CUMCM-2025 Problem B

Determination of Thickness of Silicon Carbide Epitaxial Layer

Silicon carbide, as an emerging third-generation semiconductor material, has been concerned more and more due to its superior comprehensive performance. The thickness of silicon carbide epitaxial layer is one of the key parameters of epitaxial materials, which has a significant impact on device performance. Therefore, it is particularly important to develop scientific, accurate, and reliable criteria for testing the thickness of silicon carbide epitaxial layers.

Infrared interferometry is a non-destructive measurement method for measuring the thickness of epitaxial layers. The working principle is that the epitaxial layer and substrate have different refractive indices due to the concentration of doped carriers. After infrared light is incident on the epitaxial layer, some light is reflected from the surface of the epitaxial layer, the rest is reflected from the surface of the substrate (see Figure 1), producing interference fringes under certain conditions. The thickness of the epitaxial layer can be determined based on parameters, such as the wavelength of the infrared spectrum, the refractive indices of the epitaxial layer, and the incident angle of infrared light.

The refractive indices of the epitaxial layer are usually non-constant and is related to parameters, such as the concentration of doped carrier concentrations and the wavelength of the infrared spectrum.

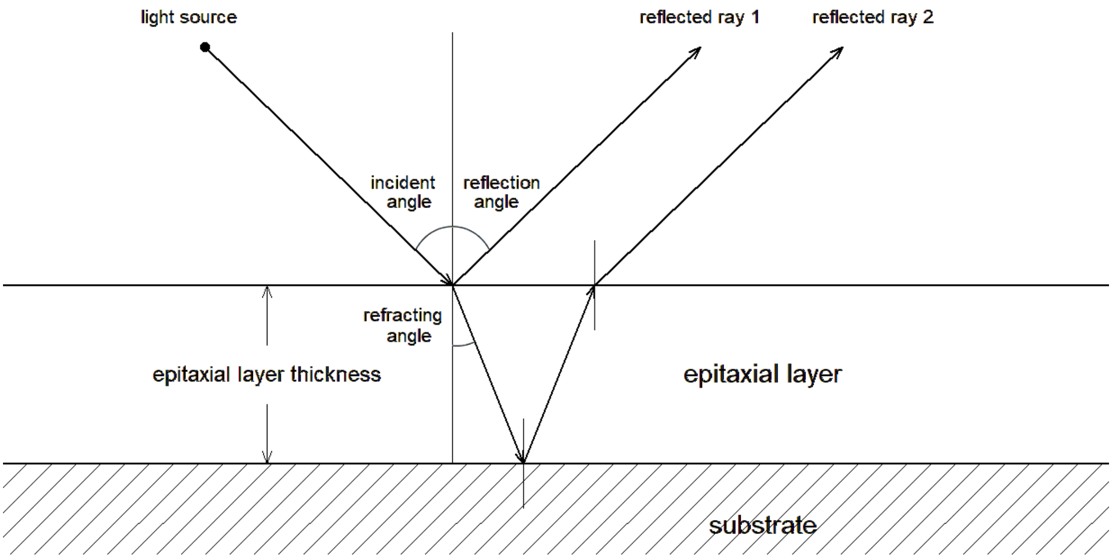

Figure 1　Schematic diagram of the principle of measuring epitaxial layer thickness

Problem 1　Considering only one reflection and transmission of interference fringes at the interface between the epitaxial layer and the substrate (see Figure 1), please establish a mathematical model to determine the thickness of the epitaxial layer.

Problem 2　Based on the mathematical model of Problem 1, design an algorithm to determine the thickness of the epitaxial layer. Provide the results by using the measured spectral data of silicon carbide wafers provided in Annex 1 and Annex 2, and analyze the reliability of the results.

Problem 3 Light waves may generate multiple reflections and transmissions at the interface between the epitaxial layer and the substrate (see Figure 2), resulting in multiple-beam interference. Please derive the necessary conditions for generating multiple-beam interference, as well as the possible impacts of multiple-beam interference on the accuracy of the thickness of the epitaxial layer.

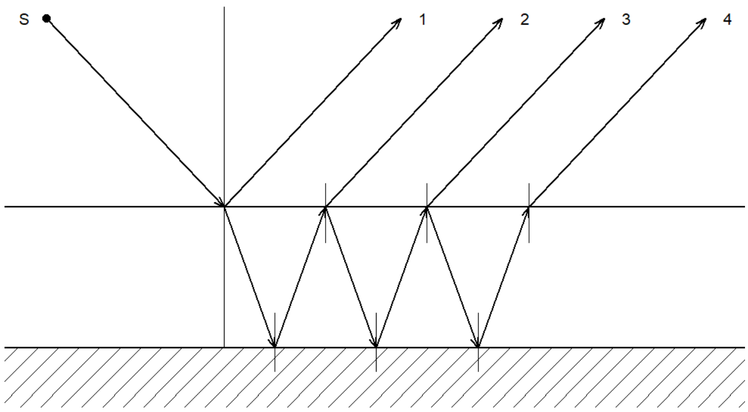

Figure 2 Schematic diagram of multiple-beam interference

Please analyze whether there is multiple-beam interference in the measured spectral data of silicon wafers provided in Annex 3 and Annex 4 based on the necessary conditions of multiple-beam interference. Please design an algorithm to determine the thickness of the silicon epitaxial layer, and provide the relevant results in the paper.

If you believe that multiple-beam interference also occurs in the measured spectral data of silicon carbide wafers (Annex 1 and Annex 2), which affects the accuracy of the thickness of the silicon carbide epitaxial layer, please try to eliminate the influence and provide the relevant results in the paper.

Description of Annexes

(1) Annex1.xlsx and Annex2.xlsx are the measured spectral data of the same silicon carbide wafer with incident angles at $10°$ and $15°$, respectively. The first column is the wave numbers (unit: cm^{-1}), and the second column is the reflectance of the interference spectrum (unit: %).

(2) Annex3.xlsx and Annex4.xlsx are the measured spectral data of the same silicon wafer with incident angles at $10°$ and $15°$, respectively. The first column is the wave numbers (unit: cm^{-1}), and the second column is the reflectance of the interference spectrum (unit: %).