A Trial Report: HiSIM-1.2 Parameter Extraction for 90 nm Technology

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ABSTRACT

This paper describes a parameter extraction procedure for HiSIM (Hiroshima-university STARC IGFET Model) [1] version 1.2 with the application result to practical devices. The procedure followed a traditional approach of the geometry selection for the parameter extraction. It starts with the long and wide channel (Large) device, then proceeds to the various channel length devices under the fixed wide channel width (L-array), finally to the various channel width devices under the fixed long channel length (W-array). No short and narrow channel devices (Small) are used. Semiconductor Technology Academic Research Center (STARC), Yokohama, Japan, permitted the paper author to use the practical device data which was said to be ready for 90 nm node. The result verified the scalability of HiSIM-1.2 down to 100 nm channel length with certain improvement required. The number of optimized parameters were 19. The details will be reported at Nanotech 2004 workshop on compact modeling.

Keywords: HiSIM, surface potential, parameter extraction, compact model

1 INTRODUCTION

As one of surface potential based Spice models, HiSIM version 1.0 was released and placed on a public domain on January 2002 [2]. Although the model was updated to the version 1.2 in April 2003, few parameter extraction result with the extraction procedure was published internationally [3], [4], [5]. This paper presents the extraction strategy with the application to practical devices. The strategy was developed with the consideration of HiSIM model derivation [6]. The device data which was said to be ready for 90 nm node was provided by STARC with the publication permission. Silvaco's UTMOST-III [7] with HiSIM-1.2 was used. In spite of using the specific extraction software, the procedure should be generic enough to be applicable to others.

2 EXTRACTION PREPARATION

2.1 Geometry Selection

The geometry selection should follow the traditional methodology for the scalable model parameter extraction [8] with one exception: HiSIM model has no small size effect parameters.
Large device: the channel width and length were 10 um.
L-array devices: the fixed channel width was 10 um and the channel lengths were 10, 5, 1, 0.5, 0.3, 0.2, and 0.1 um.
W-array devices: the fixed channel length was 10 um and the channel widths were 5, 1, 0.3, 0.15, and 0.11 um.
Small devices: the fixed channel length was 0.1 um and the channel widths were 5, 2, 1, 0.56, 0.3, 0.15, and 0.11 um.

The small devices were used for the model validation.

2.2 Measurement Conditions

The measured DC characteristics follow.
Ids vs. Vgs: Vgs = 0 –> 1.0 (V), Vbs = 0 –> 0.5 (V),
@ Vds = 0.05 and 1.0 (V)
Ids vs. Vds: Vds = 0 –>1.0 (V), Vgs ="near Vth" –>1.0 (V),
@ Vbs = 0 and –0.5 (V)
Ids vs. Vgs: Vgs = 0 –> 1.0 (V), Vds = 0.1 –> 0.5 (V)

The third characteristic is optional and prepared in case for the extraction of high field mobility parameter of HiSIM [6]. In addition to the DC characteristics, Cgg capacitance measurement is required for the oxide thickness determination. The value for this study was provided by STARC. The Cgg characteristic is also required for such effects as poly depletion and quantum-mechanical effects which parameters were untouched for this extraction study.

3 EXTRACTION STRATEGY

Initial parameter values defined were the defaults described in HiSIM1.2.0 User's Manual [9]. In a following description, HiSIM model parameters are capitalized with the bold-faced letters.

3.1 NSUBC and VFBC: Idvg_large_HiSIM

Id/Vgs curves at the low drain voltage (50 mV) under the stepped body bias were used for **NSUBC** and **VFBC** parameters. The sub-threshold to onset of the strong inversion region for the large device (W/L = 10/10 um/um) was the optimizer target. The body bias effect region must be included at this step. Because there is no body bias effect parameter in HiSIM.

