ROOM-TEMPERATURE TUNABLE PROPERTIES OF STRONTIUM TITANATE NANOSTRUCTURED FILMS

H. SOHRABI ANARAKI[1], N. V. GAPONENKO[1], S. M. ZAVADSKI[1], D. A. GOLOSOV[1], M. V. RUDENKO[1], B. S. KOLOSNITSYN[1], V. G. LITVINOV[2], A. V. ERMACHIKHIN[2]

[1]*Belarusian State University of Informatics and Radioelectronics*
P. Browka 6, 220013 Minsk, Belarus
nik@nano.bsuir.edu.by
[2]*Ryazan State Radioengineering University, Gagarin Str. 59/1, 390005 Ryazan, Russia*

Thin film $SrTiO_3$ capacitors were fabricated on silicon using the sol-gel method. The dependence of capacitance on voltage was observed at the room-temperature and frequency of 1 MHz. Tunable dielectric properties of the thin films are discussed.

1. Introduction

Strontium titanate ($SrTiO_3$, ST) is an incipient ferroelectric or quantum paraelectric material with the perovskite structure [1]. This material is widely studied because of its high dielectric constant and low dielectric losses [2], wide indirect band gap (3.2 eV) [3], insulator to metal transition by doping [4] and resistive memory effect [5]. Strontium titanate thin films have been extensively studied for application in tunable microwave devices such as varicaps, phase-shifters and tunable filter due to dependence of its dielectric constant on electric field [6]. However, the dielectric losses in film structures are known to be higher than in the single crystals that limit their application in thin film devices [7].

In this paper, we report on the capacitance tunability of nanopolycrystalline ST thin films fabricated by the sol-gel method.

2. Experimental

The initial components of the sol were strontium acetate hydrate $Sr(CH_3COO)_2 \cdot (1/2)H_2O$ and titanium tetraisopropoxide $Ti(OC_3H_7)_4$, as in [2,8]. Acetic acid and ethylene glycol monomethyl ether were used as solvents. Acetone was added to the sol as a stabilizer. The films were deposited on the silicon/titanium oxide/platinum substrate by spinning at the rate of 2700 rpm. After deposition of each gel layer, the samples were subjected to preliminary heat treatment at 200 °C. After that, the final heat treatment at the 750 °C was carried out. Finally, for fabrication of the capacitor structure the upper nickel

electrodes with a square shape of 1×1 mm^2 in size were magnetron sputtered onto the films.

3. Results and discussion

Typical capacitance-voltage and dielectric loss-voltage (dash line) dependences, measured at room temperature at 1 MHz on RLC-meter Agilent E4980A are shown in Fig. 1.

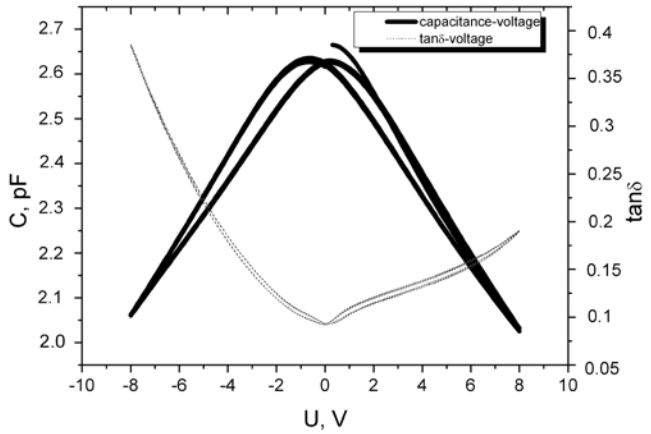

Figure 1. Capacitance-voltage and dielectric loss-voltage dependencies measured at room temperature and frequency of 1 MHz.

We studied the capacitor tunability by the ratio between the change of its capacitance when applying bias voltage at the maximum (C_{Umax}) and the capacitance at zero bias (C_{U0}) Eq. (1):

$$\Delta C\left(\%\right) = C_{U0} - C_{Umax} / C_{U0} \times 100 \,. \tag{1}$$

The tunability was measured to be around 23% that shows a low agility. According to [6,9], one can improve electrical properties of ST thin films by using oxygen relaxation technique and increasing in-plane grain size, respectively. The hysteresis loop (seen in Fig. 1) may be a result of ferroelectric domains in ST films [6]. In our experiments, in contrast to other works [6,9], dielectric losses increase with increasing of the voltage applied.

Fig. 2 shows the typical capacitor structure that we fabricated. Small grains of hundred nanometers are resolved. In such structures electrical transport properties are often explained by the double depletion-layer that accrues around grain boundaries (double Schottky barrier) [10] and the depletion-layer at the interface of metal-dielectric contact (Schottky barrier) [5].

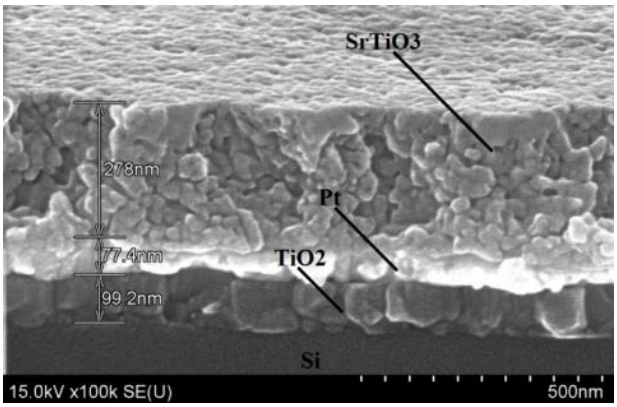

Figure 2. Typical capacitor structure of STO thin films after annealing at 750 °C.

According to [5], the charged point defects such as strontium and oxygen vacancies can be trapped at the grain boundaries producing the potential barriers. Formation of the depleted layers at the grain boundaries in ST films is considered as a main mechanism providing resistive memory effects in memristors as well as the capacitor dependence on the applied voltage.

4. Conclusion

The thin film capacitor structure on the basis of nanostructured ST was fabricated using the sol-gel method. The structure revealed the voltage dependence of the capacitance with tunability of about 23%.

References

1. K. A. Müller, H. Burkard, *Phys. Rev. B* **19**, 3593 (1979).
2. H. Sohrabi Anaraki *et al.*, *Doklady BSUIR*, **7 (85)**, 28 (2014).
3. U. Sulaeman, S. Yin, T. Sato, *Mater. Sci. Eng.* **18**, 032018 (2011).
4. G. I. Meijer, B. Delley, T. Neisius, *Phys. Rev. B* **72**, 155102 (2005).
5. S. Hirose *et al.*, *J. Appl. Phys.* **104**, 053712 (2008).
6. P. Kr. Petrova, N. McN. Alford, *Appl. Phys. Lett.* **87**, 222902 (2005).
7. K. Bouzehouane *et al.*, *Appl. Phys. Lett.* **80**, 109 (2002).
8. H. Sohrabi Anaraki *et al.*, *Semiconductors* **12**, 1685 (2014).
9. S. K. Hodak, T. C. Rogers, *Microel. Eng.* **85**, 444 (2008).
10. G. E. Pike, *Phys. Rev. B* **30**, 795 (1983).