Report for Take Home Exam: Silvaco

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Best design codes:
https://github.com/yifuhhh/EE396V_TFT/blob/master/FinalExam/BestDesign/TFT_best.in

Data processing codes:
https://github.com/yifuhhh/EE396V_TFT/blob/master/DataProcess/FinalExam.py

1. Introduction

In the report, channel length, channel height and dielectric thickness are swept to improve FOMs of TFT. Here, field effect mobility, subthreshold swing and on-current density are all improved to different extends. On-current density has been focused on as a key FOM. Dielectric thickness would be the design parametric sweep to be discussed in this report.

2. Table of Old Device Characteristics

Figures of Merit	
Field Effect Mobility, μ_{FE} [cm^2/V-s]	0.16
Subthreshold Swing, **S** [V/dec]	0.48
On-current Density, **J** [A/cm^2]	0.12
Semiconductor Channel	
Channel length, **L** [um]	50
Channel width, **W** [um]	180
Channel height, **H** [nm]	200
Gate Dielectric	
Thickness, t_{di} [nm]	200
Metal Contact	
Source work function, W_s [eV]	4.33
Drain work function, W_d [eV]	4.33

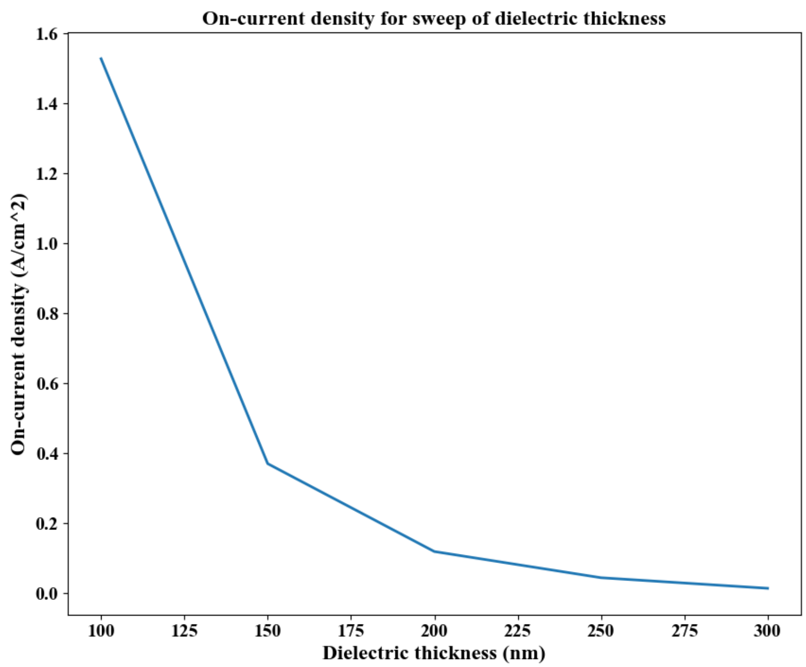
3. Summary of parameter sweep

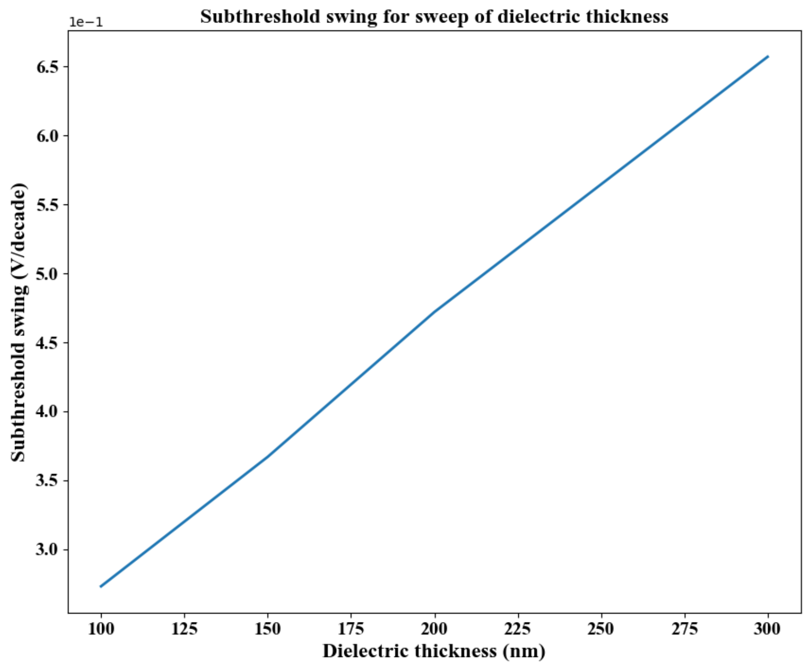
a) Channel height (**H** [nm]): 20, 40, 80, 160, 200, 300.
b) Channel length (**L** [um]): 12.5, 25, 37.5, 50, 62.5.
c) Dielectric thickness (t_{di} [nm]): 100, 150, 200, 250, 300.

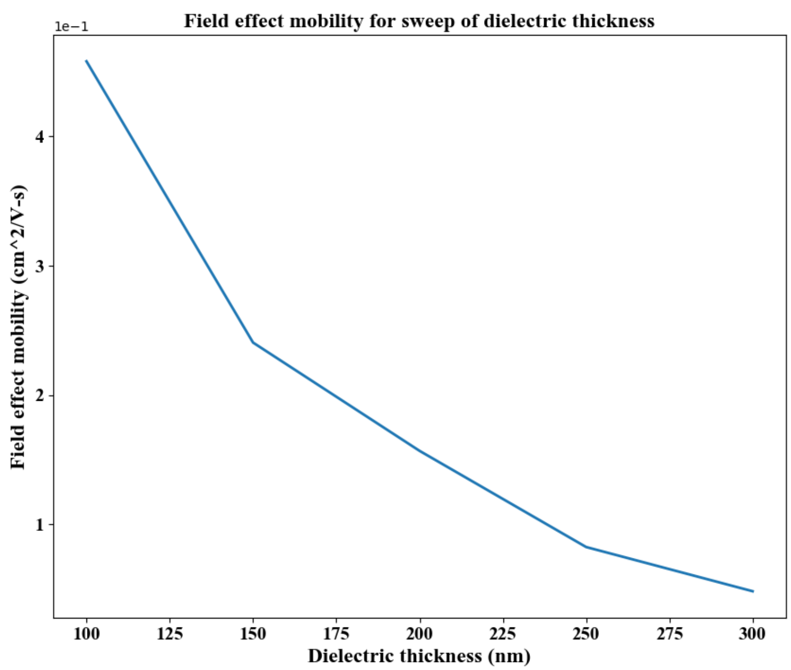
4. Reasoning for sweeping parameter

According to square model of TFT in saturation region($I_d = \frac{\mu C}{2}\frac{W}{L}(V_{gs} - V_{th})^2$) in Wager's review, with the decrease of t_{di}, the dielectric capacity would increase, thus I_d will increase in saturation region, so on-current density will increase with same channel width and height. When channel length is small, the decrease of channel length can lead to small decrease of field effect mobility. When t_{di} and channel length are small, SS will be small. Thus, on-current density enhancement is the focus of t_{di} and channel length sweep.

