# Two-Dimensional Analytical Modeling of Fully Depleted Poly-crystalline Silicon Thin Film Transistor

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## ABSTRACT

Recently polycrystalline silicon (poly-Si) thin-film transistors (TFTs) have emerged as the devices of choice for many applications such as AMLCDs, printers heads, scanners, SRAMs, image sensors, high performance EEPROMs etc. In this paper two-dimensional analytical modeling of fully depleted Poly-Si TFT is presented with no fitting parameters showing the grain-grain boundary interface effects. The results so obtained are verified with numerical model.

The forward problem in electrostatics whose only complication is due to the non-linearity of Poisson's equation: the electrostatic potential $\Phi$ is determined by the carrier concentrations $n$ and $p$ whose values depend themselves on $\phi$. Furthermore, complexity in determining potential solution increases in case of short-channel devices as Poisson's equation becomes two variable problem. This has led to the use of depletion approximation (sub-threshold regime) in our analysis. In order to analytically model the 2-D characteristics of short-channel poly-Si thin film transistor, the boundary conditions incorporated to solve 2-D Poisson's equation must be appropriate.

The Green's function technique is used to determine the exact solution of 2-D Poisson's equation and can be used for any doping profile. The basic structure of polycrystalline silicon (poly-Si) thin-film transistor is analogues to that of SOI MOSFETs but replacing single crystal silicon (c-Si) film with that polycrystalline silicon thin film (active region) and the second gate (bottom gate) is absent. The 2-D Poisson's equation for the system is given as:

$$\frac{\partial^2 \Phi(x,y)}{\partial x^2} + \frac{\partial^2 \Phi(x,y)}{\partial y^2} = -\frac{\rho(x,y)}{\varepsilon_{Si}} \qquad (1)$$

where $\rho(x,y)$ is the 2-D space charge density in the different regions and is given as

$$\rho(x,y) = \begin{cases} 0 & -t_{ox}^{g} \le y < 0 \\ -q \cdot N_{eff}(x) & 0 \le y \le t_{poly} \\ 0 & t_{poly} < y \le t_{ox}^{b} \end{cases} \qquad (2)$$

where $t_{poly}$ is the thickness of Poly – *Si* film, $t_{ox}^{g}\left(t_{ox}^{b}\right)$ is the thickness of gate oxide (buried oxide), $q$ is the elementary charge and $\varepsilon_{Si}$ $(\varepsilon_{ox})$ is the dielectric permittivity of *Si* $(SiO_2)$.

$$N_{eff}(x) = \begin{cases} N_{gr} & when\ x\ lies\ in\ grain \\ N_{gb} & when\ x\ lies\ in\ grain\ boundary \end{cases}$$

where $N_{gr}$ and $N_{gb}$ are doping densities in grain and grain boundary respectively taking into account the contribution of trap charges.

The expression for the 2-D potential using Green theorem [1] and substituting Green's function is obtained and is given by

$$\Phi(x,y) = \iint_V \frac{\rho(x',y')}{\varepsilon} \cdot G(x,y;x',y')dx'\,dy' + \oint_S \frac{\partial \Phi(x',y')}{\partial n'} \cdot G(x,y;x',y')dS - \oint_S \Phi(x',y') \cdot \frac{\partial G(x,y;x',y')}{\partial n'} dS' \qquad (3)$$

where *G(x,y,x',y')* is the green function.

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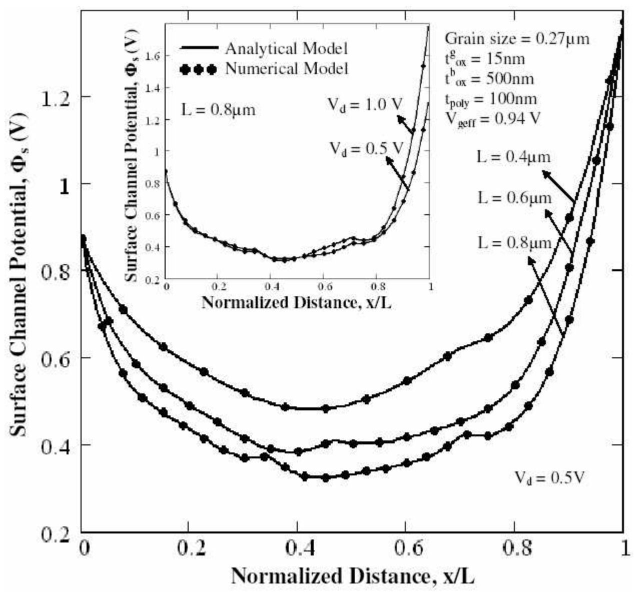


Fig.1 Variation of Surface Channel Potential with Normalized Channel Distance showing the effect of grain boundary.

The variation of Surface Channel Potential with Normalized Channel Distance showing the effect of grain boundary is shown in Fig.1. The results so obtained are compared with numerical model and show an excellent agreement, thus proving the validity of our 2-D model where no fitting parameters are used.

## REFERENCES

[1] J. D. Jackson, "Classical Electrodynamics", John Wiley & Sons, Inc., 1975.

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