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Unusual defects in silicon carbide thin films grown by multiple or interrupted growth technique

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Abstract

This paper discusses the growth and characterization of 3C-SiC films on Si (1 0 0) and (1 1 1) substrates using hexamethyldisilane (HMDS) as the source material in a resistance-heated furnace as well as the formation and microstructure of various types of unusual defects. Apart from common triangular and square voids, some unusual shaped voids like hexagonal, truncated octahedron, etc. and some irregular features (like hockey stick or pipes) were observed regularly, which are related to voids. SiC whiskers and wires with a wide range of diameters (nm to μm) were formed inside cracked regions as well as within voids. Optical microscopy, scanning electron microscopy (SEM) and Raman spectroscopy were used to study these features.

Keywords: 3C-SiC; Defects; HMDS; CVD; Interrupted growth; Voids; 3C-SiC nanowires

1. Introduction

3C-SiC thin films are of interest for power devices and high temperature electronics as well as for high frequency and optoelectronic devices [1]. After growth of SiC, the main defects observed in the Si substrate in the vicinity of the SiC/Si interface are voids [2]. Chemical vapour deposition (CVD) is most commonly used, and relatively convenient for producing 3C-SiC films on Si substrates. SiC whiskers and rods are also formed in and near defects during this process. 3C-SiC nanostructures (nanorods, nanowires, nano-whiskers, etc.) have also been shown to exhibit more superior properties than bulk [3].

This paper will discuss the growth and characterization of 3C-SiC films on Si (1 0 0) and (1 1 1) using HMDS in a resistance-heated furnace as well as formation and microstructure of various types of unusual features like voids, whiskers, etc.

2. Experimental

Atmospheric pressure chemical vapour deposition (APCVD) of 3C-SiC was carried out on Si (1 1 1) and (1 0 0) substrates in a hot wall reactor using a resistance-heated furnace (ELECTROHEAT EN345T). Single crystalline Si (1 1 1) or Si (1 0 0) wafers (p-type) were used as substrates. Hydrogen was used as the carrier gas and argon was used for purging. Propane was used for preliminary carbonization just before growth. For actual growth, organo-metallic source HMDS was used as the single source for both Si and C. Growth temperature was varied from 1150 to 1250 °C and the growth period was varied from 1 to 2 h or more, as required. Due to the use of a resistance -heated hot wall furnace, maximum deposition takes place on the hot wall of the reactor resulting in very slow growth rate on the substrates. To grow thicker films, multiple or interrupted growth technique was adopted. For multiple growth, after each growth, the system was cooled down to room temperature and after that, regrowth was carried out on the same sample under the same conditions. This technique was repeated two or three times. The thickness of the film for 2 h growth is ~0.5 μm.

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After growth, the films together with various defects have been characterized using optical microscopy (LEICA DM LM), SEM (JEOL JSM 5800 Scanning Microscope), and Raman spectroscopy (RENISHAW RA1000B LRM).

3. Results and discussion

3.1. Optical microscopy

Optical microscopy was used to study the surface morphology and to identify defects. Fig. 1(a) and (b) shows the optical micrograph of a sample grown on Si (1 1 1) substrates at 1250 °C. Similarly, Fig. 1(c)–(f) shows the optical micrographs of the films grown on Si (1 0 0) substrates at the same temperature. Voids are observed in all cases due to localized out diffusion of Si atoms at high temperature. It was observed that the shape of voids is approximately triangular on Si (1 1 1) substrates and square on Si (1 0 0) substrates and they were usually faceted with their walls parallel to {1 1 1} planes [4]. Fig. 1(a) is the optical micrograph of regular triangular voids formed on Si (1 1 1) substrate and the growth was performed at 1250 °C for 1 h. In Fig. 1(b), in addition to perfect triangular voids, some voids are hexagonal and some are intermediate between them indicating how hexagonal voids are created from triangular ones. This sample was grown at 1250 °C for 2 h. Thus it may be stated that as the growth time increases, triangular voids gradually become hexagonal in nature on Si (1 1 1) substrates due to truncation to minimize the surface energy. In case of SiC growth on Si (1 0 0) substrates the shape of the void is square, in general (Fig. 1(c)). This sample was grown for 1 h. Inset of Fig. 1(c) is the SEM image of a square void showing the faceting

