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Impact of (111)-Oriented $SrRuO_3$/Pt Tailored Electrode for Highly Reproducible Preparation of MOCVD-PZT Film for High Density FeRAM

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1. Introduction

Nowadays, ferroelectric memories (FeRAM) are widely use in the microelectronic industry since they provide non volatility, high speed and low power consumption. Actual technology are mainly based on $Pb(Zr,Ti)O_3$ ("so-called PZT") which ensures a high remnant polarization and a low coercive field. Nevertheless, the development of next generation PZT-based FeRAM requires the preparation of highly reliable ferroelectric capacitors which combine good electric properties with good resistance to reliability issues (fatigue, imprint and retention). This work presents a systematic comparison of the electrical and microstructural properties of PZT-based ferroelectric capacitors with different (111)-oriented bottom electrode stack ($SrRuO_3$/Pt, Pt and Ir substrates). Our results clearly emphasis (111) $SrRuO_3$/Pt bottom electrode as the most suitable candidate for high density FeRAM.

2. Experimental

In this work, three types of (111)-oriented bottom electrode stacks were prepared by sputtering : (111)-$SrRuO_3$/Pt/TiO_2/SiO_2/Si, (111)-Pt/TiO_2/SiO_2/Si and (111)-Ir/TiO_2/SiO_2/Si.

PZT films were deposited by pulsed-metal-organic chemical vapor deposition (MOCVD), known to be the most suitable process for high density FeRAM fabrication due to its *(i)* ability to provide high quality films, *(ii)* relatively low process temperature and *(iii)* good step coverage [1]. After having optimized the process to obtain $PbZr_{0.35}Ti_{0.65}O_3$ films, we systematically changed the Pb input ratio [R_{Pb}(cm^3/min)] in the chamber while keeping all other parameters stable (substrate temperature and pressure kept constant at 580°C and 2.5Torr respectively); this to study the so-called "Pb process window" for obtaining PZT single phase [2].

Pt top electrodes (100 μm diameter) were deposited through a shadow mask by e-beam evaporation.

3. Results and discussion

Fig. 1 shows the Pb/(Pb+Zr+Ti) and Zr/(Zr+Ti) ratios of the PZT films measured by wavelength dispersive X-ray spectroscopy (WDS). The process window relative to the input source gas of Pb is clearly evidenced since no dramatical variation in the composition of PZT films is observed for $0.11cm^3/min<R_{Pb}<0.23cm^3/min$. Only a slight decrease of the amount of Zr in the film occurred within the process window.

Fig.2 presents the X-ray diffraction patterns (θ-2θ) of the films prepared under various R_{pb} on the three kinds of substrates. Clearly, the orientation of the film depends on both the nature of the substrate and on R_{Pb}. Indeed (111)-textured PZT single phase is evidenced within the process window only on (111)-$SrRuO_3$/Pt substrates [Fig.2(a)]. Secondary phase and/or impurities appear on Pt [Fig.2(b)] and Ir [Fig.2(c)] substrates.

Such a difference in the orientation and quality of the film strongly affect the electrical properties of the device. Indeed, Fig. 3 presents the evolution of the hysteresis loops measured on every samples within the process window. One can observe that only Pt/PZT/$SrRuO_3$/Pt capacitors show reproducible well-defined square-shaped hysteresis loop with a remnant polarization around 40μC/cm^2. Furthermore, the coercive voltage [Fig.4(a)] of these capacitors is constant within the process window and remains low (0.8V<Vc<1V) as compared with other substrates. Finally, one can observe that the squareness of the hysteresis loop [Fig.4(b)], defined as P_r/P_{sat}, and the leakage currents measured at 1.5V [Fig.4(c)] remain also stable within the process window (respectively around 80% and 10^5A/cm^2). These two characteristics seem to be only slightly affected by the nature of the bottom electrode.

4. Conclusions

The influence of the bottom electrode nature ($SrRuO_3$/Pt, Pt and Ir) on the properties of PZT-based capacitors is studied in details by microstructural and electrical characterizations. Our results strongly support $SrRuO_3$/Pt substrates as the best candidate for next generation high density FeRAM since highly reproducible properties were evidenced over a wide Pb process window. Further work will be carried on the reliability and thickness dependency of these capacitors.

Acknowledgements

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References

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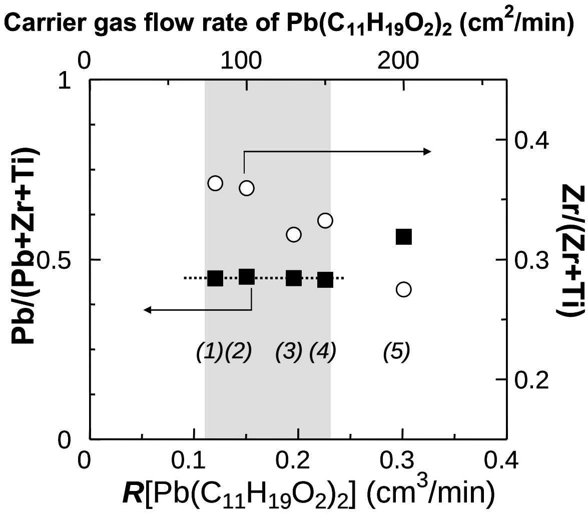

Fig. 1 : Pb/(Pb+Zr+Ti) and Zr/(Zr+Ti) ratios of the PZT films as a function of $R[Pb(C_{11}H_{19}O_2)_2]$ (R_{pb}) and/or the carrier gas flow rate of $Pb(C_{11}H_{19}O_2)_2$. The grey part corresponds to Pb/(Pb+Zr+Ti) ratio remain constant. The number in italic correspond to the MOCVD run number.