5. Device analysis





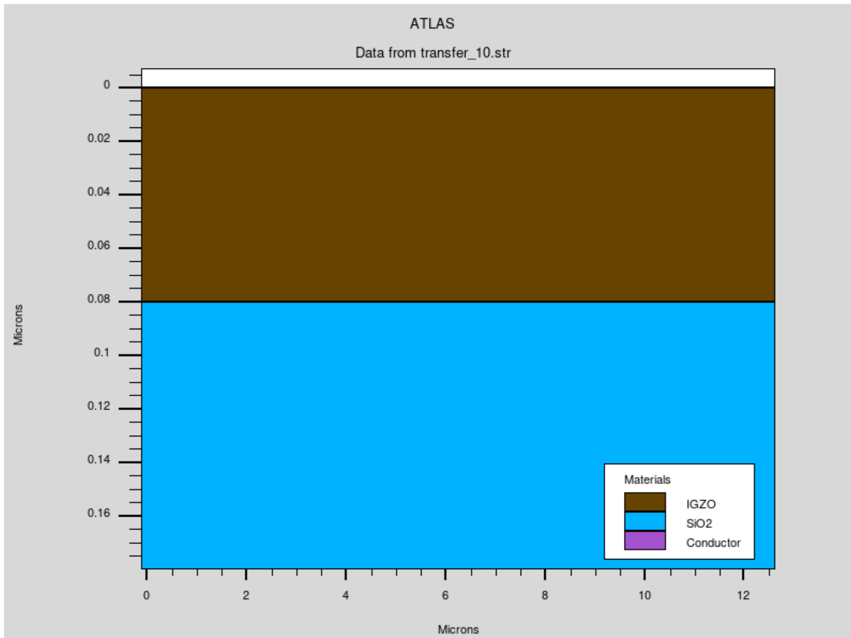


6. Parametric Study Conclusion

From the sweep we can find that when the dielectric thickness decreases, the on-current density will increase rapidly. Also, the subthreshold swing will decrease when the dielectric thickness decreases, which is desirable. The field effect mobility will increase when the dielectric thickness decreases. In general, dielectric thickness will be a good parameter for tuning.

7. Full Summary of Best Device

7.1 Figure of device



7.2 Design choice

Here I chose to tune L, H and t_{di} in order to get a higher on-current density. The parameters value and outcome of the best design are listed in the following table. Parameters modified are in the color of green. The improvements are in the color of red.

From the plots for sweep of H and L we can get that, to increase the on-current density as well as reduce the subthreshold swing, channel length should decrease. Field effect mobility would increase when channel length decreases. However, when channel height decreases a lot, mobility would decrease dramatically. Taking this information into consideration, I chose to reduce H a little, while channel length and dielectric thickness are both the smallest value in the sweep respectively.

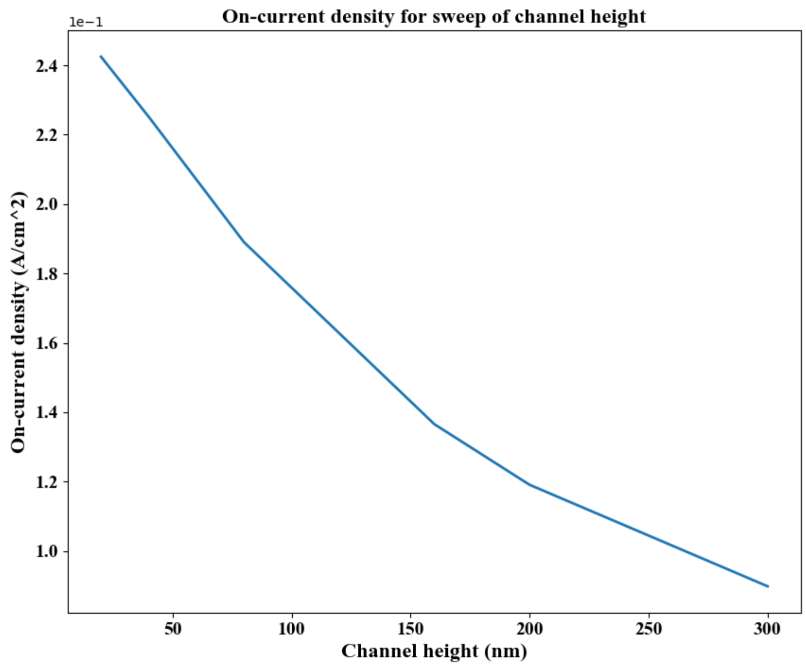
Figures of Merit		**Improvement**
Field Effect Mobility, $\boldsymbol{\mu}_{\mathbf{FE}}$ [cm^2/V-s]	0.44	175%
Subthreshold Swing, **S** [V/dec]	0.27	-43.8%
On-current Density, **J** [A/cm^2]	14.82	12250%
Semiconductor Channel		
Channel length, **L** [um]	12.5	
Channel width, **W** [um]	180	
Channel height, **H** [nm]	80	
Gate Dielectric		

