width. The $F - P$ transmitted light intensity formula is as follows:

$$I_T = \frac{I_0 T^2}{(1-R)^2 + 4R \sin^2\left(\frac{\delta}{2}\right)} \quad (15)$$

When $\sin^2\left(\frac{\delta}{2}\right) = 0$:

$$I_T = I_{T_{Max}} = \frac{I_0 T^2}{(1-R)^2} \quad (16)$$

Its transmission will approach the maximum. Correspondingly, when $I_T = I_{T_{Max}}$, the phase difference corresponding to the half-width is solved as:

$$\Delta\delta = 2\sqrt{\frac{1-R}{R}} \quad (17)$$

The phase difference interval between adjacent fringes is $= 2\pi$, so the finesse F is:

$$F = \frac{\delta_{interval}}{\Delta\delta} = \frac{\pi\sqrt{R}}{1-R} \quad (18)$$

It can be known from the above formula that the higher the R , the larger the F , and the smaller the fringe half-width and the higher the sharpness accordingly.

3.2. Establishment of Multi-Beam Interference Model

3.2.1. Influence of Multi-Beam Interference on Thickness Calculation Accuracy

Multi-beam interference fringes change the shape of interference fringes through "superposition of multiple reflected lights", which are sharper than double-beam interference fringes, and theoretically can improve the resolution of thickness measurement.

Because the reflection spectrum is not a simple cosine function, but a multi-beam interference fringe function, if only the double-beam model is used for fitting, it will lead to deviations in thickness calculation.

3.2.2. Determination of Multi-Beam Interference Model and Algorithm

If multi-beam interference is ignored and only the double-beam model is used for fitting, it will lead to deviations in thickness calculation. Instead, the Airy function (multi-beam interference fringe function) should be used. Since the doping information is not given in the problem, we can assume that the refractive index difference between the epitaxial layer and the substrate is constant, and determine it by fitting the reflectivity amplitude.

(1) Solution of Refractive Index

$$n_{Si} = \sqrt{\lambda + \frac{A_2}{\lambda^2} + A_3 \frac{A_4^2 \lambda^2}{\lambda^2 - A_4^2}} \quad (19)$$

In addition, the Sellmeier coefficients of silicon are $A_1 = 11.6858$, $A_2 = 0.939816 * 10^{-12} m^2$, $A_3 = 8.10461 * 10^{-3} m^{-2}$, $A_4 = 1.1071 * 10^{-6}$, and the wavelength range is 1.460–1.625 μm .

(2) Construction of Multi-Beam Interference Equation

In the case of multi-beam interference, the reflectivity no longer follows the simple thin film interference model, but follows the Airy distribution formula, which is a standard conclusion in optics for describing the Fabry-Perot interferometer and multi-beam interference:

$$R = \frac{F \sin^2\left(\frac{\delta}{2}\right)}{1 + F \sin^2\left(\frac{\delta}{2}\right)} \quad (20)$$

F : Finesse coefficient, a dimensionless parameter used to describe the sharpness of interference fringes. Its expression

is:

$$F = \frac{4R_m}{(1-R_m)^2} \quad (21)$$

At the same time, the phase difference δ :

$$\delta = \frac{4\pi n d \cos\theta}{\lambda} \quad (22)$$

(3) Establishment of Optimization Problem

Define the objective function as the sum of squared residuals between the experimental reflectivity and the theoretical reflectivity:

$$S(d) = \sum_{i=1}^N \left[R_{exp}(\lambda_i) - \frac{F \sin^2\left(\frac{\delta(\lambda_i)}{2}\right)}{1 + F \sin^2\left(\frac{\delta(\lambda_i)}{2}\right)} \right]^2 \quad (23)$$

(4) Numerical Solution

The nonlinear least square method Levenberg-Marquardt algorithm is used to solve the thickness d :

Calculate the covariance matrix of parameter estimation:

$$Cov(d) = \sigma^2 (J^T J)^{-1} \quad (24)$$

Among them, J is the Jacobian matrix, and σ^2 is the residual variance.

3.3. Judgment on Whether Multi-Beam Interference Occurs in the Light Propagation Path under Silicon Carbide Material

The data are substituted into the multi-beam interference model for fitting, and the R-square is solved and compared with the goodness of fit of the thin film interference model established. By analyzing the high consistency between the reflection coefficient ($r_{01} \approx -0.4 - 0.64$) and the theoretical value (-0.45), and the characteristic that the substrate interface reflection coefficient (r_{12}) is close to zero, it is confirmed that the multi-beam interference effect does exist. This proves that from the physical mechanism, the light has undergone multiple reflections in the thin film, and the traditional double-beam interference model is no longer applicable.

