Compact Modeling of SiON MOST Devices

Jakub Jasiński[(a)], Grzegorz Głuszko[(a)], Lidia Łukasiak[(a)], Andrzej Jakubowski[(a)],
Władysław Grabiński[(b)], Daniel Tomaszewski[(c)]

[a)] Institute of Microelectronics and Optoelectronics, WUT, Poland
[b)] GMC, Switzerland
[c)] Institute of Electron Technology, Poland

Motivation

The aim of this work is to extract parameters of EKV model from electrical characteristics of transistors with SiON as a gate dielectric. I-V characteristics have been measured and several transistor parameters like nominal threshold voltage (VT0) transconductance parameter (KP), series resistance (RSD), channel length correction (ΔL), channel width correction (ΔW) have been extracted. Moreover a dependence of extracted parameters on channel length and channel width has been investigated.

Introduction

One of the most critical issues of the miniaturization of MOS devices to sub-100 nm dimensions is the reduction of gate-dielectric thickness, and the resulting increase of gate leakage current (e.g. [1], [2]). This undesirable effect leads e.g. to elevated stand-by power consumption. The best way to increase the physical thickness of the gate dielectric (and reduce gate current) without detrimental influence on gate control over the channel is to use a high-k material [1]. While the dielectric constant of SiON is not very high, the quality of its interface to silicon is much better than that of many high-k materials, which is why it is often used as a part of a dual gate-dielectric, that is a gate dielectric consisting of two layers: a thin buffer layer of SiON and a high-k material on top of it [3], [4], [5].

The subject of investigation are transistors with 1.2nm SION gate dielectric. Two groups of transistors were measured. Transistors in the first group had the same channel width (10µm) and different channel length (0.13µm, 0.15µm, 0.18µm, 0.20µm, 0.23µm, 2µm, 3µm, 5µm, 7µm, 10µm). Devices in second group had the same channel length (10µm) and different channel width (0.15µm, 0.18µm, 0.20µm, 0.23µm, 0.25µm, 2µm, 3µm, 5µm, 7µm, 10µm).

