MORPHOLOGY AND STRUCTURAL INVESTIGATION OF SILICON CARBIDE LAYERS FORMATED BY SUBLIMATION

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Abstract: Thin films of silicon carbide (SiC) were grown by sublimation epitaxy in vacuum on the 6H-SiC substrates. Structural properties of the initial substrates and the epilayers were studied by both electron-diffraction and X-ray diffraction methods. Electron-diffraction measurement gives the confirmation of the crystallinity of obtained layers. Experimental results show that a lattice perfection of epilayer is equal to that of monocrystalline substrate. These results are also validated by scanning probe microscopy. So, this technology of fabrication of SiC thin films allows carry out a treatment of initial substrate defects in dependence of the process conditions.

Keywords: structural properties, lattice perfection, epilayer, substrate, epitaxy

1. INTRODUCTION

The use of classical semiconductor materials (Si, Ge, A^3B^5, A^2B^6) is not effective because of their low temperature, pressure and radiation resistance in view of an application field expansion of present-day microelectronic devices with stable parameters in extreme conditions.

Today, there is a large demand in active components on the basis of thin layers of wide band gap semiconductors, persistent thin-film coatings in industrial electronics. One of these materials is silicon carbide (SiC), which exists in about 250 crystalline forms [1]. It is widely used in high-temperature/high-voltage semiconductor electronics. Nevertheless a major problem for SiC commercialization has been the elimination of defects: edge dislocations, screw dislocations (both hollow and closed core), triangular defects and basal plane dislocations. Therefore, a formation of coatings on the basis of SiC with high chemical inertness, radiation resistance, homogeneity, uniformity, durability, mechanical strength and good adhesion to range of material is of great interest at present days [2].

Epilayer or epitaxial layer is a single crystal layer formed on top of a single crystal substrate. An epitaxial layer will typically have a different doping level and or type than the substrate upon which the epitaxial layer is formed. In some cases the epitaxial layer may be a completely different type of material than the substrate upon which it is grown. If the substrate and the epitaxial layer are both the same element or compound then the process is homoepitaxy and if the epitaxial layer and the substrate are different elements or compounds then the process if hetroepitaxy. see also, crystalline.

2. EXPERIMENTAL RESULTS

High-temperature vacuum device was used for growing of SiC layers on the 6H-SiC substrate by sublimation sandwich method. This method allows obtain an epilayer - a region of epitaxially-grown material that forms a layer on the surface of a semiconductor body (Fig.1). A straight pipe of compact chemical clean graphite is used as heating spiral in the technological device. There is a multilayer shielding system of graphite tissue and felt for heating concentration and creation of defined temperature gradient around the heater.

Growth cell (crucible) is inside of storm proof graphite container which is inside a heater. The crucible material is zirconium carbide. It allows obtain the layers with predictable stoichiometry and high structural perfection.

Silicon carbide plates of 6H polytypic having n-type conductivity and containing uncontrolled impurities Nd-Na = $6 \cdot 10^{17} \div 3 \cdot 10^{18}$ cm^{-3} were used as substrates. The cleaning and preparation of substrate surface has been considered as main characteristic steps of fabrication. In order to remove defective layers after grinding and polishing, the substrates were chemically etched in the KOH at 750 K during 20 min. Then they were washed many times in distilled water in order to remove residuum of KOH. Right before a process the substrates were washed in ethanol and dried.

The plate of 6H-SiC monocrystal was studied by scanning tunneling microscopy with measurement head ST020NTF (NT-MDT) with range of current ±100 pA (Fig.2). The result of interatomic spacing is corresponding to the theory [3]. But such order of grown crystals is not typical on large areas because of influence of growth processes which forms a large amount of different types of surface imperfections.

