Extended Abstracts of the 1997 International Conference on Solid State Devices and Materials, Hamamatsu, 1997, pp. 278-279

Invited

Fabrication Technology of Ferroelectric Memories

Takashi Nakamura, Yoshikazu Fujimori, Naoki Izumi and Akira Kamisawa
ULSI Process R&D Div., ROHM CO., LTD. 21 Saiin Mizosaki-cho, Ukyo-ku, Kyoto 615, Japan
Phone: +81-75-311-2121, Fax: +81-75-311-0643

1. Introduction

Recently, ferroelectric thin films have attracted much attention for practical use in the capacitor of nonvolatile memories. The ferroelectric memories provides clear advantages such as non-volatility, lower power consumption, higher endurance on writing cycles and higher writing speed.

However, the ferroelectric memory has several problems for practical use. The problems are mainly concerned with the reliability of the ferroelectric films. In order to solve the problems, we tried to use Ir system materials as electrodes of ferroelectric capacitors [1].

In this paper, the ferroelectric memories are introduced and our approach to the ferroelectric memories for practical use is presented.

2. Ferroelectric Memories

In 1988, a 1T1C (1 transistor and 1 capacitor) nonvolatile ferroelectric memory was presented [2]. (Fig.1). This type memory has 1 ferroelectric capacitor and 1

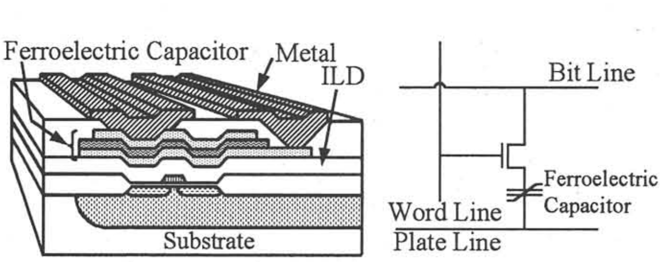

Fig. 1: 1T1C type ferroelectric memory cell

selective FET per 1 cell. The data is detected by the switching charge of the ferroelectric capacitor. The ferroelectric capacitor layer is separated from CMOS layer by thick ILD (inter layer dielectric).

Another is ferroelectric memory FET which has potential for a NDRO (non-destructive readout) non-volatile memory with single transistor per 1 cell like a flash memory. This type memory is expected a ferroelectric memory for the next generation. Figure 2 shows the model of an MFS FET (metal ferroelectric semiconductor FET) which is a typical ferroelectric memory FET. However,

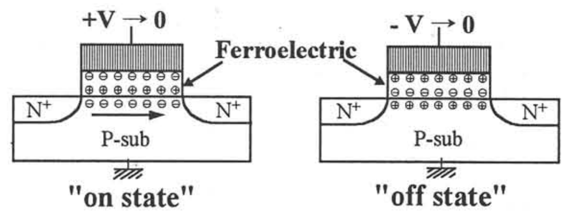

Fig. 2: MFS FET

fabrication of the conventional MFS FET [3] is very difficult because of deposition the ferroelectric film directly on Si. In order to realize the ferroelectric memory FET for practical use, we proposed an MFMIS FET (metal ferroelectric metal insulator semiconductor FET) [4] and a new material for the electrodes.

3. Electrode Materials

In this study, $Pb(Zr_{0.52}Ti_{0.48})O_3$ (PZT(52/48)) was used as ferroelectric materials. PZT thin films were prepared by the conventional sol-gel method. The top and bottom electrodes were deposited by the RF magnetron sputtering method. Pt/Ti, IrO_2, Ir/IrO_2 and Pt/IrO_2 were used as the electrodes. Fatigue properties of the PZT capacitors on SiO_2/Si substrates were shown in Fig. 3–(a). The switching charge of PZT on the Pt/Ti electrode was reduced to half by 10^8 cycles of switching pulses. When Pt/IrO_2 and Ir/IrO_2 bottom electrodes were used , neither PZT film showed fatigue up to 10^{12} cycles. It is considered the improvement is caused by a good Pb diffusion barrier effect of IrO_2.

By using the Ir system electrodes, an improvement was also found in the imprint characteristics. Figure 3–(b) shows imprint characteristics of PZT capacitors on Pt/Ti and Ir/IrO_2 electrodes. As the experimental results, the Ir system electrodes were effective for improvement in

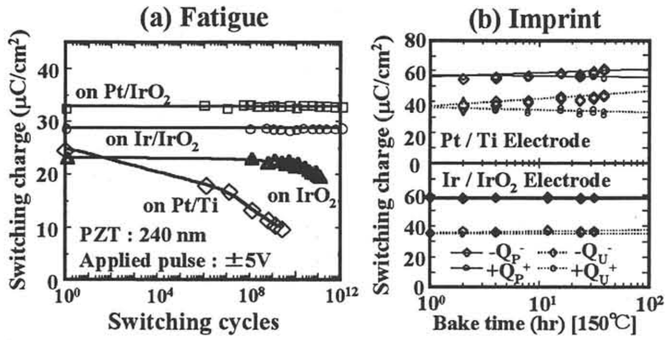

Fig. 3: Electrical characteristics of PZT capacitors

the reliability of ferroelectric thin films.