Electrical characterization

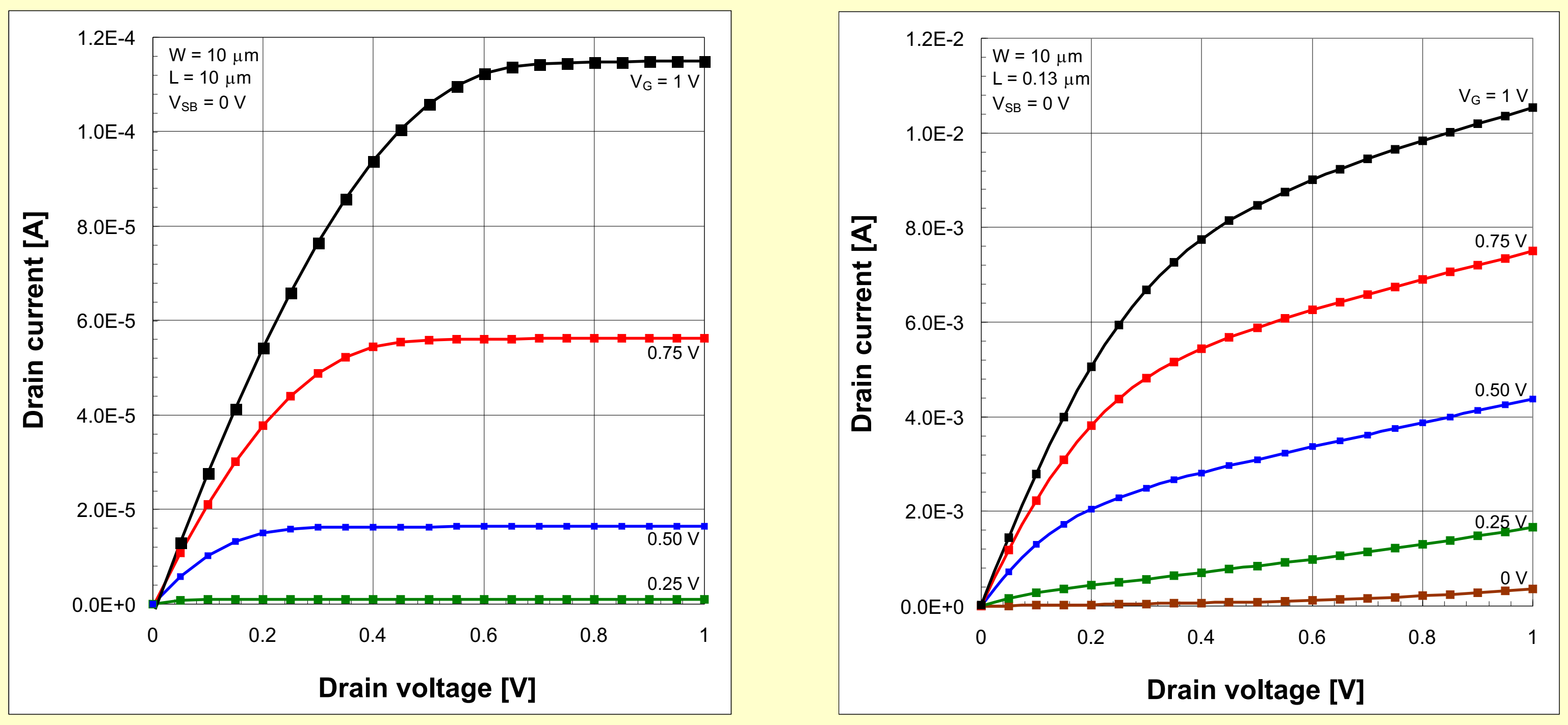


Fig. 1. Output characteristics of a long- (left) and short- (right) channel transistor.