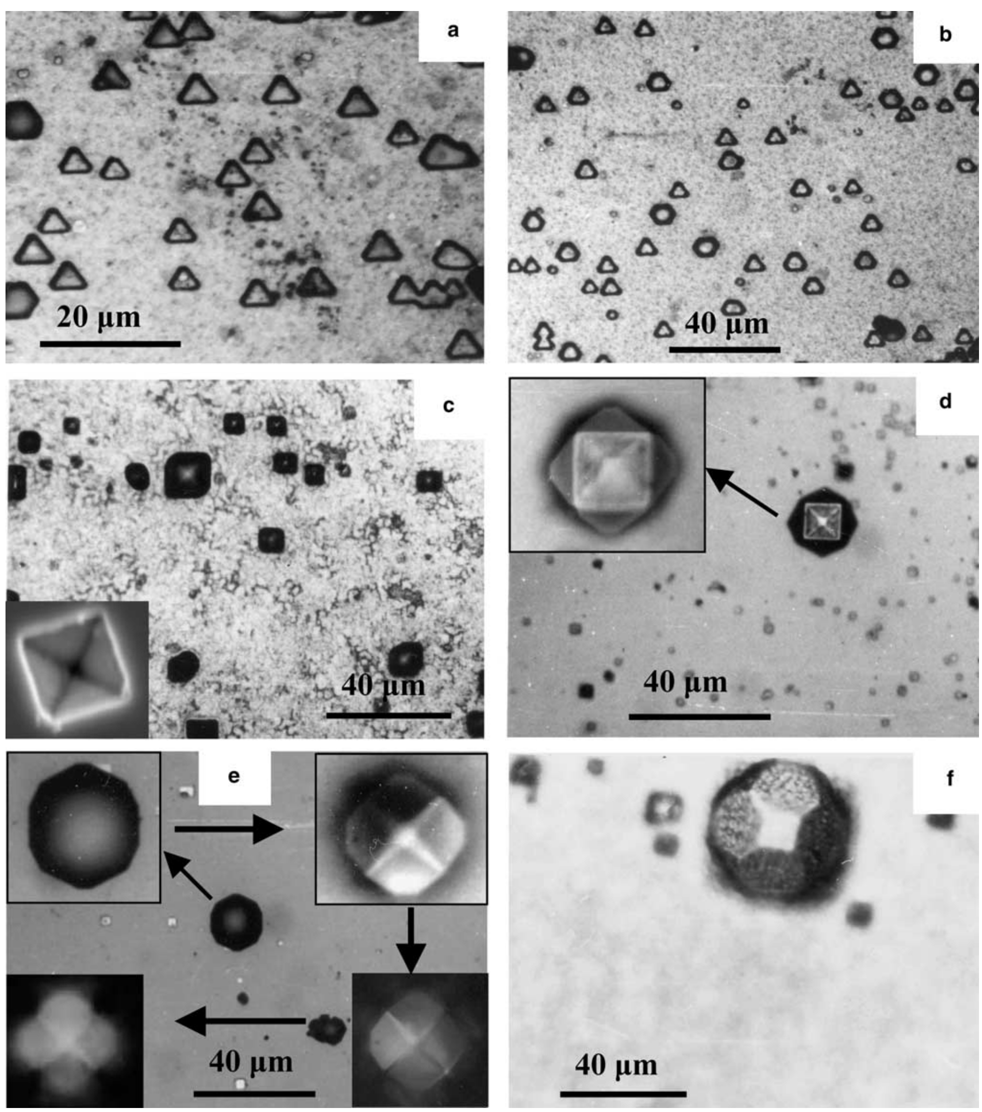

Fig. 1. Optical micrograph of different types of voids formed during the growth of 3C-SiC thin films on Si (1 1 1) (a,b) and Si (1 0 0) (c)–(f) substrates (inset of (c) is the SEM image of a square void showing triangular facets and inset of (d,e) are the optical images of the void at different focusing depths showing the faceting of the void).