

Study on Near-interface Structure of Thermal Oxides on 4H-SiC Substrates with FTIR-ATR

Hirohisa Hirai¹ and Koji Kita^{1,2}¹Department of Materials Engineering,

The University of Tokyo

²JST-PRESTO

7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan

1. Introduction

The performance of SiC MOSFET is severely limited by its MOS interface quality. It is often pointed out that slow-traps formed near interface would be one of the origins of the carrier mobility degradation at this interface. In this study we investigated the structures of thermally-grown oxides on 4H-SiC especially focusing on the near-interface region. Fourier transformed infrared spectroscopy (FTIR) is known to be one of the powerful tools to investigate the microscopic structures of ultrathin SiO₂ films, since both TO and LO modes of the Si-O-Si asymmetric stretching vibration are quite sensitive to the structural changes in SiO₂: bond-angle change by intrinsic stress and chemical-state change by sub-oxide formation [1-2]. In this study we applied the FTIR-ATR analysis to the thermally-grown SiO₂ on both Si- and C- faces of 4H-SiC.

2. Experimental

Both Si- and C-faces of 4H-SiC wafers with n-doped ($\sim 1 \times 10^{16} \text{cm}^{-3}$) epitaxial layers were cleaned in HF and oxidized in dry O₂ ambient at 1100°C. The film thickness was successively decreased by repetitive chemical etching with diluted HF. The FTIR-attenuated total reflection (ATR) spectrum was obtained at every step of etching, and the thickness dependence of the spectrum was investigated. For ATR measurement, Ge prism with incidence angle of 45° was employed. The differential spectrum was deduced by subtracting the spectrum of HF-last SiC wafer. The film thickness was accurately determined by using both grazing incident x-ray reflectivity and Si2p x-ray photoelectron spectroscopy.

3. Results and Discussion

For ~30 nm-thick film on Si-face of 4H-SiC, two peaks were clearly observed, as shown in Fig. 1. These peaks should be attributed to the TO and LO modes of Si-O-Si asymmetric stretching vibration, respectively [3]. The intensities of those peaks monotonically decrease by thinning the film down to less than 1 nm. The TO mode peak frequencies in Fig. 1 were constantly observed at around 1076 cm⁻¹, irrespective of the thickness. On the other hand, the LO mode frequency shifts from 1240 cm⁻¹ to 1252 cm⁻¹ by decreasing the thickness from 30 nm to 3 nm. This LO shift will be attributable to a geometrical effect since it coincides with the calculated spectrum for an optical model of SiC/SiO₂/air/Ge stack where a uniform optical properties was assumed for SiO₂ layer. A similar geometrical effect has been also reported for ATR spectrum of SiO₂/Si [2]. Therefore it is reasonable to conclude that the microscopic structure of the thermally-grown oxides on SiC for this thickness region is uniform and almost identical with thermal oxides on Si. A similar result was also reported for thermal oxides on 6H-SiC [4].

By decreasing the film thickness to less than 2 nm, both TO and LO peak frequencies show significant red-shifts. The LO peak shifts are shown in Fig. 2 for both films on Si- and C-faces. These shifts are attributed to the change of microscopic structure of thermal oxides in ultrathin region. Considering the reported analyzing models for the ultrathin SiO₂ films on Si substrate [1-2], there are two

possible factors for the structural change near the interface: formation of sub-oxides (SiO_{2-x}) and decrease of the Si-O-Si bond angle. From these results it is clearly shown that there exists an interface transition layer at thermal oxide/4H-SiC interface, which has different microscopic structure from the bulk SiO₂. The property of this transition layer will be worth analyzing further because the near-interface traps will exist in this region.

It is also found in Fig. 2 that the magnitude of LO peak shift is significantly different between the ultrathin oxides on Si- and C-faces. The peak shifts for the films on Si-face are significantly smaller than those on C-face. This is possibly related with the different electrical properties of MOS interfaces on Si- and C- faces.

4. Conclusions

ATR-FTIR spectra of thermal oxides on 4H-SiC substrates were examined for a wide range of the film thickness. A significant red-shifts of the absorption peaks in ultrathin region indicates that there is an interface transition layer with a different microscopic structure from that of bulk SiO₂. We also found that Si- and C-faces have interface transition layers with different structures.

REFERENCES

- [1] K. T. Queeney et al., J. Appl. Phys. **87**, 1322 (2000).
- [2] S. Miyazaki et al., Appl. Surf. Sci. **113/114**, 585 (1997).
- [3] B. C. Trasferetti and C. U. Davanzo, Appl. Spectroscopy **54**, 502 (2000).
- [4] H. Tsuchida et al., Appl. Surf. Sci. **117/118**, 225 (1997).

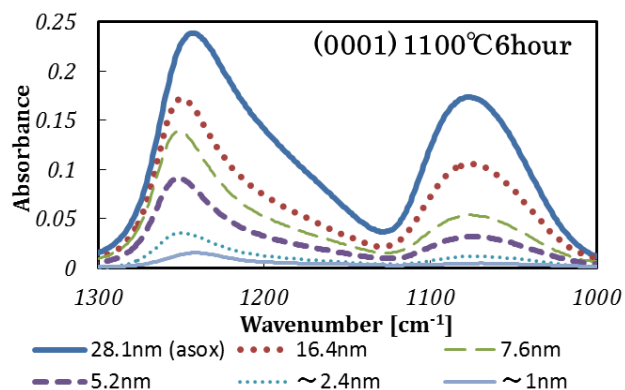


Fig. 1. Change of FTIR-ATR spectra of thermal oxides on 4H-SiC (Si-face), by thinning the film thickness. Absorption peaks for both TO and LO modes were clearly observed for the films in a wide range of thickness.

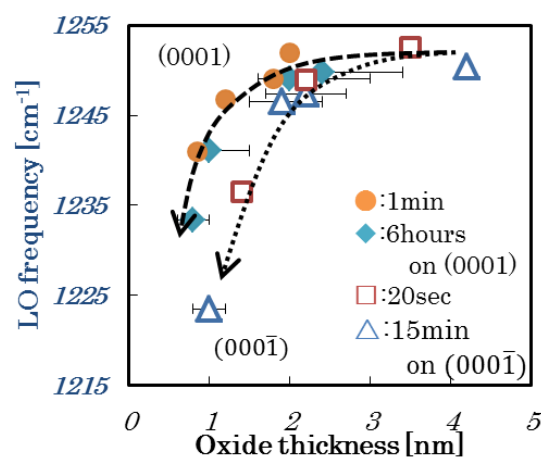


Fig. 2. Red-shift of the LO peak frequency by thinning the thermal oxides on both Si- and C- faces grown at 1100°C, in ultrathin region. The data for the films with different initial thickness are almost on an identical trend, however, the shifts for the films on Si-face (0001) and C-face (000̄1) significantly differ from each other.