Extended Abstracts of the 1999 International Conference on Solid State Devices and Materials, Tokyo, 1999, pp. 132-133

Memory Function of a SiO_2/β-SiC/Si MIS Diode

Kazuyoshi Takada, Masami Fukumoto and Yoshiyuki Suda

Faculty of Technology, Tokyo University of Agriculture and Technology
2-24-16 Naka-cho, Koganei, Tokyo 184-8588, Japan
Phone/Fax: +81-42-388-7129, E-mail: sudayos@cc.tuat.ac.jp

1. Introduction

Metal-insulator-semiconductor (MIS)-structured devices having an electron-tunneling thin oxide layer have been expected to be applied to new functional logic devices and optoelectronic devices by utilizing the electron tunneling behavior caused through the thin oxide layer. Recently, a β-SiC epitaxial layer with high quality has been formed on both Si(001) and Si(111) [1, 2].

In this work, by the use of this epitaxial β-SiC film, we have proposed a new type of a SiO_2/β-SiC/Si MIS diode having a thin oxide layer, with a thickness of less than ~100 Å, formed by oxidizing the β-SiC layer and have investigated the electronic and optoelectronic behavior of the diode. Through this work, we have found a stable memory function in the diode that the resistance is switched from a high value (an off state) to a low value (an on state) and from a low value to high value at threshold applied voltages and their states can be hold. We have also observed luminescence from the diode under the reverse bias with the peak wavelength centered at around 750 to 850 nm. The origin of the memory and luminescence behavior has been interpreted as being related to the electronic states near the SiO_2/β-SiC interface.

2. Experimental

In Fig. 1, we show the layer structure of the SiO2/β-SiC/Si MIS diode. β-SiC epitaxial layers used in this work were formed on 0.1-0.5 Ω-cm n-type Si(111) substrates by the CVD (chemical Vapor Deposition) method [1, 2]. An oxide layer was thermally grown on the β-SiC epi-layer at 1000 °C for 8-12 min. The thickness is estimated to be less than ~50 Å according to the previously reported results [3]. Au and Al were used for electrodes. Voltages were applied with respect to the Si substrate side.

3. Results and Discussion

I-V and C-V Characteristics and Luminescence Behavior

A typical *I-V* curve and the relationship between the luminescence intensity and the applied voltage are shown in Fig. 2. The MIS diode exhibits a clear and reproducible hysteresis in the *I-V* curve. At a plus threshold voltage, the off state is switched to an on state, and at a minus threshold voltage, vice versa. Relatively strong red luminescence was observed mainly at minus biases. A typical *C-V* curve obtained from the MIS diode is shown in Fig. 3. The diode exhibits a injection-type hysteresis, and the corresponding generated charge is plus, indicating donor-like electronic states are related to the hysteresis behavior. At the plus threshold voltage, the capacitance sharply decreased due to a change in the state from off to on. A 1150 °C Ar after-anneal for 10 min smeared out

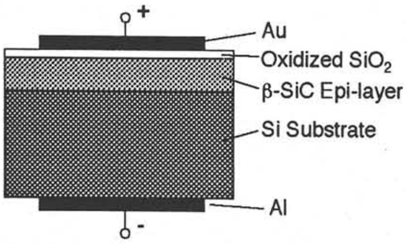

Fig. 1 The layer structure of a SiO_2/β-SiC/Si MIS diode with a very thin oxide layer.

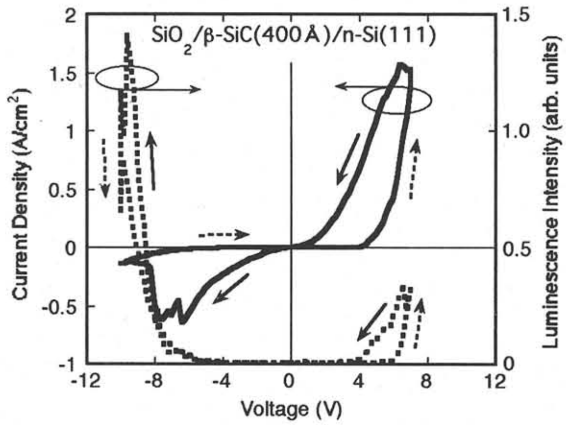

Fig. 2 A typical *I-V* curve and the relationship between the luminescence intensity and the applied voltage obtained from a MIS diode with the initial β-SiC thickness of 400 Å.

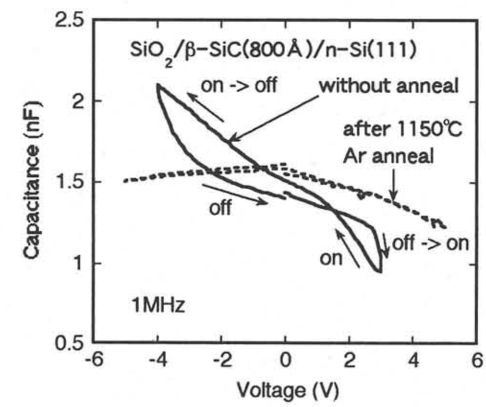

Fig. 3 Typical *C-V* curves obtained from a MIS diode with the initial β-SiC thickness of 800 Å and a sample after a 1150 °C Ar anneal for 10 min.

these donor-like states. To determine the location of the donor-like states, we measured *I-V* curves for samples formed with different processes; a sample after oxidizing the β-SiC layer, a sample after oxidizing the β-SiC layer following a 1150 °C 10 min Ar anneal, and a sample after a 1150 °C 10 min Ar anneal following the oxidation. The results are shown in Fig. 4. A 1150 °C anneal of the β-SiC layer does not smear out the electronic states and the hysteresis is caused after the oxidation indicating that the donor-like states is created in the oxidation process. After the 1150 °C anneal, the red luminescence (I_R) sharply decreased and weak green-blue luminescence (I_{GB}) centered at ~530 nm appeared. This means that the I_R relates to the interface states and the I_{GB} relates to the band-to-band recombination in β-SiC. The luminescence results also support the fact that the hysteresis relates to the electronic states produced in the oxidation process. Since we observe the relatively clear threshold voltages, the donor-like states probably locate near SiO_2/β-SiC interface.