Prior to the execution, the **TOX** and **XWD** values were specified as 2.287 (nm) and 22 (nm), respectively. The **XWD** value was determined through the tentative study for the W-array devices. Also for this extraction study, the **LP** was changed [10] from the default (15 nm) to 300 nm which is the upper limit value. The modification was required to express the reverse short channel effect. And the reasonable **LP** determination needs the further study.

The **NSUBP** value was linked to the **NSUBC** during this optimization step in UTMOST to avoid the solver convergence problem. This is assumed that the effective substrate concentration in HiSIM coupled to the **NSUBC**, **NSUBP**, and **LP** might have violated certain criteria.

3.2 MUEPH1, MUECB0, MUECB1, MUESR1: idvg_lowMue_HiSIM

The required characteristic and geometry are exactly the same as in the previous one. These parameters are for HiSIM low field mobility which adopts the mobility universality [11]. Therefore, the target characteristic regions for the parameter optimization should be chosen according to the universality. The **MUEPH1** was optimized from the sub-threshold to onset of the strong inversion region of Ids/Vgs. The **MUECB0** and **MUECB1** were to the strong inversion. And the **MUESR1** was for the maximum Vgs region. The low field mobility parameters should be optimized at this step, especially for P-channel devices. Because the default set represents N-channel devices.

3.3 NSUBP: idvg_middle_HiSIM

The required DC characteristic is the same as in the previous strategies. The geometry should be selected from the L-array devices through the observation of Vth dependency on the channel length: the reverse short channel (RSC) effect devices. Such channel length devices as 5, 1, 0.5, and 0.3 (um) were used for this extraction. The **NSUBP** was capable of expressing the RSC effect for this extraction. And such HiSIM short-channel coefficients as the **SCP1** and **SCP3** had little influence.

3.4 PARL2, SC1,and SC3: idvg_short_HiSIM

The same Id/Vgs curves for the standard short channel (SC) effect devices are used for the **PARL2**, **SC1** and **SC3**. The **PARL2** and **SC1** were optimized first to express the Vth roll-off of the devices, and followed by the **SC2** which is related to the body bias (Vbs) influence on the short channel devices.

Four strategies described so far were applied to Ids vs. Vgs at the low Vds, and the fit result should be fairly acceptable. However, 0.2 um channel length device in this study showed that the simulated Ids/Vgs had rather large Vth compared to the measurement.

3.5 SCP2 and SC2: idvg_highVT_HiSIM

Both the **SCP2** and **SC2** are related to Vds. So Ids/Vgs at the high Vds (1.0 V) was used in the strategy. And the sub-threshold to onset of strong inversion region was defined. The devices for the **SCP2** and **SC2** were 5, 1, 0.5, 0.3 um (RSC devices) and 0.2, 0.1 um (SC devices) channel length devices, respectively.

3.6 VOVER, VOVERP and VMAX: idvg_highVD_HiSIM

HiSIM high field mobility parameters such as the **VOVER**, **VOVERP** and **VMAX** were optimized to the Ids/Vgs at the large Vds (1.0 V). Also, Ids/Vgs curves at several Vds were tried to get the better dependency on the Vds.

3.7 WFC: idvg_narrow_HiSIM

The **WFC** was optimized to such W-array devices as 5, 1, 0.3, 0.15, and 0.11 um channel widths for Ids/Vgs at the low Vds. The Vth roll-off of the devices was expressed well.

