Analysis and modeling of amorphous In-Ga-Zn-O (a-IGZO) thin-film transistors

Citation for published version (APA):
Torricelli, F., Tripathi, A. K., Smits, E. C. P., Colalongo, L., Kovacs-Vajna, Z. M., & Cantatore, E. (2011). Analysis and modeling of amorphous In-Ga-Zn-O (a-IGZO) thin-film transistors. In *Proceeding of ICT.OPEN (SAFE) 2011, 14-15 November 2011, Veldhoven, The Netherlands*

Document status and date:
Published: 01/01/2011

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

Download date: 17. Mar. 2025

Analysis and Modeling of Amorphous In-Ga-Zn-O (a-IGZO) Thin-Film Transistors

Fabrizio Torricelli[1], Ashutosh K. Tripathi[2], Edsger C. P. Smits[2], Luigi Colalongo[3], Zsolt M. Kovacs-Vajna[3],
Gerwin H. Gelinck[2], Eugenio Cantatore[1]

[1] Department of Electrical Engineering, Eindhoven University of Technology, Eindhoven, The Netherlands
[2] Holst Centre/TNO science and Industry, Eindhoven, The Netherlands
[3] Department of Information Engineering, University of Brescia, Brescia, Italy

Corresponding author: e-mail: F.Torricelli@tue.nl, Tel: +31 40 247 3407, Fax: +31 40 245 5674, postal address: Den Dolech 2, Postbus 513, 5612AZ Eindhoven, The Netherlands

Keywords: a-IGZO, thin-film transistor (TFT), multiple trapping and release, contact resistance, transistor modeling.

Motivations and aim of the work: Amorphous Indium-Gallium-Zinc-Oxide (a-IGZO) TFT is expected to be a key building block in flat-panel display backplanes, electronic papers, and peripheral circuits [1]. In these applications, comprehensive understanding and accurate modeling of the transistor behavior is compulsory for a systematic circuit design.

In this work we propose an analytical model for the drain current of a-IGZO-TFTs. The model is suitable for the CAD implementation and can be used for circuit design. By means of the channel model and exploiting the scaling behavior of a set of transistors, we analyze and quantify the contact resistance at the source (injection) side of the transistor. The electrical characteristics of the injection contact as a function of both gate and drain voltages are unambiguously determined. This study shows that the charge injection in a-IGZO TFTs cannot be neglected when the transistor channel length is shrunk down (L<10µm).

Results and discussion:

In the last years, the charge transport in a-IGZO TFTs has been studied both experimentally [2,3] and numerically [4]. These studies revealed that the drain current is thermally activated and the subgap tail-states DOS can be approximated by an exponential function. Basing on this physical knowledge, we use the multiple trapping and release model to describe the charge transport in the transistor channel and we assume an exponential tail states DOS. Solving the drift-diffusion equation we propose an analytical expression of the DC current, which is valid for all the operating conditions of the transistor: subthreshold, linear, and saturation. The model is validated by means of a set of measurements collected from bottom-gate bottom-contact a-IGZO TFTs fabricated by us. The transistors have the same width W=1000 µm and different channel lengths L={100, 80, 60, 40, 20, 10, 5, 3} µm. In fig. 1 and 2 the model is compared with the measurements of the longest channel TFT: they are in fully agreement and the model is very accurate. Shrinking down the transistor length, the channel model gives a good fit until L>10 µm. For shorter channels the charge injection from the source side of the transistor plays a role in determining the drain current and the contact cannot be considered ohmic any more. We quantify this contribution by extracting the contact resistance as a function of the gate voltage V_G and for different channel lengths; the results are displayed in fig. 3. For small values of V_G the contact resistance R_c reduces by increasing the lateral electric field while for large values of V_G the R_c is independent on the channel length and it becomes nearly constant. These results suggest that the injection depends on both the drain-source and gate-source voltages.

References:

[1] K. Nomura, H. Ohta, A. Takagi, T. Kamiya, M.Hirano, H. Hosono, *Nature* 432, 488 (2004).