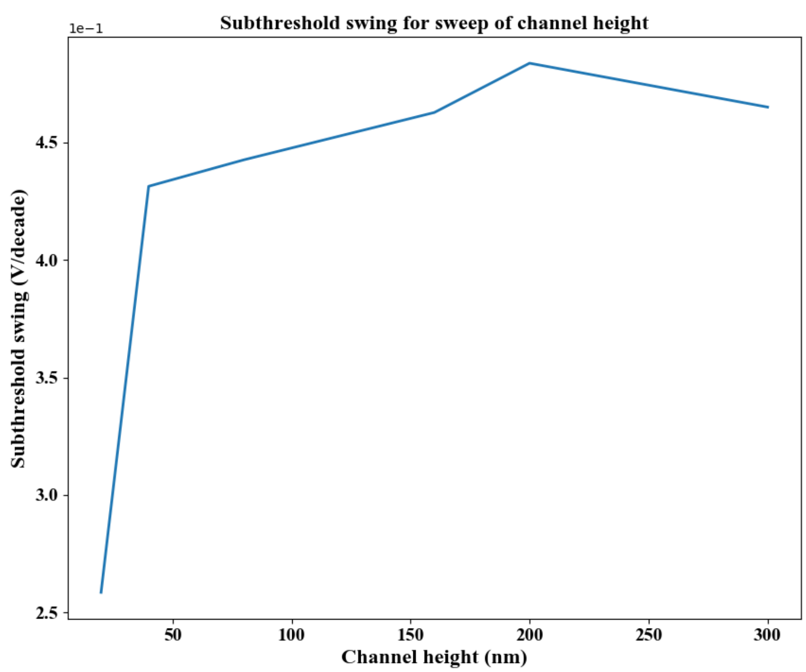
Thickness, $\mathbf{t_{di}}$ [nm]	100
Metal Contact	
Source work function, $\mathbf{W_s}$ [eV]	4.33
Drain work function, $\mathbf{W_d}$ [eV]	4.33