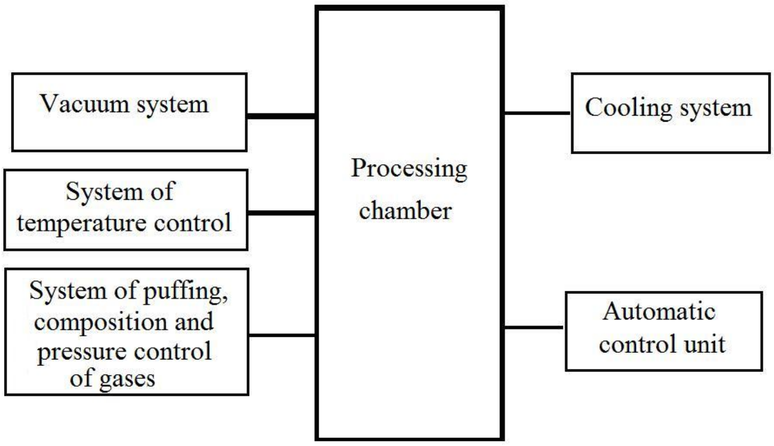

Figure 1: Structure chart of high-temperature device for SiC growth by sublimation sandwich method.

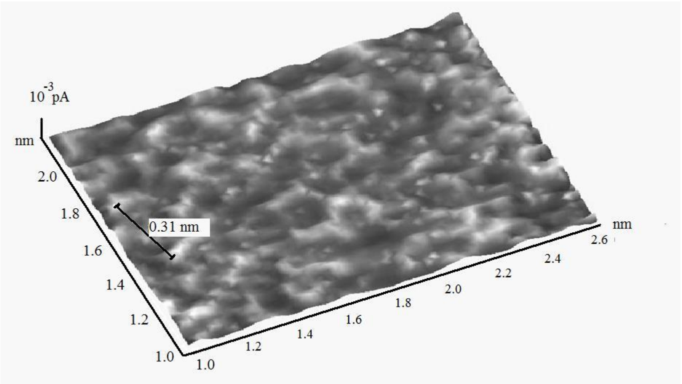

Figure 2: STM-image of 6H-SiC monocrystal surface.

Films of SiC had the thickness from tens of nanometers up to units of micrometers and for fast tests the Linnik interferometer MII-4 was used which allows defining the thickness of layers by shift of interference fringes connected with reflection from upper and bottom plates with max.10% errors. Diffraction pattern of the SiC film is be characterized by two pronounced peaks (doublet $K_{\alpha 1}$ and $K_{\alpha 2}$) at $2\theta = 133.3^{o}$ and 133.9^{o} angles. Their appearance is connected with the fact that even after filtering the CuK_{α} radiation is not monochromatic. There are two wavelengths $\lambda_{\alpha 1} = 1.54051$ Å and $\lambda_{\alpha 2} = 1.54433$ Å in radiation and generally at large angles doublet $K_{\alpha 1}$ and $K_{\alpha 2}$ is registered (at sufficient resolution of the spectrograph). Parameters calculated by this diffraction pattern are c = 5.1164 Å and a = 3.083 Å and matched with known parameters for 6H-SiC (Fig.3).

In order to study structural perfection, the X-ray rocking curves were measured from substrates and epitaxial film. The spectra slightly differ. This means that perfection of obtained films and substrates is almost similar (Fig.4).