4 ACKNOWLEDGEMENT

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(LEVEL = 111
VERSION = 1.2 **CORSRD** = 0 **COOVLP** = 0
COSMBI = 0 **TOX** = 2.287E-9* **XLD** = 0
XWD = 2.2E-8* **XPOLYD** = 0 **XDIFFD** = 0 **TPOLY** = 0
NSUBC = 1.223637E18* **VFBC** = -1.0788913*
LP = 3E-7* **NSUBP** = 1.866911E18* **XQY** = 0
KAPPA = 3.9 **SCP1** = 0 **SCP2** = 0.2063246*
SCP3 = 0 **PARL1** = 1 **PARL2** = 5E-8* **SC1** = 199.64881*
SC2 = 98.54520* **SC3** = 3.027419E-9* **PTHROU** = 0
WFC = 3.744748E-14* **W0** = 0 **COISTI** = 0
WVTHSC = 0 **NSTI** = 1E17 **WSTI** = 0 **QME1** = 4E-11
QME2 = 3E-10 **QME3** = 0 **PGD1** = 0.01 **PGD2** = 1
PGD3 = 0.8 **RS** = 1E-4 **RD** = 1E-4 **RPOCK1** = 1E-4
RPOCK2 = 0.1 **RPOCP1** = 1 **RPOCP2** = 0.5
BGTMP1 = 9.025E-5 **BGTMP2** = 1E-7
MUECB0 = 297.8752771* **MUECB1** = 35.8615598*
MUEPH0 = 0.3 **MUEPH1** = 2.327467E4* **MUEPH2** = 0
MUETMP = 1.5 **MUESR0** = 2 **MUESR1** = 2.180765E15*
NDEP = 1 **NINV** = 0.5 **NINVD** = 1E-9 **BB** = 2
VMAX = 2.034986E7* **VOVER** = 5E-4*
VOVERP = 6.095994E-4* **CLM1** = 0.7 **CLM2** = 2
CLM3 = 1 **COISUB** = 0 **SUB1** = 10 **SUB2** = 20
SUB3 = 0.8 **COGIDL** = 0 **COGISL** = 0 **GIDL1** = 5E-6
GIDL2 = 1E6 **GIDL3** = 0.3 **COIIGS** = 0 **GLEAK1** = 1E4
GLEAK2 = 2E7 **GLEAK3** = 0.3 **GLPART1** = 0
GLPART2 = 0 **VZADD0** = 0.01 **PZADD0** = 5E-3
CONOIS = 0 **NFALP** = 1E-16 **NFTRP** = 1E10
CIT = 0 **EF** = 0)

Table 1: Extracted HiSIM-1.2 model parameters.
The values marked with (*) were optimized.