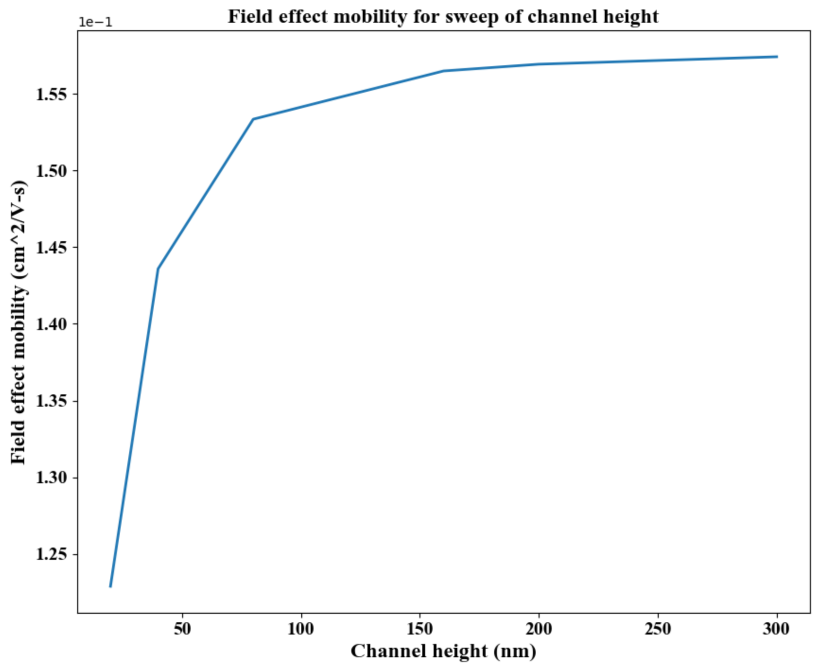
7.3 Design summary table

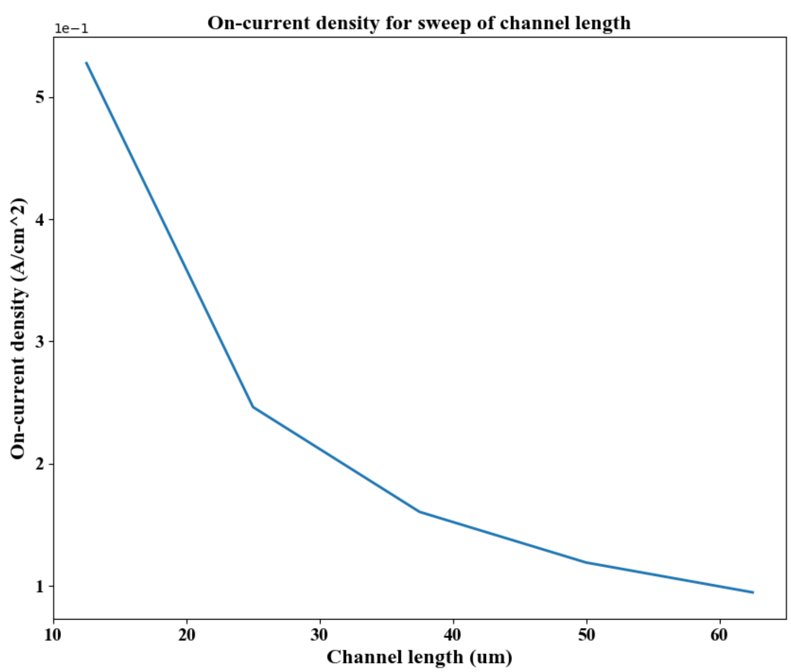
Figures of Merit														
μ_{FE} [cm^2/V-s]	0.16	0.12	0.14	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.46	0.24	0.08	0.05
S [V/dec]	0.48	0.26	0.43	0.44	0.46	0.46	0.17	0.47	0.48	0.47	0.27	0.37	0.57	0.66
J [A/cm^2]	0.12	0.24	0.23	0.19	0.14	0.09	0.53	0.25	0.12	0.09	1.53	0.37	0.04	0.01
L [um]	50	50	50	50	50	50	12.5	25	37.5	62.5	50	50	50	50
W [um]	180	180	180	180	180	180	180	180	180	180	180	180	180	180
H [nm]	200	20	40	80	160	300	200	200	200	200	200	200	200	200
$\mathbf{t_{di}}$ [nm]	200	200	200	200	200	200	200	200	200	200	100	150	250	300
$\mathbf{W_s}$ [eV]	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33
$\mathbf{W_d}$ [eV]	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33

