The Effect of Atmospheric Air in Flexible Organic Transistors

Andre F. S. Guedes
Organic Microelectronic Laboratory:
SENAI College of Technology
Av. Assis Brasil, 8450
Porto Alegre, Brazil
andre.felipe@senairs.org.br

Vilmar P. Guedes
Nanotechnology Laboratory:
Intellectos Center For Research
R. São Miguel, 301
Torres, Brazil
labnano@intellectos.org

Simone Tartari
Nanotechnology Laboratory:
Intellectos Center For Research
R. São Miguel, 301
Torres, Brazil
labnano@intellectos.org

ABSTRACT
The development of new organic semiconductors, with improved performance in organic thin film transistors, has been a major challenge for researching scientific materials. Therefore, we have demonstrated a successful integration for the process of manufacturing an organic transistor flexible prototype as well as discussed the factors that have enabled this process. During the procedure, the maximum time of exposure in atmospheric air, with and without encapsulation, reached 3000 hours, for three different temperatures: 50°C, 100°C and 150 °C. In addition, the maximum temperature was 160°C, corresponding to the baking of the polymeric gate dielectric. All organic transistors were submitted to a supply voltage of 5.0 V, and the signal propagation delay was of 30 microseconds per stage, making them, so far, the fastest organic complementary circuits reported at supply voltages below 8 V. In conclusion, the electron mobility of all two thin film transistors demonstrated only very little degradation over a period of several hours in air environment without encapsulation.

Keywords
Polyaniline Additive; PANI; Thin-film transistors; TFT; Flexible Organic Transistor.

1. INTRODUCTION
The development of organic thin-film transistors, using methods to deposit small molecules, has been considerably improved during the last years [1] [2]. Organic semiconductor materials present the main advantage of counting on a potentially simple and low-temperature thin-film process, utilizing techniques as spin coating, ink jet printing or stamping [3] [4]. This fact has suggested that organic thin-film transistors can be competitive for applications requiring large-area coverage, low temperature processing and low cost [5]. However, these utilized deposition methods do not have an adequate stability when in contact with atmospheric air [7].

In this research, we have presented the static current-voltage characteristics of flexible organic transistors, manufactured on a polymer flexible with silver source and drain contacts, and operated in air environment with and without any encapsulation. Furthermore, we have presented the evolution effect mobility in thin-film transistors manufactured with polyaniline additive (PANI-A) and polymethyl methacrylate (PMMA) as the dielectric material. The PMMA is a polymeric resistor commonly utilized in high resolution nanolithographic processes, which use electron beam and deep UV radiation (200–260 nm) [8].

2. EXPERIMENTAL DETAILS
In this study, the utilization of a structure in a device with thin-film transistors has been shown in Figure 1. We have utilized Polypropylene, PP, as a substrate because of its flexibility, and, before the deposition of the PMMA dielectric film, an ITO layer was thermally evaporated to form the gate electrode. As purchased, PMMA with molecular weight of 950 K, diluted in anisole (5%), was, then, utilized. The resistor was spun at 3500 RPM for 30 seconds to form a uniform coating. Finally, the resistor was baked at 160 °C for 30 minutes in a conventional oven. The PMMA thickness was of 600 nm, as determined by the profilemetry surface.

In addition, silver contacts were thermally evaporated through a shadow mask in order to form electrodes of drain and source. These devices had channel length of 100 µm and width of 400 µm. Finally, Polyaniline (Sigma - Aldrich), with additive Hydrogen chloride acid at 10%, was deposited at room temperature by the electrodeposition system, and voltage of 10.0 volts was applied for 5 minutes [9]. No optimization of technological parameters, utilized to deposit Polyaniline films, has been carried out yet. In order to define and isolate devices, polyaniline was evaporated through a metallic mask. The thickness of the polyaniline layer was approximately 300 nm

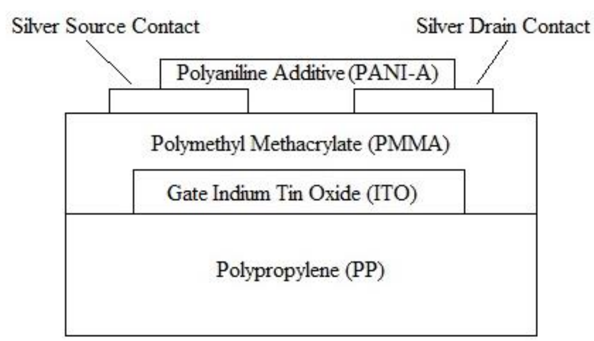

Fig. 1. Schematic cross-section of the polyaniline additive thin-film transistor. The width of the channel was of 400 µm, its length was of 100 µm, and the thickness of PMMA dielectric was of 600 nm.