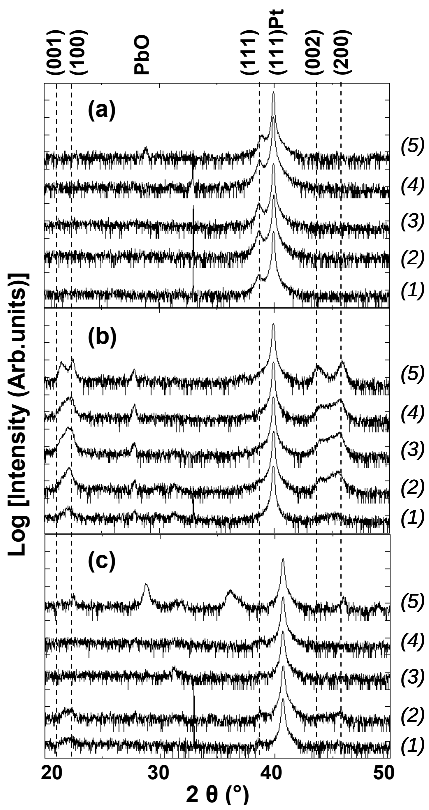

Fig. 2 : XRD patterns (θ-2θ) of films deposited on different substrates : (a) $SrRuO_3$/Pt; (b) Pt; (c) Ir. The number in italic correspond to the MOCVD run number.

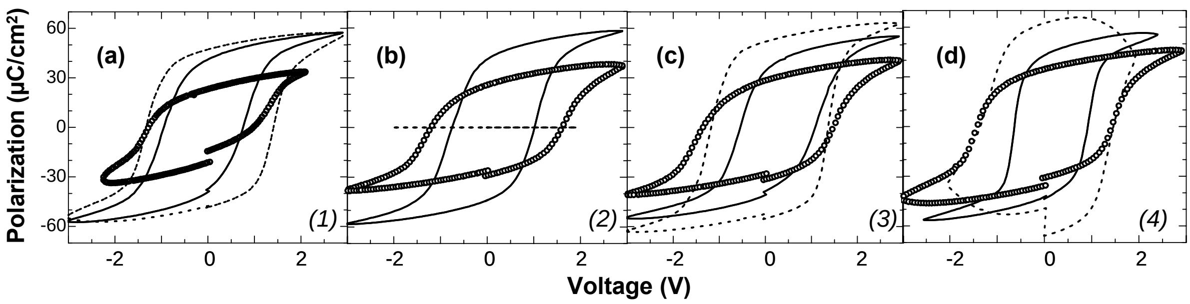

Fig. 3 : P-E hysteresis loops measured at 20 Hz of PZT-based capacitors with $SrRuO_3$/Pt (plain line), Pt (circles) or Ir (dashed line) bottom electrodes. Figure (a), (b), (c) and (d) correspond respectively to the deposition run (1), (2), (3) and (4) characterizing the process window.

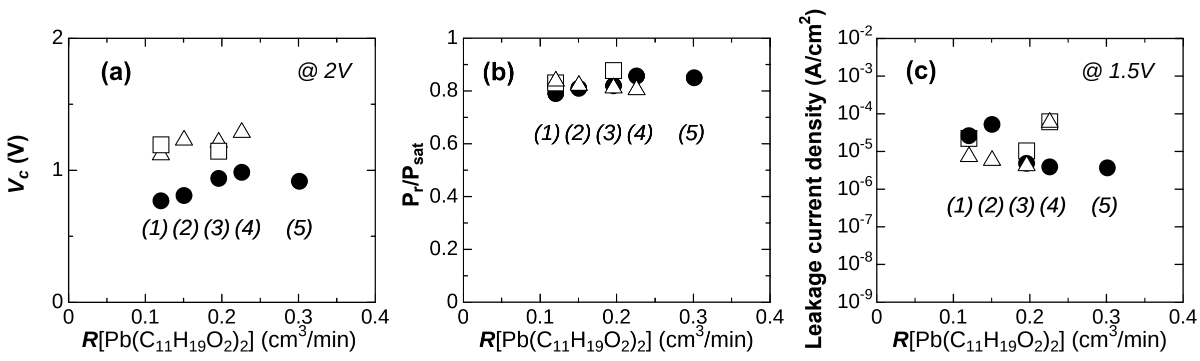

Fig. 4 : Electric properties of PZT-based capacitors with $SrRuO_3$/Pt (●), Pt (Δ) or Ir (□) bottom electrodes as a function of $R[Pb(C_{11}H_{19}O_2)_2]$: (a) coercive voltage (V_c) measured at 2V; (b) hysteresis squareness (P_r/P_{sat}); (c) leakage current density measured at 1.5V. The number in italic correspond to the MOCVD run number.