

Effect of por-SiC buffer layer on the parameters of thin Er₂O₃ layers on silicon carbide substrates

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Abstract. Using optical absorption and Auger spectrometry techniques, we studied the effect of rapid thermal annealing (RTA) on the properties of erbium oxide films deposited onto a porous silicon carbide buffer layer formed on 4H-SiC substrates. An analysis of atomic composition of the films under investigation as a function of RTA duration was performed. It is shown that phase composition of erbium oxide films on silicon carbide substrates with a porous SiC layer can be changed by varying RTA duration.

1. Introduction

High thermal stability, big values of permittivity and relative simplicity of growing process for films of a number of rare earths oxides make them promising for preparation of isolating layers in microelectronic circuits. So development of high-quality stable dielectric layers (in particular, those based on erbium and dysprosium oxides) makes an up-to-date problem in silicon carbide-based high-temperature electronics.

It is known that, in the course of further high-temperature technological process, structural defects of a semiconductor substrate penetrate a thin film growing on that substrate. This can substantially impair the device characteristics. One of the ways for reduction of the above effect is formation of a porous interlayer between the substrate and epitaxial layer [1, 2]. To illustrate, layers of porous silicon carbide (por-SiC) are used to decrease defect concentration at the porous layer-epitaxial film interface in composite structures [2-6], and porous InP and GaAs layers are applied to obtain quite unstrained autoepitaxial films on them [7, 8].

The object of the present work is investigation of the features of formation of 4H-SiC/por-SiC/Er₂O₃ structure in which por-SiC serves as a buffer layer between Er₂O₃ film and silicon carbide substrate.

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2. Samples and measurement techniques

As a first step in obtaining SiC/por-SiC/Er₂O₃ structure, we formed a por-SiC layer on the silicon carbide substrate. Porous surface of silicon carbide was obtained using electrochemical etching in the HF:C₂H₅OH = 1:1 solution for 10 min.; the current density was 10 mA/cm². After this, before deposition of rare-earth element, pore opening was made in KOH melt at a temperature of 550°C. Formation of Er₂O₃ film was performed in several technological steps. Firstly an erbium film was deposited onto the por-SiC surface with thermal spraying. Then the specimens were annealed in the vacuum at a temperature of 800°C for 8 min. After this the specimens were subjected to rapid thermal annealing (RTA) at 400°C for 1, 3 and 5 s.

An analysis of atomic composition of the structures under investigation was made using the Auger electron spectroscopy technique at layer-by-layer etching of the specimens by 1 keV argon ions. The specimens were studied using an instrument system LAS-2000 (Riber, France) with a cylindrical mirror spectrometer. The transmission spectra were registered with a ДФC-24 spectrometer at room temperature.

3. Results and discussion

Earlier [9-10] we considered the features of erbium oxide formation on crystalline 6H-SiC substrates by RTA at 350°C for 1, 3 and 5 s. It was found [9-10] that a thin (~100-150 nm) Er₂O₃ layer is formed on the 6H-SiC substrate in the course of RTA. An increase of RTA duration leads to increase of layer thickness and promotes formation of stoichiometric erbium oxide. The specimen surface was investigated with a scanning electron microscope (SEM) S-4800 (Hitachi, Japan).

Figure 1 presents a SEM image of porous surface. One can see that diameter of pores in the buffer por-SiC layer is ~30 nm.