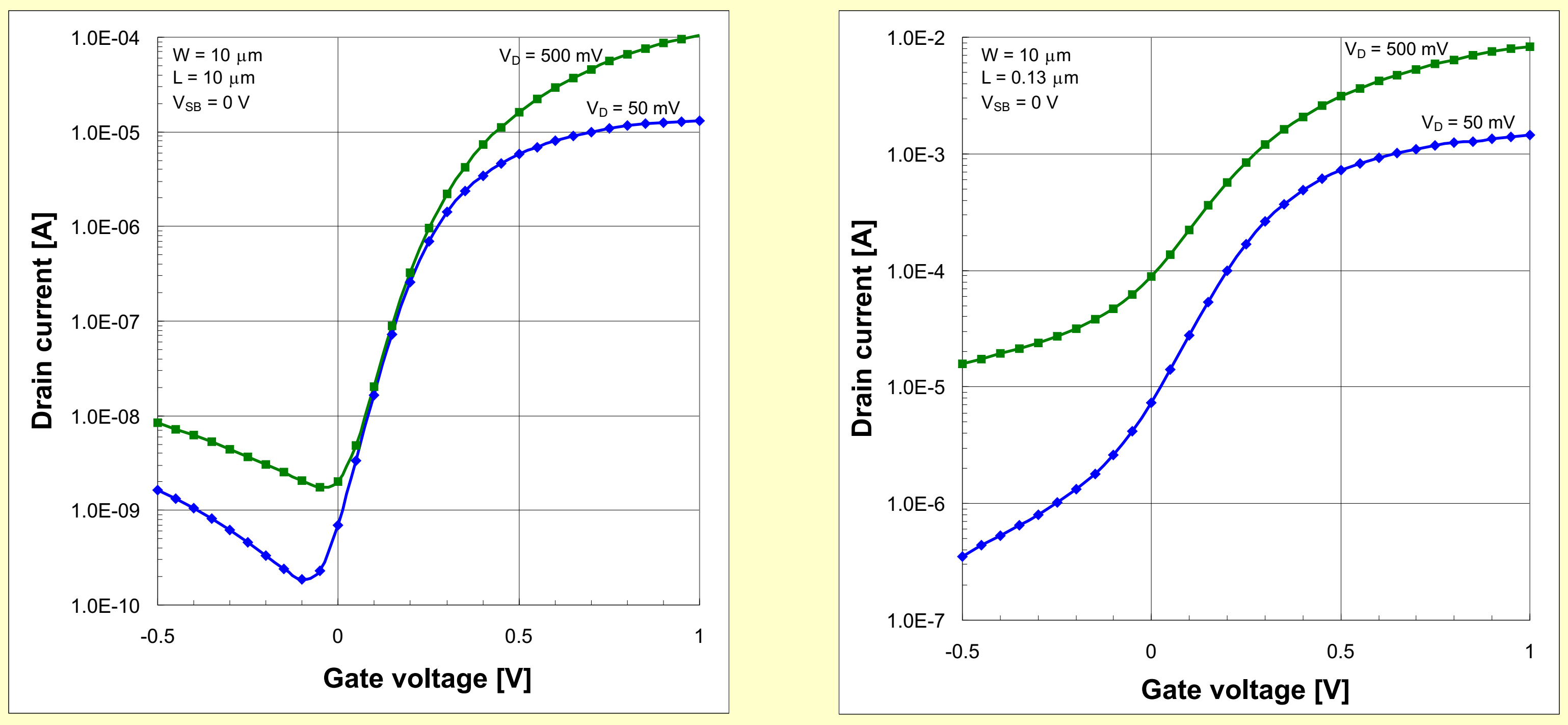


Fig. 2. Transfer characteristics of a long- (left) and short- (right) channel transistor.

It may be seen that while the characteristics of a long-channel MOSFET behave as expected in the saturation region, the case of the short-channel device is quite different. The drain current of the latter device rises steeply in the saturation region Fig.1 (right), most probably due to a punch-through or considerable lateral diffusion of source and drain regions under the gate comparable to the projected gate length (confirmed later by extraction of series S/D resistance).

Short-channel effects like influence of series resistance can be also observed in Fig. 3.

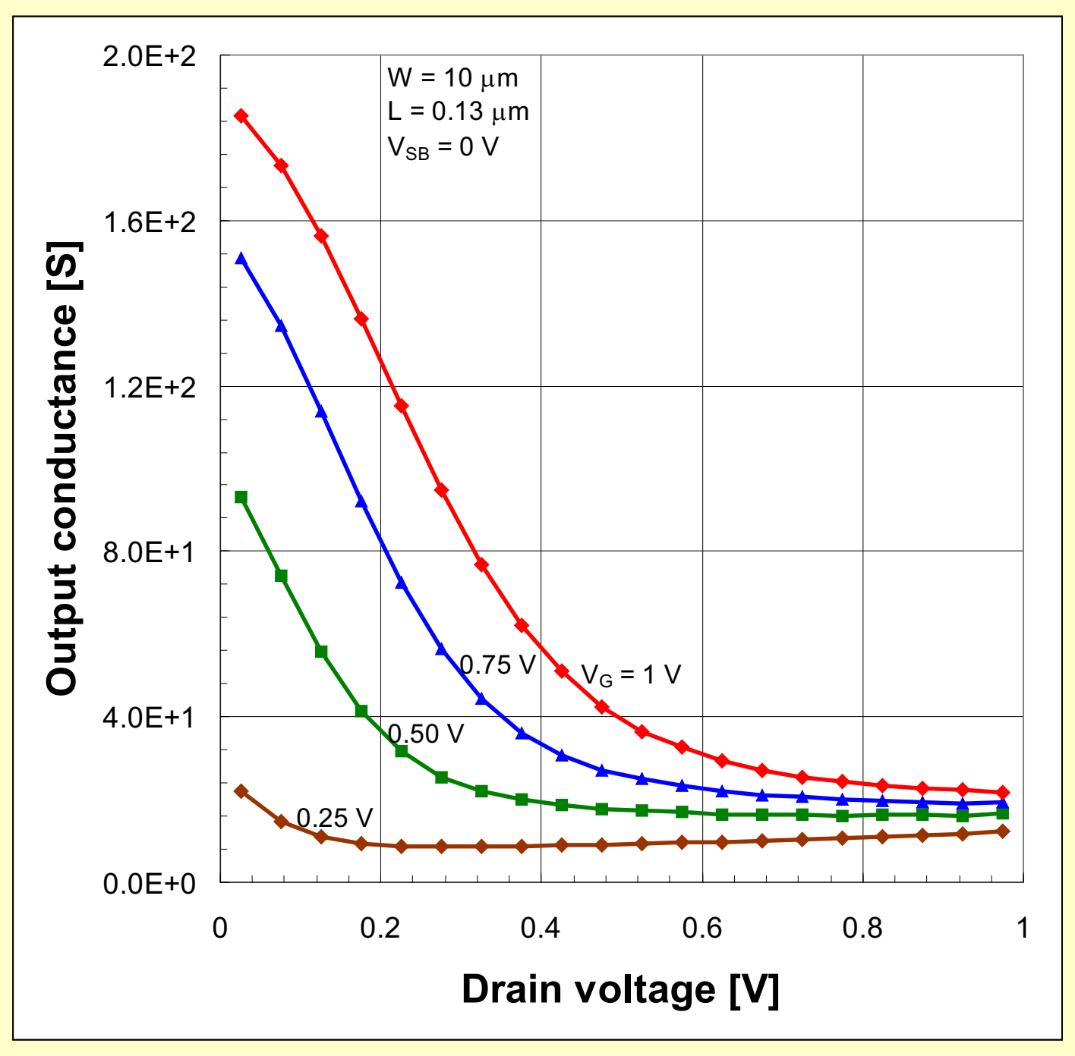


Fig. 3. Output conductance of short-channel transistor.