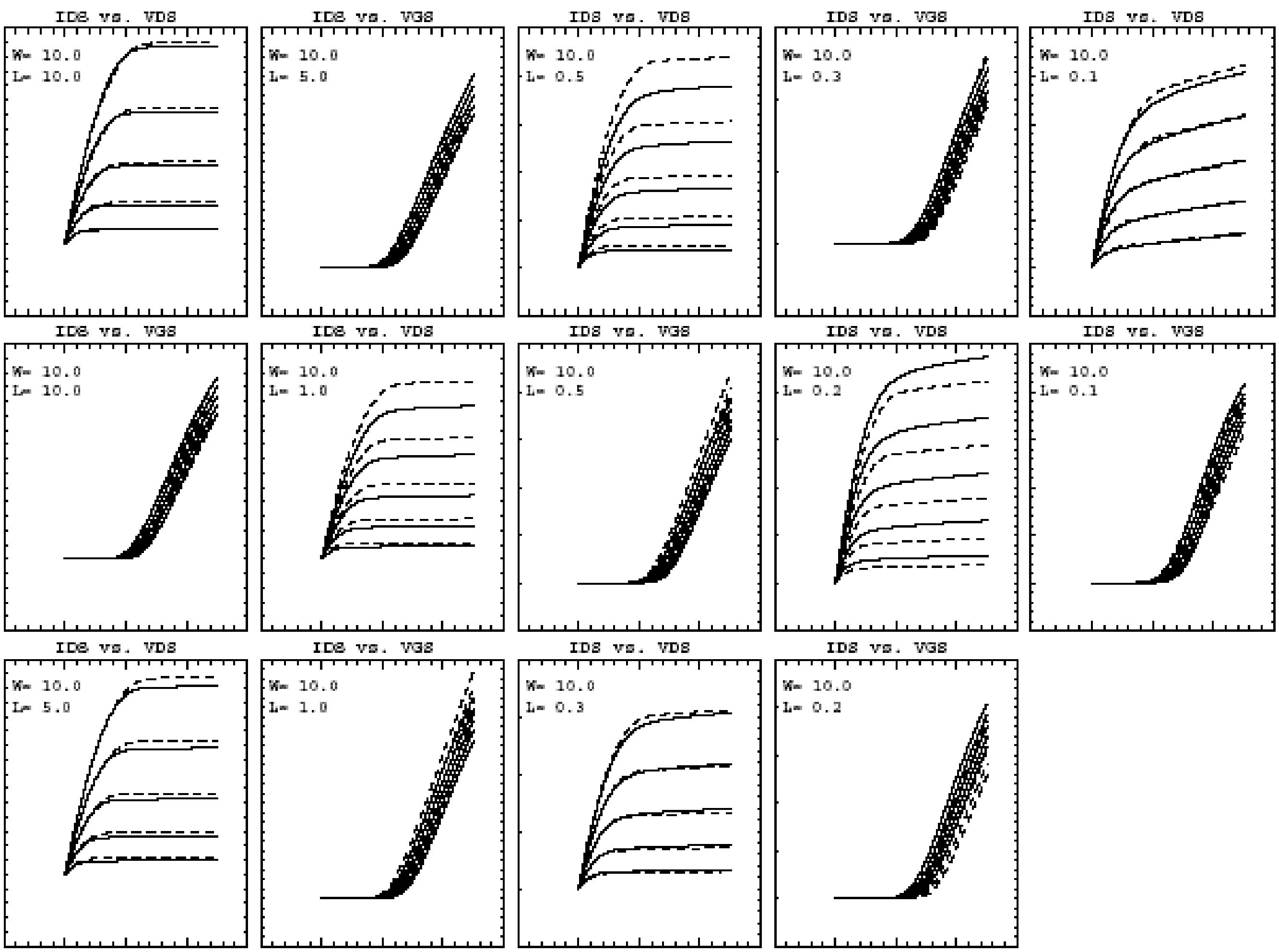

Figure 1: Measured (solid lines) and simulated (dotted)
L-array devices
Ids/Vgs @Vds = 50 (mV), Ids/Vds @Vbs = 0 (V)