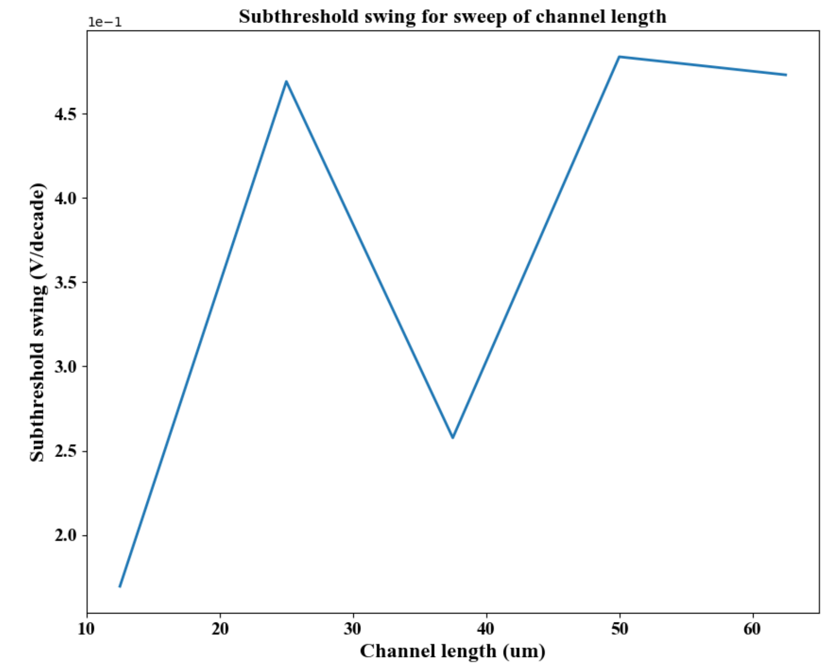
7.4 Plots for sweep of H and L

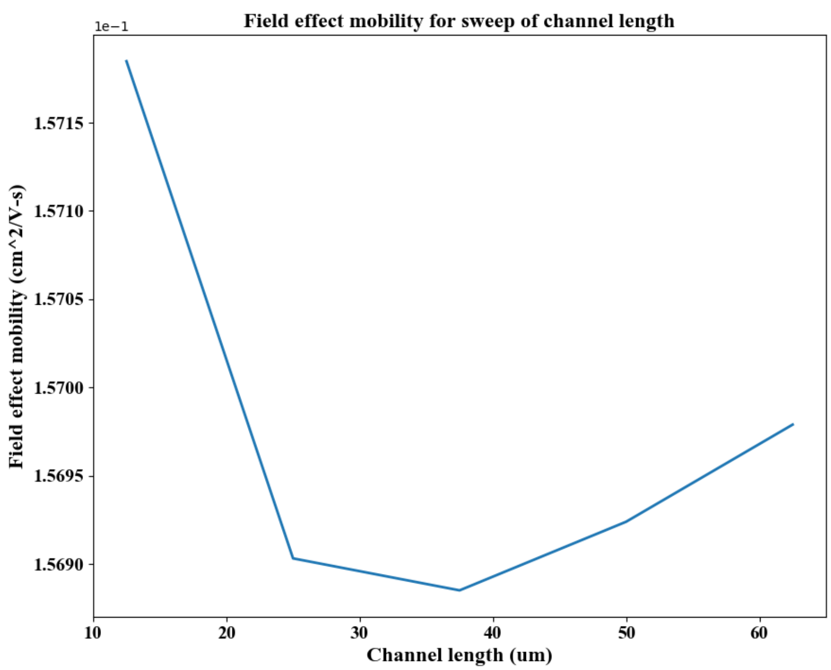

On-current density for sweep of channel height
1e−1
On-current density (A/cm^2)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
50
100
150
200
250
300
Channel height (nm)


Subthreshold swing for sweep of channel height
1e−1
Subthreshold swing (V/decade)
4.5
4.0
3.5
3.0
2.5
50
100
150
200
250
300
Channel height (nm)


Field effect mobility for sweep of channel height
1e−1
Field effect mobility (cm^2/V-s)
1.55
1.50
1.45
1.40
1.35
1.30
1.25
50
100
150
200
250
300
Channel height (nm)


On-current density for sweep of channel length
1e−1
On-current density (A/cm^2)
5
4
3
2
1
10
20
30
40
50
60
Channel length (um)


Subthreshold swing for sweep of channel length
1e−1
Subthreshold swing (V/decade)
4.5
4.0
3.5
3.0
2.5
2.0
10
20
30
40
50
60
Channel length (um)


Field effect mobility for sweep of channel length
1e−1
Field effect mobility (cm^2/V-s)
1.5715
1.5710
1.5705
1.5700
1.5695
1.5690
10
20
30
40
50
60
Channel length (um)