Model of the Mechanisms of the Memory Function

The suggested mechanisms of the memory reactions are illustrated according to the above analyses in Fig. 5. Donor-like states filled with electrons act to flatten the β-SiC bands resulting in that the electric field in the SiO_2 becomes higher and electrons are easier to tunnel; an on state (B, C).

Dynamic Memory Response

In Fig. 6, we show the results of the dynamic response experiments of an write operation for an on state, an erase operation to switch to an off state from an on state, and an operation of reading of the memory state. We can detect on and off memory states and have succeeded in utilizing the memory function dynamically as shown in Fig. 6.

4. Conclusions

We propose a new memory device having a SiO_2/β-SiC/Si MIS structure with a thin electron-tunneling oxide layer. The electronic and luminescence behavior explained with donor-like states created probably near SiO_2/β-SiC interface. This stable states may be produced by the results of oxidation of a binary system (SiC). We have also succeeded in the memory function dynamically.

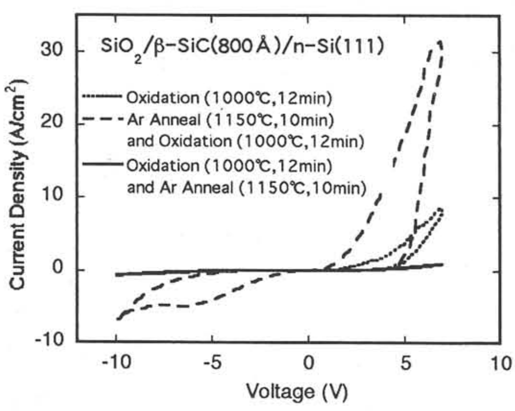

Fig. 4 *I-V* curves obtained from a sample after oxidizing the β-SiC layer, a sample after oxidizing the β-SiC layer following an anneal at 1150 °C, and a sample after an anneal at 1150 °C following an oxidation.

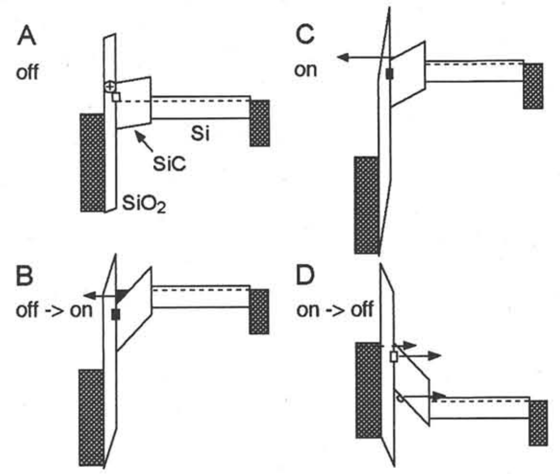

Fig. 5 The suggested mechanisms of the memory behavior in the SiO_2/β-SiC/Si MIS diode with a very thin oxide layer.

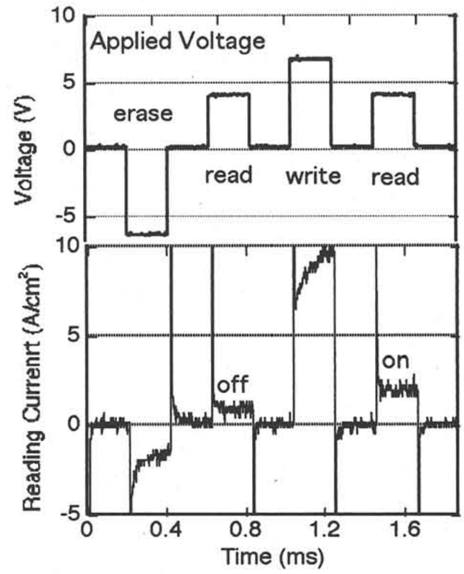

Fig. 6 The results of the dynamic responses of an write for an on state, an erase to switch to an off state, and a read of the memory state.

Acknowledgements

We greatly acknowledge the research support by Dr. Y. Furumura, Dr. M. Yamada and Mr. M. Takeda in Fujitsu Ltd. This work is supported in part by Fujitsu Ltd.

References

[1] Y. Furumura, M. Doki, F. Mieno, T. Eshita, T. Suzuki, and M. Maeda, J. Electrochem. **135**, 1255 (1988).

[2] T. Eshita, T. Suzuki, T. Hara, F. Mieno, Y. Furumura, M. Maeda, T. Sugii, and T. Ito, Mat. Res. Soc. Symp. Proc. **116**, 357 (1988).

[3] J. A Powell, J. B. Petit, J. H. Edgar, I. G. Jenkins, L. G. Matus, W. J. Choyke, L. Clemen, M. Yoganathan, J. W. yang, and P. Pirouz, Appl. Phys. Lett. **59**, 183 (1991).