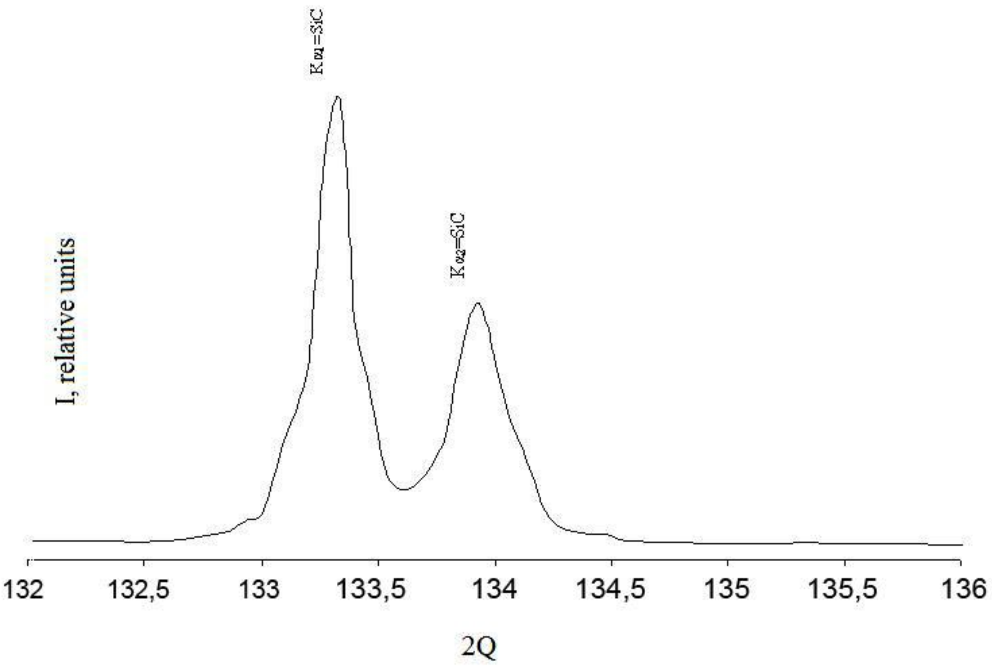

Figure 3: Diffraction X-rays on SiC film.

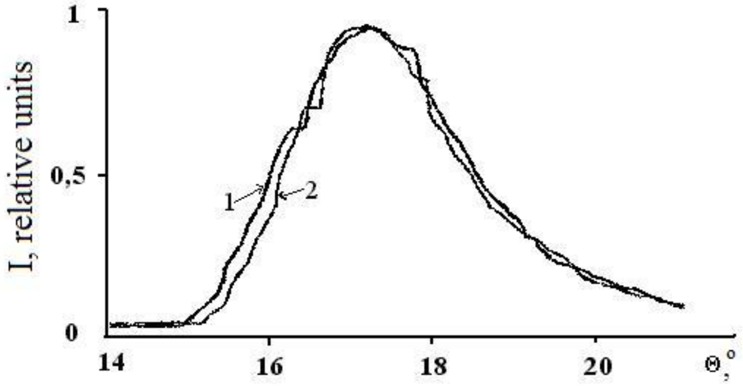

Figure 4: X-ray rocking curve of SiC film (1) and SiC substrate (2)

Structural features were also measured by diffraction fast electrons. In Figs. 5 and 6 the point electron diffraction patterns are shown. The point reflections confirm the monocrystallinity of the films.

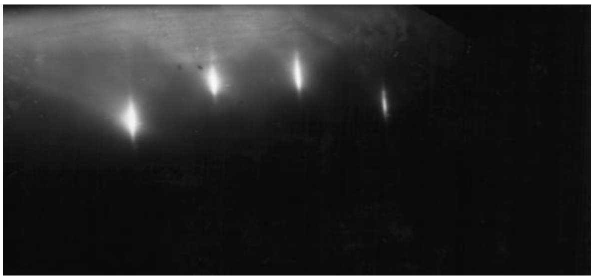

Figure 5: Electron-diffraction of monocrystalline 6H-SiC substrate.

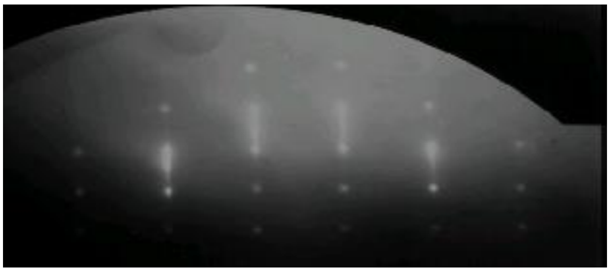

Figure 6: Electron-diffraction of monocrystalline SiC film.

The atomic-force microscopy also confirms the monocrystalline structure of the films. But in some places the micropores have been observed. These micropores are caused by imperfection of the substrate (Fig. 7), but the micropores have disposition to overgrowing with growth of film thickness (Figs. 8a, 8b).