3. RESULTS AND DISCUSSION
The electrical characterization of thin-film transistors was made at room temperature, utilizing an Electrometer Keithley 6517A semiconductor parameter analyzer. All measurements were made

without vacuuming, and no precautions were taken to prevent the degradation of polyaniline additive films.

Figure 2 has shown current-voltage characteristics with the polyaniline additive thin-film transistor manufactured on a Polypropylene substrate and operated in air environment without any encapsulation. These results considered the duration of operation of 3000 hours, with organic transistor temperatures at 50 °C, 100 °C and 150 °C. In this test, the response curve demonstrated a greater shift of temperature at 150 ° C, caused by the degradation of the polymer when in contact with the atmospheric air.

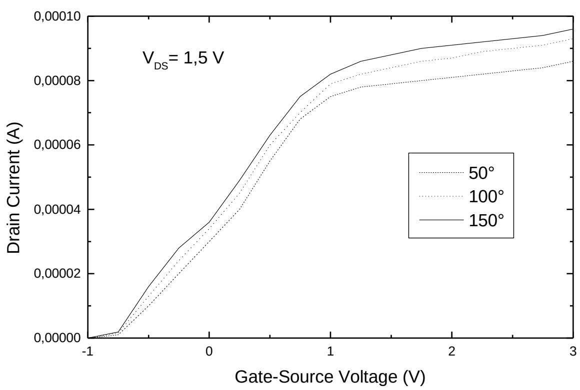

Fig. 2. Current-voltage characteristics of the polyaniline additive thin-film transistor operated in air environment without any encapsulation.

Figure 3 has shown a current-voltage characteristic, with the polyaniline additive thin-film transistor manufactured on a Polypropylene substrate and with plastic encapsulation. These results consider the duration of operation of 3000 hours, with organic transistor temperatures at 50 °C, 100 °C and 150 °C. In this case, the response curve demonstrated little variation by using different temperatures in the test.

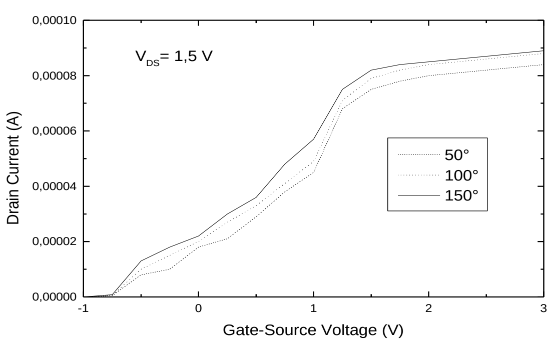

Fig. 3. Current-voltage characteristics of the polyaniline additive thin-film transistor operated in air enviorment with plastic encapsulation.

Figure 4 has shown the evolution of the field-effect mobility with the polyaniline additive thin-film transistor, for three different transistor operating temperatures, in this case, at 50 °C, 100 °C and 150 °C. In this test, it may be observed a region of temperatures between 50 °C and 150 °C, and an excellent operation stability of the organic transistor. As can be seen, the electron mobility of the polyaniline additive thin-film transistor has demonstrated only very little degradation over a period of several hours in air environment with and without encapsulation [10].

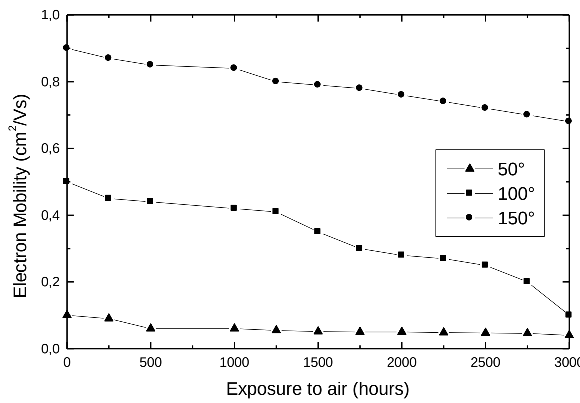

Fig. 4. The evolution of the field-effect mobility of the polyaniline additive thin-film transistor (with plastic encapsulation).