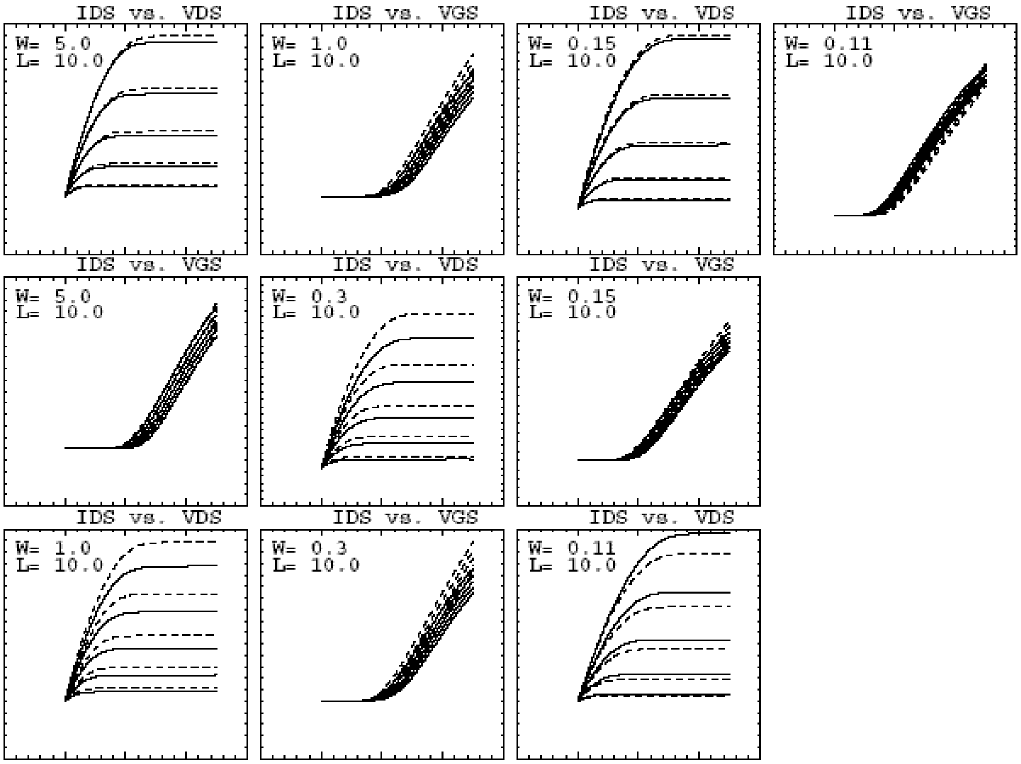

Figure 2: Measured (solid lines) and simulated (dotted)
W-array devices
Ids/Vgs @Vds = 50 (mV), Ids/Vds @Vbs = 0 (V)

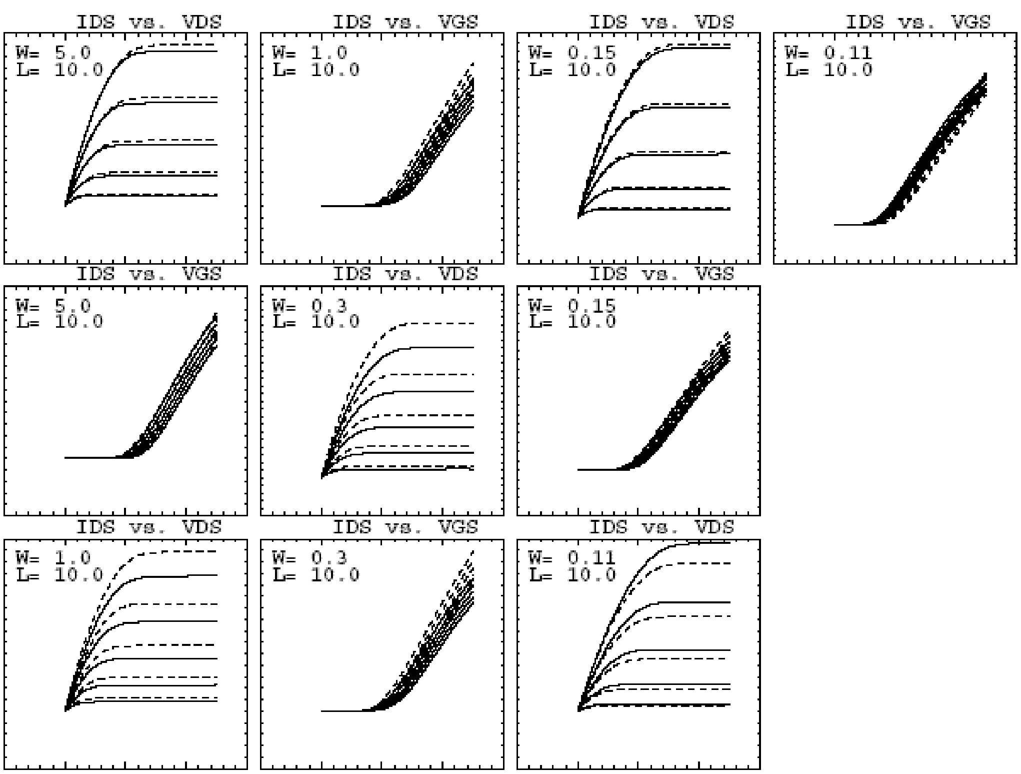

Figure 3: Measured (solid lines) and simulated (dotted)
Small devices
Ids/Vgs @Vds = 50 (mV), Ids/Vds @Vbs = 0 (V)