As another advantage of Ir system electrodes, we could obtain good ferroelectric characteristics of PZT capacitors on poly-Si. From X-ray diffraction analysis, in the case of used Pt or Pt/Ti electrodes, the perovskite PZT films were not obtained due to silicide formation of Pt and Ti. When electrodes including the IrO_2 layer were used, the silicide formation was never found and the perovskite single phase PZT films were obtained.

4. Device Fabrication

The technique of fabrication PZT capacitor on poly-Si was very effective for the high density 1T1C ferroelectric memory and MFMIS FET. The high density 1T1C ferroelectric memory needs a stack cell with the capacitor on a poly-Si plug. In order to confirm that the PZT capacitors with Ir system electrodes was useful for the stacked capacitor on the poly-Si plug, we fabricated the test device shown in Fig. 4. Hysteresis curves were measured

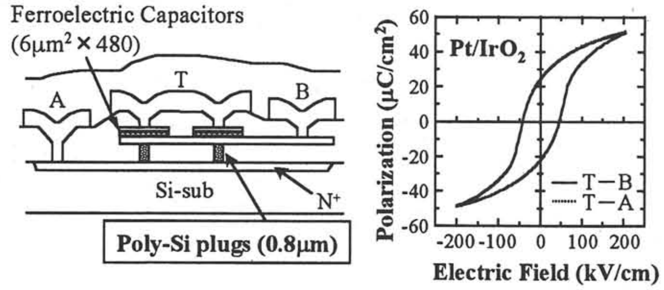

Fig. 4: PZT capacitors on poly-Si plugs

through (T–A) and not through (T–B) the poly-Si plugs. The characteristics from hysteresis curves show no difference between T–B and T–A. From the measurement, Ir system electrodes were useful for the PZT capacitor on the poly-Si plug.

The MFMIS FET was required a poly-Si/SiO_2/Si structure for clear MOS interfaces. When the MOS structure was used in the MFMIS FET, the technique of fabrication PZT capacitors on poly-Si was necessary. We tried to fabricate MFMIS FET with poly-Si/SiO_2/Si structure using Ir system electrodes. Figure 5 shows the

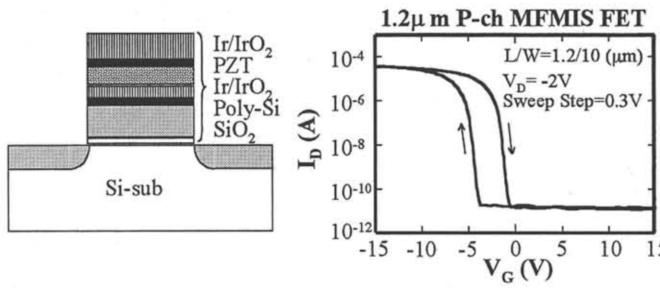

Fig. 5: MFMIS FET with Ir system electrodes

cross section of the MFMIS FET and an I_D-V_G characteristic of the FET. From the measurement, the FET shows the stable memory effect.

5. Conclusions

Two types of ferroelectric memories were introduced. One is a 1T1C type and another is a FET type.

In order to improve in the characteristics of ferroelectric capacitors, Ir system electrodes were proposed. When an Ir/IrO_2 was used as the electrode of the PZT capacitor, fatigue and imprint properties were dramatically improved. In addition, good ferroelectric properties of PZT capacitors on poly-Si could be obtained by using Ir system electrodes. The technique of fabrication PZT capacitor on poly-Si was very effective for the high density 1T1C ferroelectric memory and MFMIS FET with stable properties.

Acknowledgments

We would like to thank Mr. Katsumi Ogi and other staff of Mitsubishi Materials Corporation for the supply of ferroelectric source materials.

References

1) T. Nakamura, Y. Nakao, A. Kamisawa and H. Takasu: Appl. Phys. Lett. **65** 12 (1994) 1522.
2) S. S. Eaton, D. B. Butler, M. Paris, D. Wilson and H. Mcnellie: *Dig. Tech. Pap. IEEE Int. Solid-State Circuit Conf., New York, 1988* (1988) p.130.
3) S. Y. Wu: Ferroelectrics **11** (1976) 376
4) T. Nakamura, Y. Nakao, A. Kamisawa and H. Takasu: *Dig. Tech. Pap. IEEE Int. Solid-State Circuit Conf., San Francisco, 1995* (1995) p.68.