Evaluation of curvature and stress in 3C-SiC grown on differently oriented Si substrates

B.E. Watts\textsuperscript{a}, G. Attolini\textsuperscript{a}, T. Besagni\textsuperscript{a}, M. Bosi\textsuperscript{a}, C. Ferrari\textsuperscript{a}, F. Rossi\textsuperscript{a}, F. Riesz\textsuperscript{b}, L. Jiang\textsuperscript{c}

Email: watts@imem.cnr.it

\textsuperscript{a} IMEM-CNR Institute, Parco Area delle Scienze 37A. 43124 Parma, Italy
\textsuperscript{b} Hungarian Academy of Sciences, Research Institute for Technical Physics and Materials Science, P.O. Box 49, H-1525 Budapest, Hungary
\textsuperscript{c} School of Engineering Sciences, University of Southampton, Highfield, Southampton, SO17 1BJ, United Kingdom

In order to relieve the high lattice strain in 3C-SiC/Si heteroepitaxy it is common to deposit a thin carbonization layer using C\textsubscript{3}H\textsubscript{8}. However, large bending and wafer warp are still reported, with complex shapes depending on the growth recipes and on reactor geometries. This problem hinders the subsequent wafer processing, such as photolithography and micromachining.

To assess issues that cause deformation, different kinds of pre-growth procedures were investigated, involving the addition of SiH\textsubscript{4} to C\textsubscript{3}H\textsubscript{8} during the temperature ramps used for the carbonization and while heating to the growth temperature. 3C-SiC layers were deposited on (001) and (111) Si substrates by vapor phase epitaxy using SiH\textsubscript{4} and C\textsubscript{3}H\textsubscript{8} diluted in H\textsubscript{2}. The mechanical deformation of the samples was measured by an optical technique called Makyoh, which creates 3D maps of the entire wafers (fig. 1). Each step of the growth, including bare substrates, thermal etching, carbonization and epitaxial film was evaluated with Makyoh.

Curvature profiles for the different growths were extracted from the 3D maps and curvature radius was calculated (fig. 2). The stress profiles were calculated from the thickness of the film, using the Stoney formula. These were correlated to the results from X-Ray Diffraction (XRD) and Raman spectroscopy. XRD was used to check the crystal quality of the layers and by using it transmission geometry it was possible to verify the presence of a residual strain in the wafer, then to assess whether the observed deformation was plastic or elastic. The 2” wafers were mapped in several points with Raman and the peak position was related to the residual internal stress. For the same pre-growth procedures, the substrate curvature (convex, concave, saddle) depends strongly on the orientation of the substrate, (001) or (111), being generally lower for (111) substrates. Moreover, the addition of SiH\textsubscript{4} during the carbonization ramp from 400°C to 1100°C increased the deformation for SiC/Si(001) and decreased it for SiC/Si (111) with respect to the carbonization performed without SiH\textsubscript{4}.

Thermal stress generated while cooling after growth is unable to explain the different kinds of curvature observed. Even the stress due to lattice mismatch may not be sufficient to explain the observed behaviour, and alternative mechanisms and
phenomena could be present and should be eventually considered in order to clarify the measured curvature shapes [1].

Fig. 1: deformation map obtained on a 3C-SiC/Si (111) layer using a carbonization with 2 sccm SiH$_4$ in temperature ramp.

Fig. 2: curvature radius obtained from the map shown in fig.1 in the flow direction.