Thin film analytics with VUV reflectometry

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In present and future semiconductor manufacturing processes, complex layer sequences of ultra-thin functional layers with layer thicknesses below 10 nm and new material systems are increasingly being applied. Metrology for fast and non-destructive characterization of these material systems regarding layer thickness, material composition, morphology, and optical properties is inevitable for process control during device fabrication [1]. Vacuum Ultra-Violet (VUV) reflectometry is a promising method for fast and non-destructive optical inline characterization of these ultra-thin films. The extension of the measurement wavelengths into the VUV region below 200 nm (6.2 eV) to 120 nm (10.3 eV) in commercially available systems specifically enables the investigation of important dielectric films applied in semiconductor manufacturing, e.g. SiO_2, Al_2O_3, ZnO_2, HfO_2 and combinations thereof, with significantly increased measurement sensitivity [2]. The increase in sensitivity is due to the excitation of interband transitions and the capability to analyze the absorption properties of the respective material.
In this paper, the experiences and results obtained during the investigation of VUV reflectometry for application in semiconductor manufacturing are reviewed [3-8]. The investigations were performed on a commercial VUV reflectometer for the measurement on 200 mm and 300 mm wafers, which enables the measurement at a minimum wavelength of 120 nm. An overview of calibration and measurement strategies is provided, which are required to obtain reliable measurements at optimized accuracy and precision by minimizing effects due to environmental and surface contamination as well as layer modification effects due to the high energy of the VUV radiation. Application examples for optimized VUV measurement on different dielectric materials and layer systems including SiO_2, Si_3N_4, SiON, Al_2O_3, HfO_2, TiO_2, GIZO and ZnO_2 are provided and compared to results obtained by reference methods, e.g. spectroscopic ellipsometry, XRR, XPS, and TEM. The applicability of effective-medium approximation and dispersion models for the determination of optical material properties is discussed and the results from comparative measurements, which were performed by use of the VUV reflectometer at PTB's "Metrology Light Source" and the commercial VUV reflectometer, are presented. Based on the presented results, the prospects and current limitations for the wide applicability of VUV reflectometry for material characterization are reviewed.

References

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