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Materials Science in Semiconductor Processing 9 (2006) 275–278
MATERIALS SCIENCE IN SEMICONDUCTOR PROCESSING

Morphological defects and uniformity issues of 4H-SiC homoepitaxial layers grown on off-oriented (0 0 0 1) Si faces

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Available online 28 February 2006

Abstract

The morphological defects and uniformity of 4H-SiC epilayers grown by hot wall CVD at 1500 °C on off-oriented (0 0 0 1) Si faces are characterized by atomic force microscope, Nomarski optical microscopy, and Micro-Raman spectroscopy. Typical morphological defects including triangular defects, wavy steps, round pits, and groove defects are observed in mirror-like SiC epilayers. The preparation of the substrate surface is necessary for the growth of high-quality 4H-SiC epitaxial layers with low-surface defect density under optimized growth conditions.

Keywords: 4H-SiC; Homoepitaxial layers; Surface morphological defect; Optical microscopy

1. Introduction

It has been shown that major requirements for SiC epitaxy are good morphology, high-purity, low-defect density, wide-range and abrupt doping control, thickness and doping uniformity, and high-growth rate [1]. Because SiC has many polytypes, such as 4H-, 6H-, and 3C-SiC, polytype control is the key issue in SiC epitaxial growth. The growth on off-oriented SiC {0 0 0 1} substrates by chemical vapor deposition (CVD) utilizing step-controlled epitaxy [2–4] at around 1500 °C is the standard technique to produce device-quality epilayers. In this process, growth occurs at steps rather than at sites of two-dimensional nucleation on atomically flat terraces between steps or at other unwanted nucleation sites caused by defects or contamination.

In this paper, we report on the surface morphological defects and uniformity of 4H-SiC epilayers grown on off-oriented (0 0 0 1) Si faces by using atomic force microscopy (AFM), Nomarski differential interference contrast (NDIC), and micro-Raman spectroscopy.

2. Experimental

The epilayer growth experiments were carried out in a low-pressure CVD system that has been described previously [5]. The substrate surface preparation is the critical step to ensure an optimized morphology after the epitaxial growth. During etching and growth, the H_2 carrier gas flow was maintained at 3 SLM. The typical growth temperature is around 1500 °C with a pressure of 40 Torr. Prior to growth, the substrates were typically subjected to a 30 min H_2 etch in order to remove unintentional contamination and to reduce

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doi:10.1016/j.mssp.2006.01.080

the surface damage caused by the wafer cutting and polishing process. The morphological defects were characterized by NDIC and AFM. The origin of the morphological defects was also studied using molten KOH etching at a temperature of 500 °C for 6 min.The crystal structure and quality of selected epilayers were determined by micro-Raman scattering measurements in back-scattering configuration.

3. Results and discussion

Fig. 1 shows the typical surface defects, namely triangular defects, protrusions and grooves observed on 4H-SiC epilayers. It can be seen that the triangular defect is the in-grown stacking fault characterized by a right-angled-triangle or isosceles shape (as shown in the inset in Fig. 1(a)) along the off-cut direction [11–20]. At the top corner of the ‘‘triangular defect’’, a structural defect was found. The AFM image of triangular defect as shown in Fig. 1(b) shows that triangular defect originates from a micropipe or a deep-hole defect. This means that the epilayer inherits both the structure and the defects of the substrate in the growth of SiC on off–oriented substrates. The protrusions shown in Fig. 1(c) originate from the scratch line left on the substrate surface after wafer polishing. Fig. 1(d) shows the groove defects. It can be clearly observed that there is a structural defect at the end of up-step side of the groove defect. Obviously, the groove defects originate from the substrate surface defect. It can be concluded that these surface defects are induced by the structural defects on substrates. To eliminate these defects, the preparation and pregrowth of substrate surface have to be optimized further.

The surface defects of n-type 4H-SiC epilayers grown on both n- and p-type substrates were investigated by KOH etching. Fig. 2 shows the Nomarski optical micrographs of 4H-SiC epilayers after molten KOH etching at 500°C for 6 min grown on both p- and n-type substrates. The distribution of etch pits is random. According to the shape, size and direction of the etching pits, it can be identified that threading edge dislocations (TEDs)[6], screw dislocations (SDs)[1] and basal plane dislocations (BPDs)[7] existed in the 4H-SiC epilayer grown on

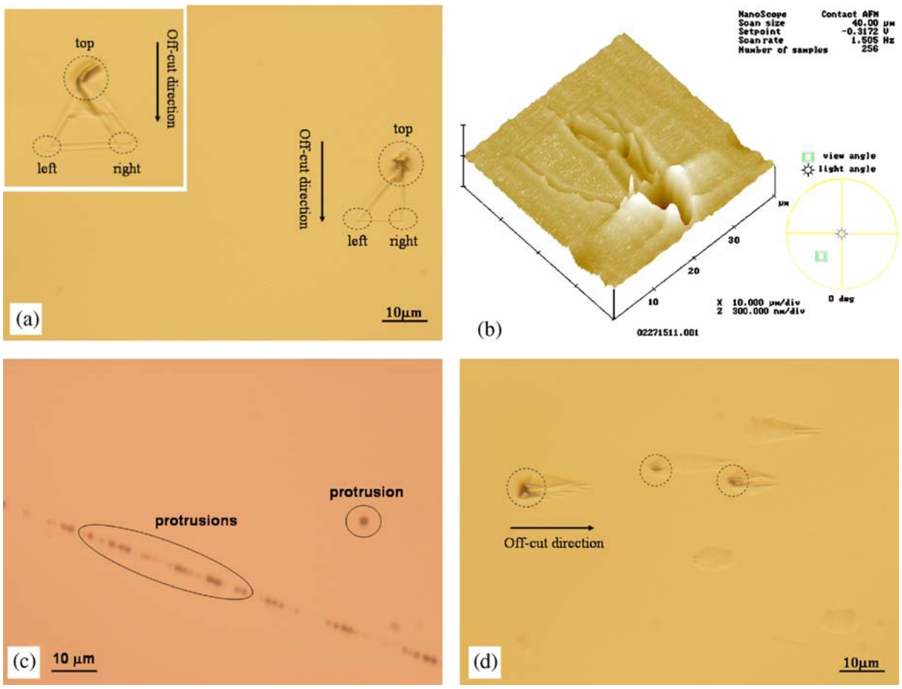

Fig. 1. NDIC and AFM images of the morphological defects of 4H-SiC epilayers. The triangular defect in (a) is the in-grown stacking fault characterized by a right-angled-triangle and/or isosceles shape along the off-cut direction [11–20]. The AFM image of triangular defect in (b) shows that triangular defect originates from a micropipe or a deep-hole defect. The protrusions in (c) originate from the scratch line left on the substrate surface after wafer polishing. The groove defects in (d) originate from the substrate surface defect, and a structural defect was clearly observed at the end of up-step side.