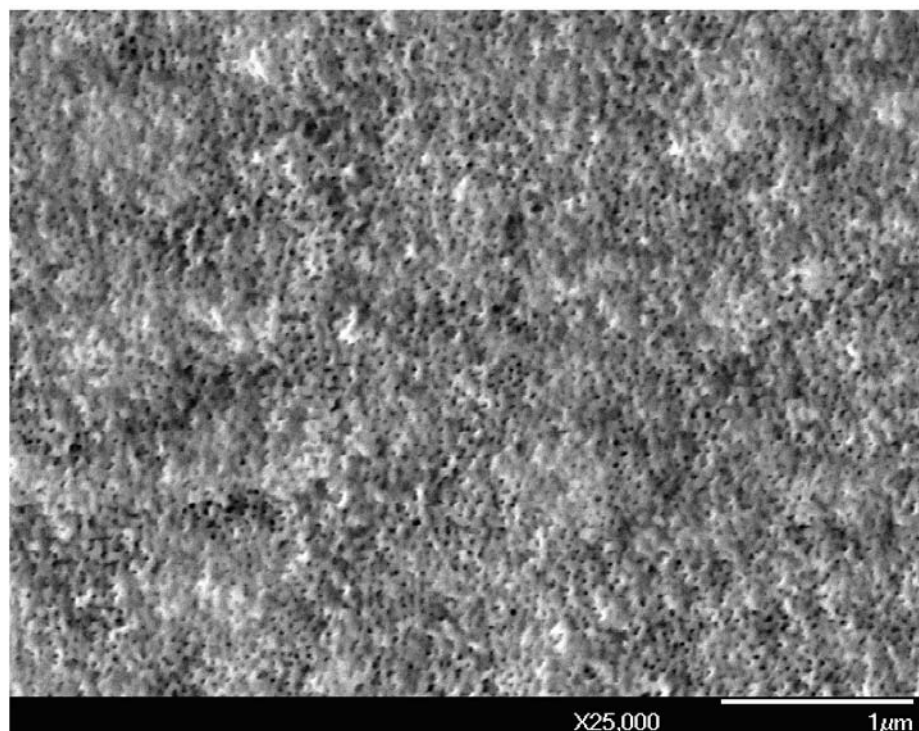


Figure 1. SEM image of porous surface .

Shown in Fig. 2 are SEM images of Er_2O_3 films subjected to RTA for 1 and 5 s. One can see from Fig. 2a that, at RTA duration of 1 s, the erbium oxide film is of island type. The characteristic island sizes lie within 110-500 nm. As RTA duration is increased, the film structure becomes more uniform (Fig. 2b).

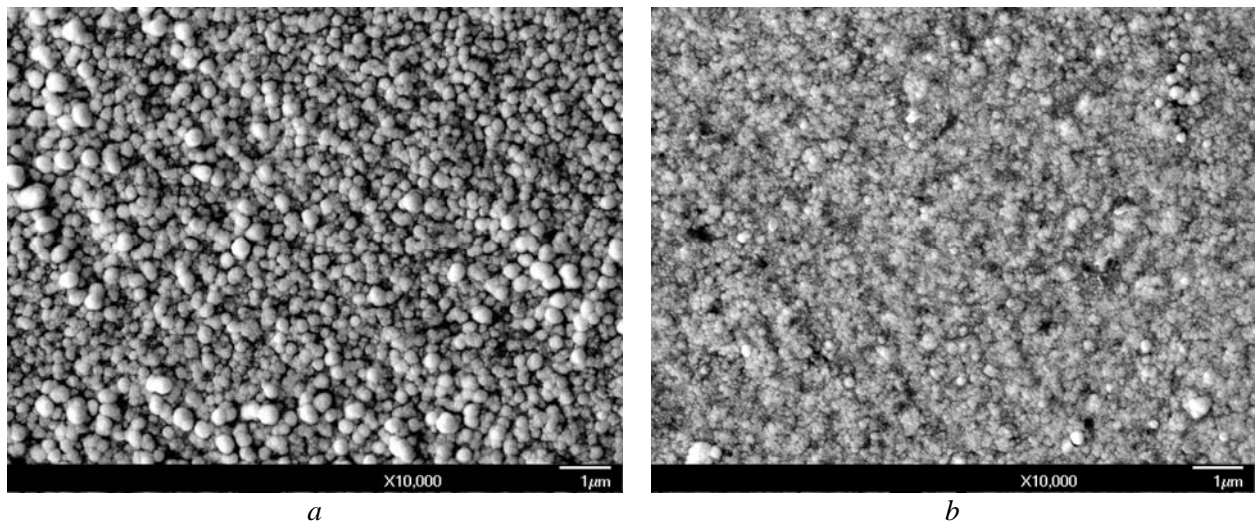
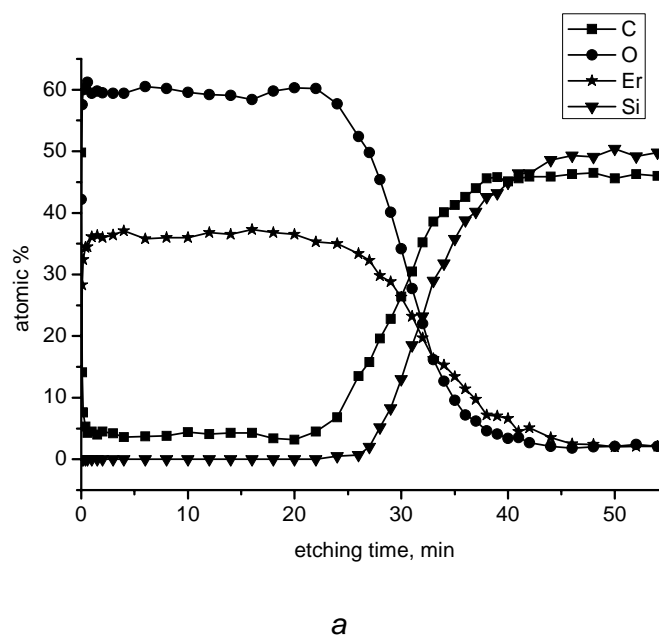


