Curvature and stress analysis in 3C-SiC layers grown on (001) and (111) Si substrates

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Silicon carbide is an attractive material for the realization of devices and Micro Electro Mechanical Systems working in harsh environment and for biocompatible applications. More than 100 polytypes of SiC exist but the SiC cubic phase (3C-SiC) has drawn particular attention because it can be deposited on Si, enabling the low cost and large area growth and the use of conventional microfabrication processes. Unfortunately, high lattice and thermal mismatch (20% and 8%, respectively) hinder SiC growth on Si, leading to high residual stress and creating a highly defective layer at the interface, which must be effectively controlled for many applications. The residual stress can potentially lead to macroscopic wafer bending, while variation of stress through the film thickness could generate undesired deformation for SiC microstructures.

In the standard 3C-SiC growth, a thin carbonization layer can help to relieve the lattice mismatch and thus high quality 3C-SiC/Si layers are commonly realized. However, large bending and warping of the structures are still reported, with complex shape depending on the growth recipes. This hinders the following-on wafer level processes..

To assess these key stress and deformation issues, we tested several kinds of pre-growth (carbonization) procedures, adding various amount of SiH_4 to C_3H_8. 3C-SiC layers were grown on (001) and (111) Si substrates by Vapor Phase Epitaxy (VPE) using SiH_4 and C_3H_8, diluted in H_2. The mechanical deformation of the samples was measured by an optical technique called Makyoh, through which 3D deformation maps of the entire wafers were obtained. Curvature radius and stress profiles, parallel and perpendicular to the gas flow direction, were extracted from these maps and compared with those for the different growth conditions. These were correlated to the results of X-Ray Diffraction (XRD) and Raman spectroscopy (RS). XRD was used to check the crystal quality of the layers and, in transmission geometry, to assess whether the observed deformation was plastic or elastic. The 2’’ wafers were mapped in several points with RS and the peak position was related to the residual internal stress.

It was observed that, for the same pre-growth procedures, the substrate curvature (convex, concave) is dependant on the (001) or (111) Si substrate used. In particular, the addition of SiH_4 during carbonization ramp induced increased deformation for SiC/Si(001), while decreased deformation for SiC/Si (111). These results agree with the stress analysis from RS and XRD.