Combustion Solution Based Zinc Tin Oxide TFTs: the dual role of organic solvent

Daniela Salgueiro*, Asal Kiazadeh, Rita Branquinho, Lídia Santos, Pedro Barquinha, Rodrigo Martins, Elvira Fortunato*

i3N/CENIMAT, Department of Materials Science, Faculty of Science and Technology, Universidade NOVA de Lisboa and CEMOP/UNINOVA, Campus de Caparica, 2829-516 Caparica, Portugal
*Corresponding authors: d.salgueiro@fct.unl.pt, emf@fct.unl.pt

ABSTRACT

In this work, we studied the role of 2-methoxyethanol in solution based synthesis of ZTO thin films and its influence on the performance of ZTO TFTs. The thermal behaviour of ZTO precursor solutions confirmed that 2-methoxyethanol acts simultaneously as solvent and fuel, replacing the fuel function of urea.

EXPERIMENTAL PART

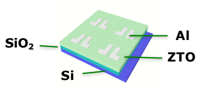
ZTO deposition

MOx Synthesis

Al evaporation

Combustion
Sol-Gel
Ammonium

TFT structure

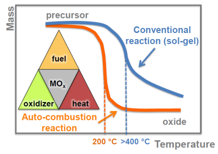


MOx SYNTHESIS

Combustion

$$3Zn(NO_3)_2.6H_2O_{(s)} + 5CO(NH_2)_{2(s)} \rightarrow 3ZnO_{(s)} + 8N_{2(g)} + 28H_2O_{(g)}$$

$$SnCl_{2(s)} + \frac{1}{3}CO(NH_2)_{2(s)} + NH_4NO_{3(s)} + \frac{1}{2}O_2 \rightarrow SnO_{2(s)} + \frac{4}{3}N_{2(g)} + \frac{1}{3}CO_{2(g)} + \frac{5}{3}H_2O_{(g)} + 2HCl$$



Metal = Zn^{2+}, Sn^{2+}

Fuel = $CO(NH_2)_2$ Reducing Valence (RV)

Oxidizer = NO_3^- Oxidizing Valence (OV)

$$\Phi = \frac{RV}{OV}n$$

Sol-Gel

$$8Zn(NO_3)_2.6H_2O_{(s)} + 5CH_3OC_2H_4OH_{(l)} \rightarrow 8ZnO_{(s)} + 8N_{2(g)} + 68H_2O_{(g)} + 15CO_{2(g)}$$

$$4SnCl_{2(s)} + CH_3OC_2H_4OH_{(l)} + 6O_{2(g)} \rightarrow 4SnO_{2(s)} + 3CO_{2(g)} + 8HCl_{(l)}$$

Can 2-methxyethanol replace the Urea function?

Ammonium

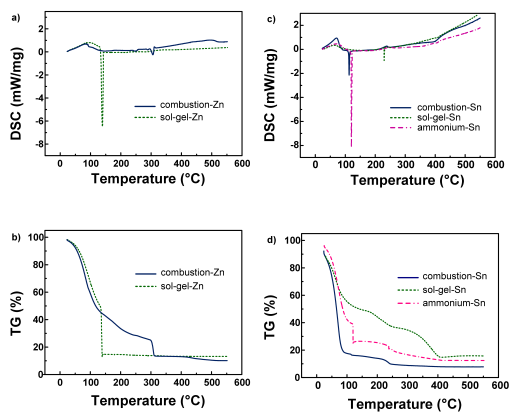
$$8SnCl_{2(s)} + 5CH_3OCH_2CH_2OH_{(l)} + 12NH_4NO_{3(s)} \rightarrow 8SnO_{2(s)} + 15CO_{2(g)} + 24NH_{3(g)} + 16HCl_{(g)}$$