[2] C. Chen, K. Abe, H. Kumomi, J. Kanicki, IEEE Trans. Electr. Devices 56, 1177 (2009).

[3] S. Lee, S. Park, S. Kim, Y. Jeon, K. Jeon, J-H. Park, J. Park, I. Song, C. J. Kim, Y. Park, D. M. Kim, D. H. Kim, IEEE Electr. Device Lett. 31,231 (2010).

[4] T. Fung, C. Chuang, C. Chen, K. Abe, R. Cottle, M. Townsend, H. Kumomi, J. Kanicki, *J. Appl. Phys*. 106, 084511 (2009).

Figures:

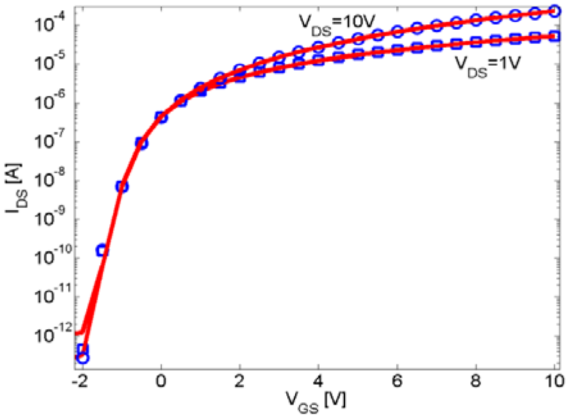

Figure 1: Measured (symbols) and modeled (solid lines) transfer characteristics for several drain voltages of an a-IGZO TFT (W=1000μm, L=100μm).

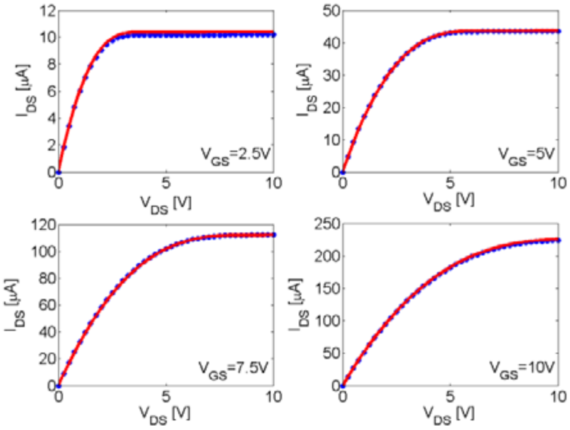

Figure 2: Measured (symbols) and modeled (solid lines) output characteristics for several gate voltages of an a-IGZO TFT (W=1000μm, L=100μm).

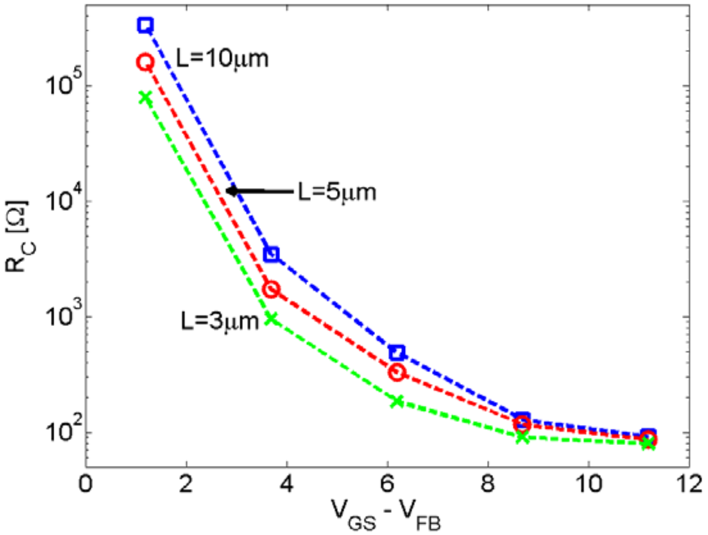

Figure 3: Extracted contact resistance as a function of the gate voltage for transistors with different channel lengths (W=1000μm). VFB=-1.19V is the flat-band voltage.