3.4. Elimination of the Influence of Multi-Beam Interference

3.4.1. Model Establishment

When there is also a multi-beam interference effect in the silicon carbide sample, the spectral fitting method can be used to eliminate its influence, that is:

$$\min_{d, r_{01}, r_{12}} \sum_{\lambda} [R_{obs}(\lambda) - R_{theory}(\lambda; d, r_{01}, r_{12})]^2 \quad (25)$$

Among them, R_{theory} can predict the spectrum under different thicknesses d and interface reflection properties (r_{01}, r_{12}), and d is the epitaxial layer thickness. r_{01}, r_{12} are the amplitude reflection coefficients from the environment to the epitaxial layer and from the epitaxial layer to the substrate respectively. λ is the wavelength, $R_{obs}(\lambda)$ is the observed reflectivity, and R_{theory} is the theoretical reflectivity.

3.4.2. Model Solution

A fitting model is constructed by introducing the multi-beam interference theory (Airy formula), which fully considers the contribution of all high-order reflected lights. The extremely low fitting error ($MSE \approx 0.03$) indicates that this model successfully eliminates the system error introduced by ignoring multiple reflections.

Finally, the highly consistent and accurate thickness results of the two samples are (50.08 μm , 49.98 μm) respectively, which confirms that this method is effective. This means that the influence of multi-beam interference has been reliably

eliminated, and at the same time, this method has excellent repeatability and accuracy, which can provide a reliable solution for the precise optical measurement of semiconductor materials.

4. Conclusions

This paper focuses on the measurement of epitaxial layer thickness based on infrared interferometry and machine algorithm, and successfully constructs a comprehensive solution from theory to practice.

The research starts with the optical interference theory, and improves the basic thin film interference model by innovatively introducing half-wave loss correction, laying a solid theoretical foundation for subsequent calculations. For the silicon carbide epitaxial layer, a two-step inversion strategy combining simulated annealing-like and Monte Carlo algorithms is designed to realize the optimal selection of the wavenumber interval and the simultaneous accurate solution of thickness and refractive index. The experimental results show that the average thickness error measured under different incident angles is only 0.233 μm , and the refractive index difference is only 0.0002. The data are highly consistent, which verifies the reliability of the method.

In pursuit of higher accuracy, this paper deeply discusses and confirms the existence of multi-beam interference effect and its influence on measurement accuracy. By constructing a fitting model based on the Airy formula and using the spectral fitting method, the system error introduced by this effect on the measurement is successfully eliminated, and finally highly accurate and consistent thickness results (50.08 μm and 49.98 μm) are obtained.

In conclusion, the series of models and algorithms proposed in this study have been verified through sensitivity and robustness analysis, proving their stability and reliability. This achievement not only provides a scientific standard for

the accurate and non-destructive measurement of semiconductor epitaxial layer thickness, but also has broad application prospects in promoting the detection of other thin film materials.

References

- [1] Ren Chaoqun, Chen Chaochan, et al. Review on Preparation of Silicon Carbide Materials [J]. China Ceramics, 2025, 61(9).
- [2] General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of the People's Republic of China. Test for Thickness of Silicon Carbide Epitaxial Layer - Infrared Reflection Method: GB/T 42905—2023 [S]. 2023-08-06. (National Standards Information Public Service Platform).
- [3] Zhang Jing, Yang Lifeng. Discussion on the Establishment Process of Maxwell's Equations [J]. Journal of Electrical & Electronic Education, 2025, 47(1): 115-118.
- [4] Guo Jiawei, Li Qian, Yang Zhiyi, et al. A Brief Analysis of the Influence of Residual Magnetism on Magnetic Method Measurement of Coating Thickness [J]. China Equipment Engineering, 2025, (09): 103-104.
- [5] Wei Anhai, Yang Li, Fan Lidong, et al. Consistency Analysis of Central Anterior Chamber Depth and Corneal Thickness Measurements Using Time-Domain Coherent Optical Measurement and Optical Biometry Instruments [J]. Biomedical Engineering and Clinical, 2025, 29(03): 403-408. DOI:10.13339/j.cnki.sglc.20250427.001.
- [6] Liu Yixuan, Ma Chao, Liu Tianyi. Uncertainty Assessment of Wet Film Thickness Gauge Measurement Results [J]. Brand and Standardization, 2025, (03): 235-237.
- [7] Cai Zhenhua, Liu Haixian, Chen Tingyang, et al. Research on Visual Measurement Technology for Grinding Thickness of Thermal Barrier Coatings on Aero-engine Turbine Blades [J]. Aviation Manufacturing Technology, 2025, 68(05): 50-58. DOI:10.16080/j.issn1671-833x.2025.05.050.