Verification of the validity of MOSFET lab

(<http://nanohub.org/tools/mosfet>)

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**Simulation setup**

 We will validate results obtained from MOSFET Lab by comparing with analytical model. Set up a simulation run using the following input parameters

1. Input deck page 1

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1. Input deck page 2



**Simulation Output**

1. Transfer characteristics obtained after running MOSFET tool using above input deck. Estimated threshold voltage from the ID-VG plot, **VT ~ 0.33 V*.***

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Figure 1 Id-Vg plot from MOSFET tool

1. Output characteristics obtained after running MOSFET tool using above input deck.



Figure 2 Id-Vd plot from MOSFET tool

**Analytical Verification**

 Output characteristic of a bulk MOSFET are computed using Bulk Charge theory (R.F Pierret, SDF pg. 625). Further results from the analytical model were adjusted for parasitic resistance (RSD) to match simulation results. A value of RSD=1000 Ω was used to fit the data. (MATLAB script given at the end)



Figure 3 Analytical verification of MOSFET Lab. Analytical model using Bulk-Charge (blue) is used to compare simulation results from MOSFET lab (red)

**MATLAB script used for verification**

% Output characteristic (Id-Vd) computed for a bulk MOSFET using Bulk Charge theory

% Series resistance adjusted to compare with MOSFET Lab (https://nanohub.org/tools/mosfet)

% Author: Saumitra R Mehrotra (Purdue University)

clear all

% Load results from MOSFET Lab

load v1.txt;load v2.txt;load v3.txt;load v4.txt;load v5.txt

hold on

disp(['Start of verification']);

% INPUT

% Threshold voltage

 vt=0.33;

% Parasitic Resistance

Rsd=1000; % in Ohms

% CONSTANTS

kT\_q=0.02585; q=1.6e-19;

ni=1e16; %in /m3

Ks=11.9;

% Oxide thickness

tox=2e-9; %in m

% Channel length

L=1000e-9; %in m

% Device width

W=1000e-9; %in m

% Oxide dielectric constant

ko=3.9;

eo=8.85e-12; % in F/m

% Gate capacitance

Co=(ko\*eo)./tox; % in F/m2

% Channel doping

Na= 1e18\*1e6; %in /m3

phiF=(kT\_q)\*log(Na/ni);

Wt=(sqrt((2\*Ks\*eo\*2\*phiF)/(q\*Na)));

Vw=(q\*Na/Co)\*Wt;

% Averaged Mobility for given Na

mu=300e-4; % in m2/Vs

factor=(W\*mu\*Co)./L;

vg=linspace(0.6,1,5); vd=linspace(0,2,100);

for ii=1:1:length(vg) % VG step loop

 for jj=1:1:length(vd) %VD loog

 VG1=vg(ii);VD1=vd(jj);

 term1=Vw\*(sqrt((VG1-vt)./(2\*phiF)+ (1+Vw./(4\*phiF))^2) - (1+Vw./(4\*phiF)));

 if (VD1 <= VG1-vt-term1)

 term2=(4/3)\*Vw\*phiF\*((1+VD1./(2\*phiF)).^1.5-(1+(3\*VD1)./(4\*phiF)));

 id(jj)=factor\*((VG1-vt)\*VD1-(VD1\*VD1/2)-term2);

 else

 term2=(4/3)\*Vw\*phiF\*((1+(VG1-vt-term1)./(2\*phiF)).^1.5-(1+(3\*(VG1-vt-term1))./(4\*phiF)));

 id(jj)=factor\*((VG1-vt)\*(VG1-vt-term1)-((VG1-vt-term1)\*(VG1-vt-term1)/2)-term2);

 end

 f1=VG1-vg(ii)+id(jj)\*Rsd/2;

 VG2=vg(ii)-0.01;VD2=vd(jj)-0.01;

 term1=Vw\*(sqrt((VG2-vt)./(2\*phiF)+ (1+Vw./(4\*phiF))^2) - (1+Vw./(4\*phiF)));

 if (VD2 <= VG2-vt-term1)

 term2=(4/3)\*Vw\*phiF\*((1+VD2./(2\*phiF)).^1.5-(1+(3\*VD2)./(4\*phiF)));

 id(jj)=factor\*((VG2-vt)\*VD2-(VD2\*VD2/2)-term2);

 else

 term2=(4/3)\*Vw\*phiF\*((1+(VG2-vt-term1)./(2\*phiF)).^1.5-(1+(3\*(VG2-vt-term1))./(4\*phiF)));

 id(jj)=factor\*((VG2-vt)\*(VG2-vt-term1)-((VG2-vt-term1)\*(VG2-vt-term1)/2)-term2);

 end

 f2=VG2-vg(ii)+id(jj)\*Rsd/2;

 % adjust for Rsd

 err=1;id\_old=1e7;count=0;

 while(err > 1e-4 & count<=50)

 VG=VG2-f2\*(VG2-VG1)/(f2-f1);

 VD=vd(jj)+2\*(VG-vg(ii));

 term1=Vw\*(sqrt((VG-vt)./(2\*phiF)+ (1+Vw./(4\*phiF))^2) - (1+Vw./(4\*phiF)));

 if (VD <= VG-vt-term1)

 term2=(4/3)\*Vw\*phiF\*((1+VD./(2\*phiF)).^1.5-(1+(3\*VD)./(4\*phiF)));

 id(jj)=factor\*((VG-vt)\*VD-(VD\*VD/2)-term2);

 else

 term2=(4/3)\*Vw\*phiF\*((1+(VG-vt-term1)./(2\*phiF)).^1.5-(1+(3\*(VG-vt-term1))./(4\*phiF)));

 id(jj)=factor\*((VG-vt)\*(VG-vt-term1)-((VG-vt-term1)\*(VG-vt-term1)/2)-term2);

 end

 f=VG-vg(ii)+id(jj)\*Rsd/2; f2=f1;VG2=VG1; f1=f;VG1=VG;

 err=abs(VG2-VG1);

 count=count+1;

 end

 % end Rsd adjusting

 end

 plot(vd,id\*1e6,'b'); % convert in microAmps

end

plot(v1(:,1),v1(:,2)\*1e6,'ro-');

plot(v2(:,1),v2(:,2)\*1e6,'ro-');

plot(v3(:,1),v3(:,2)\*1e6,'ro-');

plot(v4(:,1),v4(:,2)\*1e6,'ro-');

plot(v5(:,1),v5(:,2)\*1e6,'ro-');

disp(['End of verification']);