Adding NH_4NO_3 we do not have the consumption of O_2

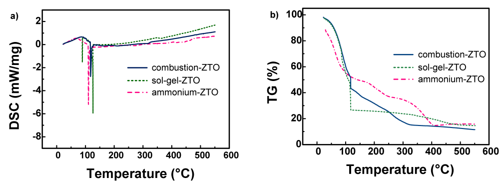
RESULTS AND DISCUSSION

Precursor Solution Characterization

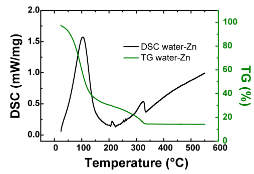
TG-DSC curves of individual precursor solutions



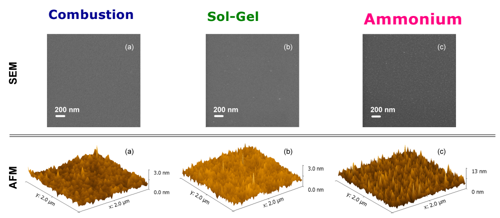
TG-DSC curves of ZTO precursor solutions

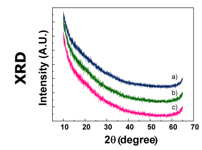


TG-DSC curves of Zinc metal precursor in water

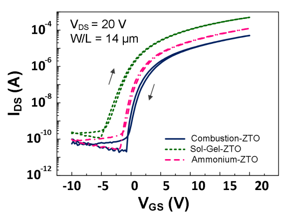


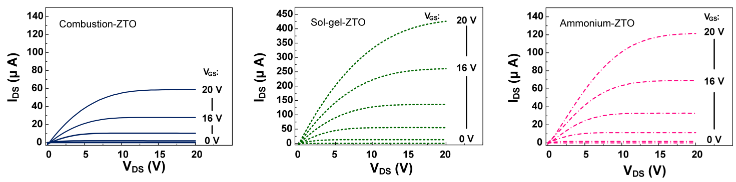
Structural and Surface Analyses



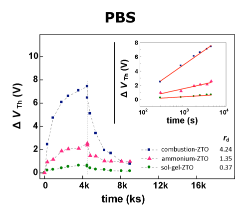


Electrical Characterization of TFTs





PBS



	V_{on} (V)	I_{on}/I_{off}	μ_{sat} ($cm^2 V^{-1} s^{-1}$)	V_{Th} (V)	SS ($V dec^{-1}$)	ΔV (V)
combustion-ZTO	-3.5 – 2.4	10^6	1.9 – 3.8	-1.16 – 3.98	0.38 – 0.89	-0.47 – 1.0
sol-gel-ZTO	-5.2– -2	10^5-10^6	3.9 – 4.9	-2.24 – 1.55	0.25 – 1.00	-0.31 – 0.46
ammonium-ZTO	-2.0 – 1.2	10^6-10^7	2.3 – 4.2	-1.64 – 0.23	0.20 – 0.47	-0.33 – 0.49

Conclusion

- Different precursor solutions were prepared and analyzed by TG-DSC in order to prove that the organic solvent used in this work, 2-methoxyethanol, more than a solvent can act as fuel in the same way as Urea, as it would be expected due to reducing valence.
- Solution processed ZTO TFTs were prepared at 350 ºC and electrical characterized with I_{ON}/I_{OFF} up to 10^6. However, when urea was used these devices showed poorer performance and higher variability under positive bias stress. This is attributed to the excess of fuel present when urea is added to the precursors, which can increase defect states generation at the semiconductor-dielectric interface.
- The best equilibrium between the TFT electrical performance/stability is obtained using the sol–gel ZTO, as a result of the 'self-induced' combustive nature enabled by the solvent itself.

References

D. Salgueiro, *et al.* J. Phys. D: Appl. Phys. Vol. **50**, p. 065106 (2017)
Y. Jeong, *et al.* ACS Appl. Mater. Interfaces, Vol. **2**, p. 611 (2010)
R. Street, *et al.* ACS Appl. Mater. Interfaces, Vol. **6**, p. 4428 (2014)
R. Branquinho, *et al.* Semicond. Sci. Technol., Vol. **30**, p. 24007 (2015)
A. Kiazadeh, *et al.* APL Mater. Vol.**3**, p. 62804 (2015)

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