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Highly perfect thin films of SiC: X-ray double crystal diffractometry and X-ray double crystal topographic study

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Abstract

The structure, strain and defect density of SiC thin films epitaxially deposited on 6H-SiC (0001), Si(111) and Si(001) from the single-source organosilane precursor silacyclobutane (c-$C_3H_6SiH_2$) were determined by X-ray double crystal diffractometry and topographic methods. All the films grown on Si were found to be 3C-SiC type. The films grown on 6H-SiC (0001) at 800 to 1000°C were found to be 3C-SiC type, whereas the films grown on 6H-SiC (0001) at 1100°C were a mixture of 3C, 4H and 6H polytypes of SiC. All the films grown on Si had very high defect densities. However, the defect density was reduced by a factor of 10^4 for the films of similar thickness on 6H-SiC (0001), with the film grown at 900°C being the optimum one exhibiting structural properties nearly equal to those of the substrate.

Keywords: Chemical vapour deposition (CVD); Epitaxy; Silicon carbide; X-ray diffraction

1. Introduction

SiC, with its superior physical properties [1], is a potentially useful semiconductor material for various devices [2] requiring a wide bandgap energy, high breakdown electric field, high thermal conductivity, etc. The heteroepitaxial growth of SiC on Si substrate using conventional CVD reactors has yielded high-quality thin films with the 3C cubic crystal structure [3]. This enables the construction of devices which combine the wide bandgap semiconductor properties of SiC with the well developed technology of Si, such as SiC–Si wide-gap emitter heterojunction bipolar transistors [4].

However, epitaxial growth of (111) 3C-SiC on c-plane (0001) 6H-SiC is the material system of choice because of the very small ($<0.1\%$) lattice mismatch between the film and substrate. In addition to providing 3C-SiC epilayers for homojunction applications, the growth of 3C-SiC on 6H-SiC also produces a junction with a 0.7 eV bandgap energy difference for heterojunction device application. Previously, 3C-SiC has been grown epitaxially on Si and 6H-SiC(0001) at high temperature (>1300 °C) [5–12]. Reduction of the growth temperature is an important goal in the fabrication of SiC devices in order to reduce the defects caused by high-temperature processing. The successful growth of crystalline 3C-SiC films on Si and 6H-SiC substrates at relatively lower temperatures (700–1150 °C) has been reported earlier [13–18].

The 6H polytype (0006) and zincblende (111) stacking planes in SiC have the same lattice spacing. Therefore the standard θ–2θ X-ray diffraction scan cannot distinguish between these structures since it measures only the lattice spacings parallel to the surface. In the present study, the polytype, structure, stress and defect concentration in the SiC thin films grown on Si and SiC substrates at reduced temperatures (700–1100 °C) were characterized using X-ray double crystal diffractometry and X-ray double crystal topographic techniques [19,20]. The thin films were grown using a rapid thermal (RT) chemical vapor deposition system. The advantages of X-ray characterization over other analytical techniques are its large field of view, non-destructiveness and speed. The X-ray double crystal topographic method is capable of recording individual topographs from the film and substrate, has high resolution, with the ability to reveal small defect concentrations in highly perfect crystals.

2. Experimental

The substrates used in the experiments were on-axis n-type Si(001), Si(111) and 6H-SiC(0001). The deposition exper-

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