EKV model

Charge-based, fully-symetric standardized model of DC and AC electrical MOSFET characteristics [6].

- Different mechanisms of transport (e.g. vertical field-dependent mobility, based on effective field
- Vertical/lateral non-uniform doping effects, including Halo/Pocket implant effects and
- Small size effects, accounting for
  - Velocity saturation/channel length modulation
  - DIBL, charge-sharing
  - RSCE, INWE, combined short & narrow-channel effects
- Polydepletion/quantum effects
- Gate tunnelling
- Bias-dependent series resistance model

- Accounts for geometry scaling and temperature scaling

- Predestined for analog ICs design and diagnostics; Implemented in CAD systems

Parameter extraction

- Estimation of size variation ΔW, ΔL and series resistance (Schroder approach [7])

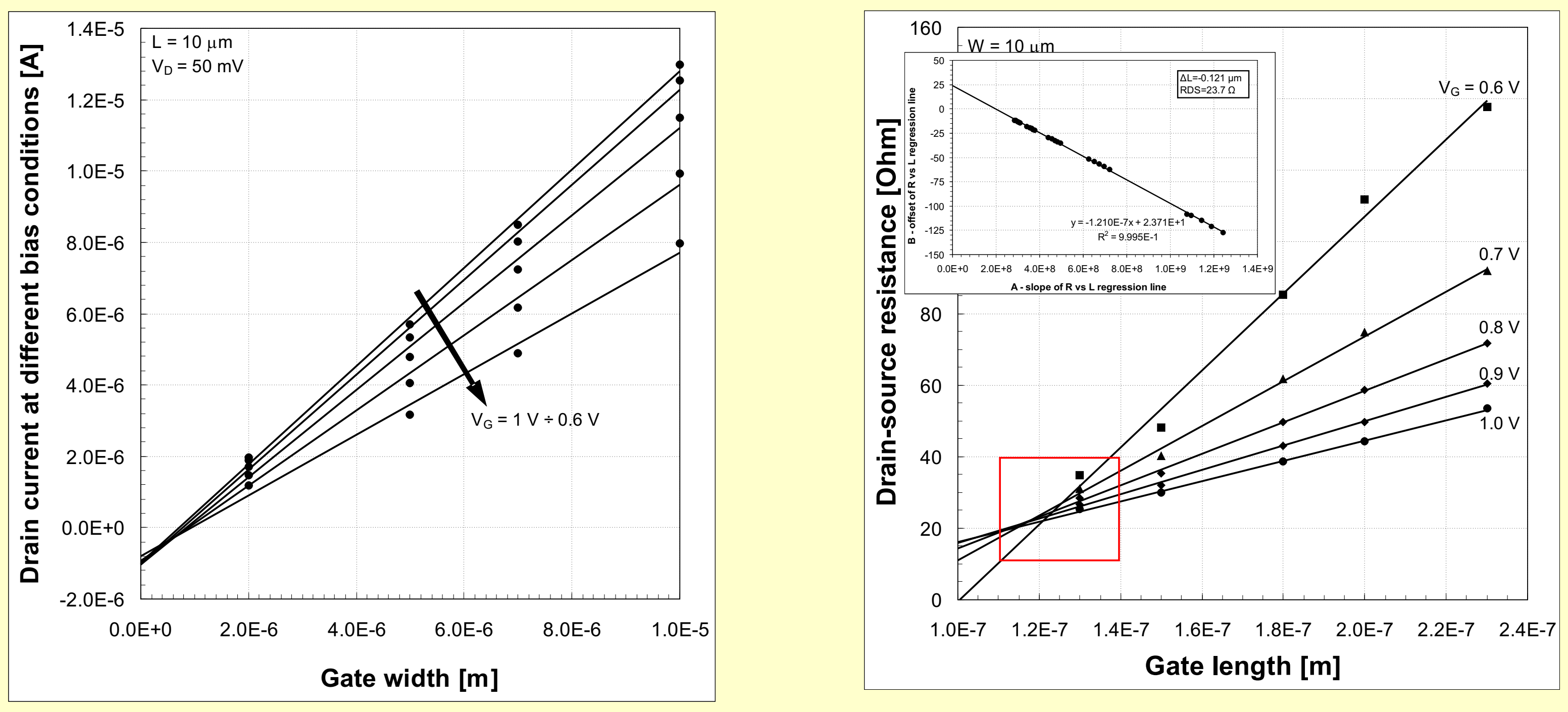


Fig. 4. Extraction of width, length correction and series resistance

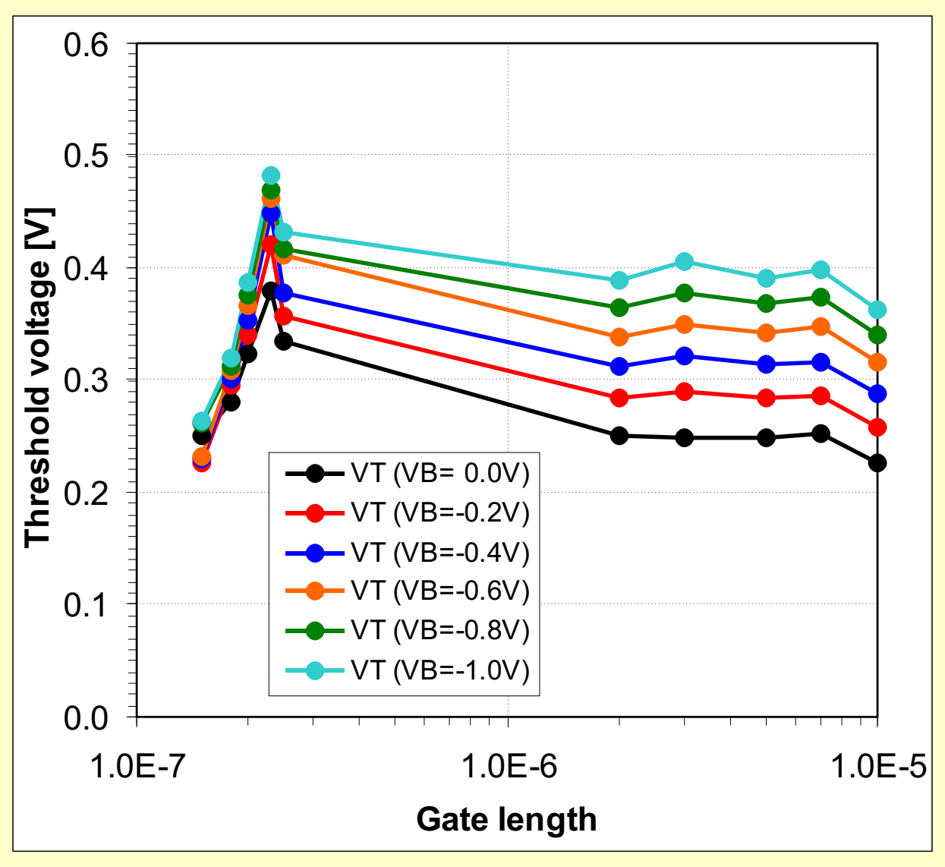
- Estimation of threshold voltage and transconductance
- Estimation of threshold voltage parameters $V_T = V_{T0} + t \cdot \gamma \cdot \left(\sqrt{\Psi_0 - t \cdot V_{BS}} - \sqrt{\Psi_0} \right)$

$$V_{T0} = V_T(0)$$

regression $$V_T - V_{T0} = - \frac{t \cdot 0.5 \gamma^2}{\frac{d V_T}{d V_{BS}}} - t \cdot \gamma \cdot \sqrt{\Psi_0}$$

Selected results

Serial resistance	RSD	Ohm	23.7
Channel shortening	DL	m	-1.21E-7
Channel narrowing	DW	m	-2.07E-7
Transconductance factor	KP	A/V^2	4.59E-4
Threshold voltage	VTO	V	0.245
Body effect factor	GAMMA	V^0.5	0.355
Fermi potential	PHI	V	0.520
Subthreshold slope	S	mV/dec	73.8



Summary:

1) extensive electrical characterization of MOSFETs with ultrathin gate SiON dielectric is presented.
2) basic MOSFETs parameters of EKV model are extracted.
3) due to the short-channel effects and gate leakage current further analysis is necessary in case of small size devices

Acknowledgements:

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