As can be seen through the optical microscopy, shown in Figure 5, the polyaniline additive thin-film transistor obtained exhibitions of a flat surface without irregularities. The result of optical microscopy and electrical measurements has suggested an innovative configuration of thin-film transistors to the Flexible Organic Transistor.

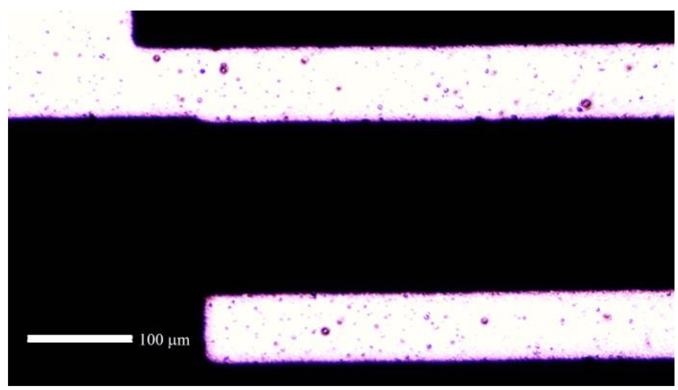

Fig. 5. Optical Microscopy of the polyaniline additive thin-film transistor.

4. CONCLUSIONS

The results presented in this research have demonstrated that ITO can be utilized as a gate in thin-film transistors. The electrical characterization, considering the duration of operation of 3000 hours, with organic transistor temperatures at 50 °C, 100 °C and 150 °C, was, then, observed. The response curve with greater shift was at 150 ° C, caused by the degradation of the polymer, when in contact with atmospheric air. However, the highest stability can be observed with the presence of plastic encapsulation. In this study, the relationship of temperature and time of the transistor operation, in harsh environmental conditions, has been considered another important result. In conclusion, the use of organic semiconductor materials, deposited by the electrode position, allows the combination of semiconductor layers with different organic polymers.

5. ACKNOWLEDGMENTS

MCTI, FINEP, CNPq, SENAIRS, SENAI College Porto Alegre and INTELLECTOS.

6. REFERENCES

[1] MacDiarmid, A.G. 1, 2001. Current applied physics. 1, 269-279.

[2] White, M.A. 1999. Properties of materials, Library of Congress Cataloging-in-Publication Data. New York.

[3] Somani, P.R. and Radhakrishnan, S. 2002. Electrochromic materials and device: present and future. *Mater. Chem. and Phys.* 77, 117-133.

[4] Rosseinsky, D.R. and Mortimer, R.J. 2001. Electrochromic Systems and the Prospects for Devices. *Adv. Mater.* 13, 783-793.

[5] Mortimer, R.J. 1999. Organic electrochromic materials. *Electrochemical Acta.* 44, 2971-2981.

[6] Paoli, M.A. and Gazotti, W.A. 2002. Electrochemistry, Polymers and Opto-Electronic Devices: A Combination with a Future. *J. Brazilian Chem. Soc.*, 13, 1-15.

[7] Guedes, A.F.S.; Guedes, V.P.; Tartari,S. and Cunha, I.J. 2013. The Application of Electrodeposition in Thin Film Transistors for Flexible Organic Electronics. *SBMicro IEEE*, 1-2.

[8] Jaeger, R.C. 5, 1989. Introduction to microelectronic fabrication. *Addison-Wesley Publishing Co.*, Massachusetts. 5.

[9] Guedes, A.F.S; Costa, E.M. and Guedes, V.P. 31, 2010. Formation of Nanoparticles in Organic Materials used in Semiconductors Optoelectronic Devices. *ECS Trans.* 231-236.

[10] Guedes, A.F.S; Guedes, V.P. Tartari, S.; Souza, M.L. and Cunha, I.J. 2013. New Electronic Technology Applied in Flexible Organic Optical System. *J. of Syst, Cyb. and Inform*. 285-288.