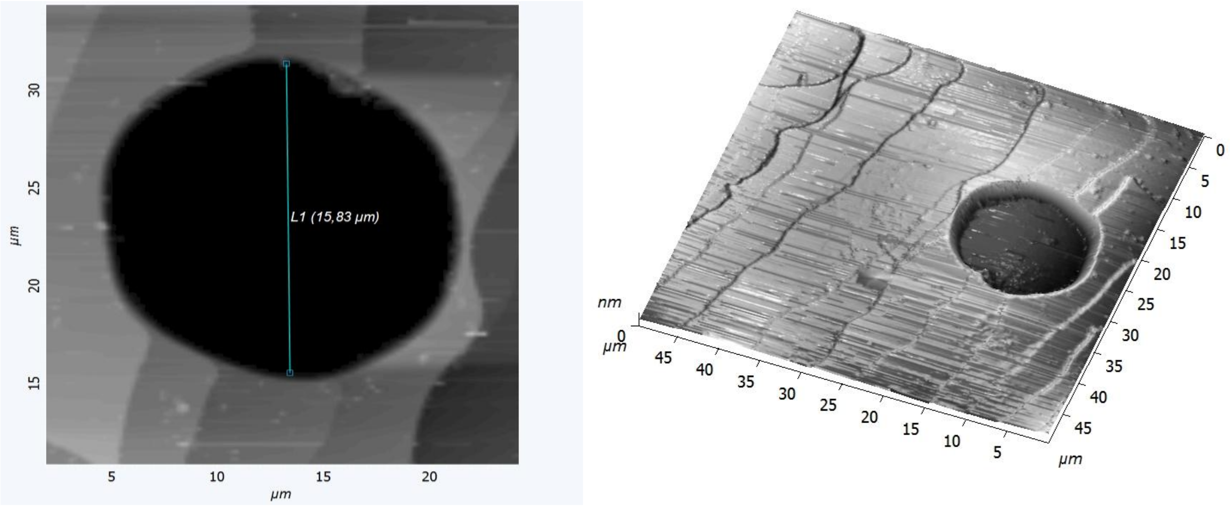

Figure 7: Micropore of SiC film with depth 293 nm**.**

On the basis of Figs. 8 the tolerance of polishing (0°24.06′) has been calculated, which shows the deviation of the processed wafer from the crystallographic direction (0001).

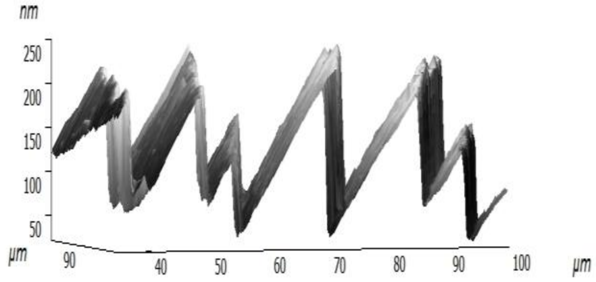

Figure 8a: AFM-image of SiC film (scan size 25x25 μm)

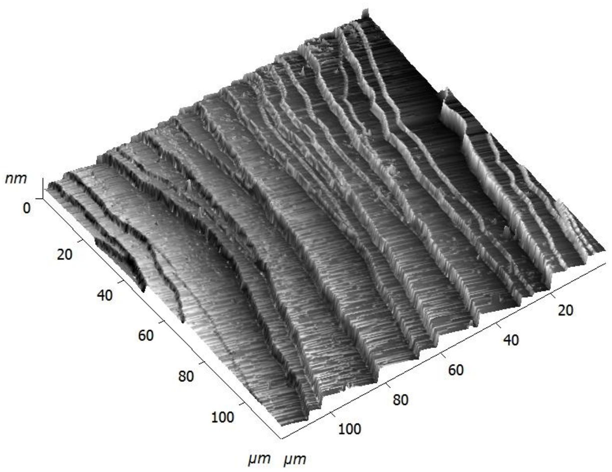

Figure 8b: AFM-image of SiC film (scan size 120x120 μm). Average roughness = 81,4107 nm.

CONCLUSION

Thus, thin films of SiC are grown up by sublimation epitaxy in vacuum on the 6H-SiC substrates with thickness from tens of nanometers up to units of micrometers. Fashioned films are quite uniform in surface and volume. The crystal properties of the wafers and epitaxial layers are studied by electron diffraction investigation, X-ray techniques, and scanning probe microscopy. X-ray rocking curves show that structural perfection of SiC films is comparable with the structural perfection of monocrystalline 6H-SiC substrates. Calculated lattice parameters (c=5,1164 Å, a=3,083 Å), of epilayer by X-ray diffractometry also match with known values for 6H-SiC. Electron-diffraction measurement gives the confirmation of the crystallinity of the obtained layers and it is also proved by scanning probe microscopy. This technology allows making of defect treatment of the wafer in dependence on epitaxial conditions.

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