

Hybrid optical measurement technique for detection of defects in epitaxially grown 4H-SiC layers

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Abstract. Recent developments in power electronics require the use of new wide bandgap compound semiconductor. We demonstrate the use of the ellipsometry and white light interference microscopy to detect defects in epitaxially grown SiC layers on SiC substrates. Such hybrid optical metrology methods can be used to better understand the mechanism of the development of the defects as well as their effects on the material's optoelectronic properties.

1 Introduction

Silicon carbide (SiC) is one of the most promising materials for power electronics due to its outstanding properties and commercial availability. However, defects in the SiC substrates or homoepitaxial SiC layers can affect the performance of electronic devices in a serious manner [1]. Some types of them, so called triangular “killer defects” in epilayers have been known to even make the operation of device impossible. To effectively exploit these materials, we need to understand mechanisms of defect formation. Moreover, the density of different types of defects is supposed to play a crucial role. In this contribution we demonstrate how optical methods such ellipsometry and white light interference microscopy can be applied for fast and non-contact investigation of epitaxially grown 4H-SiC layers on 4H-SiC substrates.

2 Ellipsometry measurements of 4H-SiC epitaxial layers

Ellipsometry can be used for the accurate characterization of thin layers in a broad spectral range. This is a powerful technique that measures changes in polarization during light reflection from the sample surface. The obtained ellipsometric transfer quantities Ψ and Δ represent material fingerprints. To determine the thickness of thin layers as well as optical/dielectric properties of layer materials a model-based fitting procedure is applied [2, 3]. Imaging ellipsometry combines the capabilities of ellipsometry and optical microscopy. Due to polarization

sensitivity and very high contrast for surface structures, the different areas within a defect can be detected.

We have investigated 4H-SiC epilayers with a 12 μm thickness on 4H-SiC substrates using an EP4 imaging ellipsometer (Accurion).

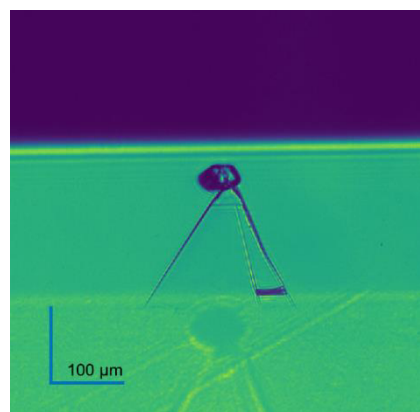


Fig. 1 Ellipsometric microscope image of a triangular defect on 12 μm 4H-SiC epilayer grown on 4H-SiC substrate

In the detected defect (Fig. 1) the spherical and triangle areas can be distinguished. The spherical area is reported to be caused by the landing of particles during the epitaxy process [4]. In the triangular area terrace-like structures are formed [4]. Using Raman spectroscopy, it was found previously that the triangular regions content 3C-SiC polytype inclusions. [4, 5] The high lateral resolution and the mapping of the physical quantities of interest over selected regions provide better opportunities for qualitative and quantitative investigations of defects using

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imaging ellipsometry. Line profiles of measured Ψ and Δ at certain wavelengths and angles of incidence enables first conclusions about the structure of different defect areas. Spatial resolution for these quantities were found to depend on the wavelength. In addition, spectroscopic measurements in wide spectral range were carried out for selected regions of interest within the defect area.

3 White light interferometry measurements of 4H-SiC epitaxial layers

Information about the surface structure contributes to understanding of the formation mechanisms of defects in 4H-SiC epilayers and help to reduce defect density already during production process and achieve the high quality of epilayers. Therefore, for investigation of the surface structure of the triangular defects white light interference microscopy (WLIM) was used.

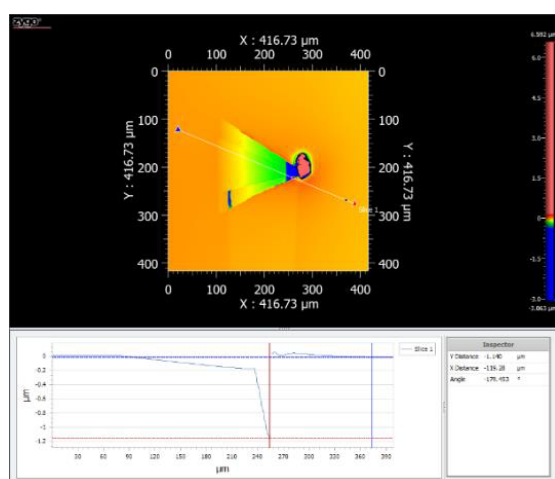


Fig.2 WLIM image and surface profile of a triangular defect on 12 μm 4H-SiC epilayer grown on 4H-SiC substrate

Measurements were carried up with the microscope Zygo NewView with a 20x objective (Fig. 2). The resolution was ~ 1 nm in vertical and $\sim 0,7$ μm in horizontal directions. These measurements brought into light some structures in the 4H-SiC epilayer, which were not visible by imaging ellipsometry.

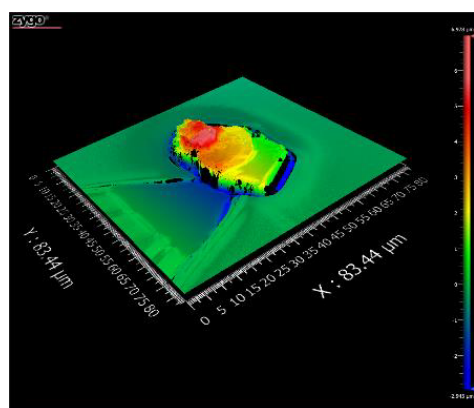


Fig. 3 WLIM 3D-image of the spherical area of defect on 12 μm 4H-SiC epilayer grown on 4H-SiC substrate

It was observed that the spherical area of the defects (“head”) extends several μm above the layer surface (Fig. 3). It has a step-like structure, that may be expected for the case than a particle lands on the surface during the epitaxy process. The triangle extensions go up to 1 μm deep into the layer and become even steeper near the “head”. They have different height profiles and slopes.

These non-contact 3D topography investigations can provide detailed information about morphology and propagation of defects in epitaxial 4H-SiC layers.

4 Conclusion

Hybrid measurement technique using spectroscopic and imaging ellipsometry as well as white light interference microscopy enables fast and non-destructive detection and traceable characterization of complex defects in epitaxially grown 4H-SiC layers. Ellipsometry and White Light Interference Microscopy are accredited measurement methods according to DIN EN ISO/IEC 17025 [6]. Therefore, both methods are very promising candidates for use already during production of SiC epilayers and for subsequent industrial quality control.

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