Figure 2. SEM images of erbium oxide film surface. RTA duration: a – 1 s, b – 5 s

Figure 3 presents elemental composition of the SiC/por-SiC/ Er_2O_3 structures. An analysis of the elemental concentration depth profiles in those structures obtained with Auger electron spectroscopy showed that the oxide film composition is approaching to stoichiometric one ($N_{\text{O}}/N_{\text{Er}} \approx 1.6\text{--}1.7$) as RTA duration increases. The oxide film thickness was 80-100 nm.



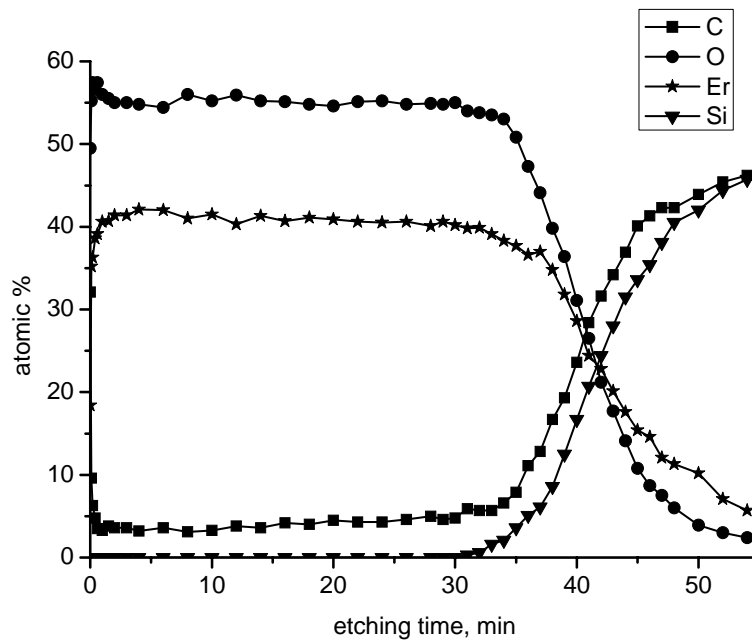
*b*

Figure 3. Elemental contents in the SiC/por-SiC/Er₂O₃ specimens. RTA duration: *a* - 1 s, *b* - 5 s.

Shown in Fig. 4 are optical transmission spectra for the SiC/por-SiC/Er₂O₃ structures. One can see that for those structures (as well as for the 6H-SiC/Er₂O₃ structures [9]) increase of RTA duration results in growth of transmission in the 400-800 nm spectral range. This effect is due to increase of the part of erbium oxide film of stoichiometric composition relative to sub-oxidized metal layer, which is supported by the results of Auger electron spectroscopy.

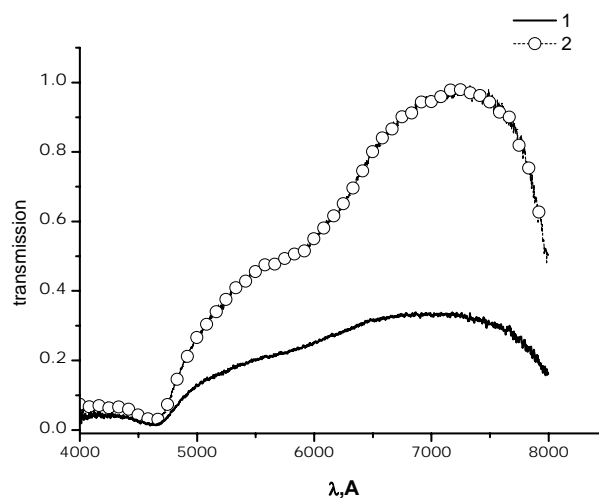


Figure 4. Optical transmission spectra of the SiC/por-SiC/Er₂O₃ structures. RTA duration: *a* - 1 s, *b* - 5 s.

4. Conclusions

So the experimental results obtained by us show that application of RTA makes it possible to form thin layers of stoichiometric erbium oxide on the surface of por-SiC. As RTA duration grows, a clearer por-SiC/Er₂O₃ interface is formed.

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