In–situ Strain Control in Epitaxial Silicon Carbide Compound Semiconductor

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We report about strain control for the highly mismatched heteroepitaxy of cubic silicon carbide on silicon (3C–SiC/Si) only by changing carbon to silicon atomic ratio of precursors (C/Si) during growth. Residual strain in an epilayer grown on a foreign wafer refers to elastic distortion of crystal lattice under intrinsic stress gradient; and leads to defects and curvatures, upon relaxation. Large amount of research has been dedicated to understanding and reduction of defects in 3C–SiC/Si, but very little to curvature (strain–stress) in these thin films. Defects are harmful for application of a semiconductor material in electronics. However, curvature, devastating for wafer processing and devices fabrication, could be beneficial for niche micro electro mechanical systems (MEMS) applications. Resonators are one such example where knowledge about direction and magnitude of strain is vital.

Recently, there was renewed interest in the issue via introducing high levels of (aluminium) dopants into epilayers [1, 2] or change of substrate orientation (from 001 to 111) [3, 4]. These works are short of independent investigation of material system in terms of fabrication, and drift away from the original idea of 3C-SiC/Si(001) material system.

Our studies show that while Si–rich conditions enhance growth and generate positive curvature (tensile strain), C–rich suppress growth and produce negative curvature (compressive strain). An optimum region also emerges with virtually no strain and superior crystal quality. This evolution is hypothesized to be due to structural defects generated within the epilayer during growth. The defects are impactful enough to transform mechanical properties, but not to fundamentally change monocrystalline character. We postulate that as C/Si atomic ratio rises, so does the C content incorporated into crystal lattice. Our findings are significant for the knowledge of heteroepitaxy involving 3C–SiC/Si and may be extended to other compound semiconductors with lattice mismatch, such as GaN and AlN.

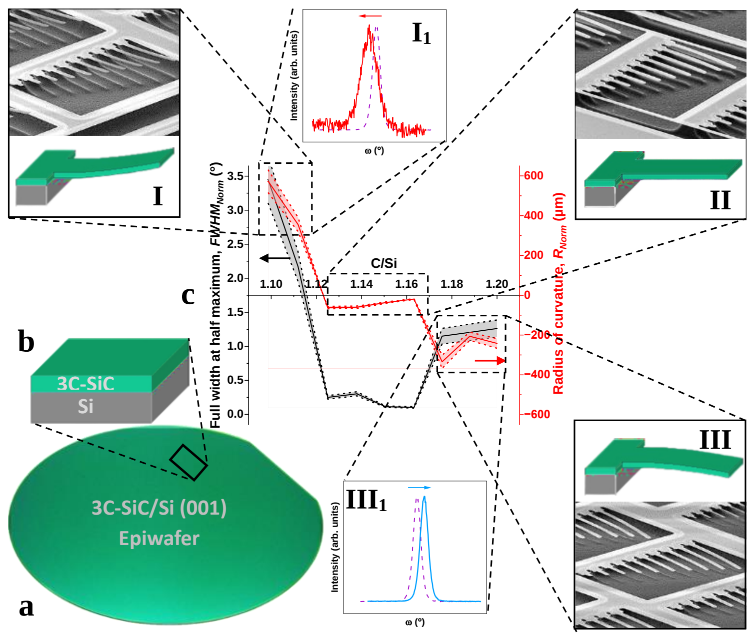

Fig. 1. (a) photograph of actual 3C–SiC/Si (001) epiwafer grown in house for this study. (b) Schematic of a standard sample, cleaved parallel to the large wafer flat, from which the cantilevers were fabricated. (c) Graphs of full width at half maximum (*FWHM*) for ω rocking curves (left Y–axis) and radius of curvature (*R*) (right Y–axis), both superimposed as a function of C/Si. I, II and III Insets show scanning electron microscopy (SEM) images of cantilever arrays with states of curvature in tensile, zero and compressive, respectively. I_1 and III_1 Insets present rocking curves shifted to lower angles (uniform tension), and higher angles (uniform compression), respectively.

References

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