Universal Mobility-Field Curves For Electrons In Polysilicon Inversion Layer

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***Abstract*-- This paper reports the studies on the inversion-layer mobility in n-channel Poly-Si TFT's with 10^{16}cm^{-3} substrate impurity concentration. The validity and limitations of the universal relationship between the inversion layer mobility and the effective normal field (E_{eff}) was examined.**

***Index Term*– TFT, Grain boundaries, carrier mobility, polysilicon**

I. INTRODUCTION

It is strongly required to understand the inversion – layer mobility from modeling viewpoint for accurate device simulation, as well as from two-dimensional physics viewpoint. Though a qualitative understanding has already been obtained within moderate device parameters, it is indispensable to establish an accurate mobility model in a wide range of device parameters for realizing future ULSI's. Furthermore, the characterization of mobility degradation is important, in order to predict the performance of Poly-Si TFT's degraded by electric stress and others like trap, de-trap and surface roughness scattering.

On the other hand, it has already been reported that electron and hole mobilities in the inversion-layer follow universal curves, independent of the substrate impurity concentration, when plotted as a function of effective normal field [1]-[3]**.**This relationship provides a simple guideline, which gives mobility values under a combination of various device parameters.

This paper reports results of mobility behaviors in n-channel Poly-Si TFT's with 10^{16} cm^{-3} substrate impurity concentration . Also, the mobility degradation by phonon scattering was studied. From these experimental results, the validity and limitations of the universal relationship have been examined.

II. SAMPLE PREPARATION AND MEASUREMENT

The n-channel Poly-Si used in this study was fabricated on (100)Si wafer. The substrate impurity concentration is 10^{16}cm^{-3} and the gate oxide's thickness is 30nm. The measured devices had 1um gate lengths and 100um gate widths. The carrier mobility μ_{eff} was determined from the drain conductance g_D for the Poly-Si TFT in the linear region(V_D =50mV).

$$\mu_{eff} = \frac{L}{W} \cdot \frac{g_D(V_G)}{qN_s(V_G)} \quad (1)$$

Where,

$$E_{eff} = \frac{N_{dpl}+\eta N_s}{\varepsilon_{Si}} \quad (2)$$

and

$$N_{dpl} = \frac{4\varepsilon_{Si}N_{sub}\phi_b{}^{1/2}}{q} \quad (3)$$

In order to determine μeff accurately, the inversion carrier density $N_s(V_G)$ must be measured with a minimal measurement error. $N_s(V_G)$was therefore ,determined directly through gate-channel capacitance C_{gc} (V_G) measurement[4-5].

$$qN_s(V_G) = \int_{-\infty}^{V_G} C_{gc}(V_G)dV_G \quad (4)$$

Here, the measurement frequency was 300kHz (depend on the type of device), which enable to measure capacitance values accurately, even near the threshold voltage[5]. The effective normal field , E_{eff} ,was defined by the following equation.

$$E_{eff} = \frac{q(N_{dpl}+\eta N_s)}{\varepsilon_{si}} \quad (5)$$

where N_{dpl} = (4 Є $_{Si}$N$s_{ub}$$\phi_b$/q)/$^{1/2}$is the bulk surface charge density. N_{sub} is the substrate impurity concentration, and ϕ_b is the bulk Fermi energy. Here, η=1/2 for electron mobility was used, following previous reports [1]-[3].

III. EXPERIMENTAL RESULT AND DISCUSSION

3.1 *I-V* Measurent Result

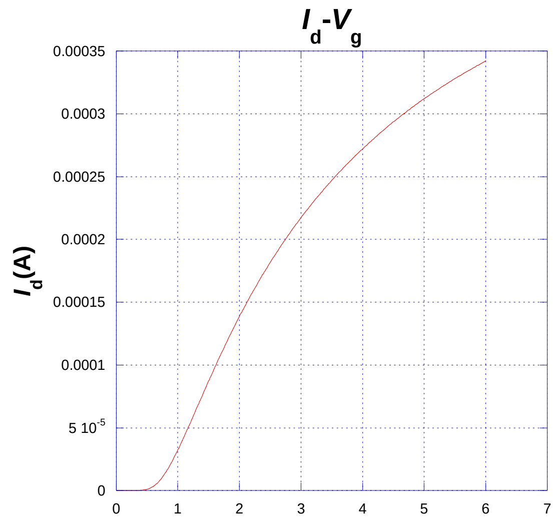

Fig.. 1. Measured drain current versus gate voltage.

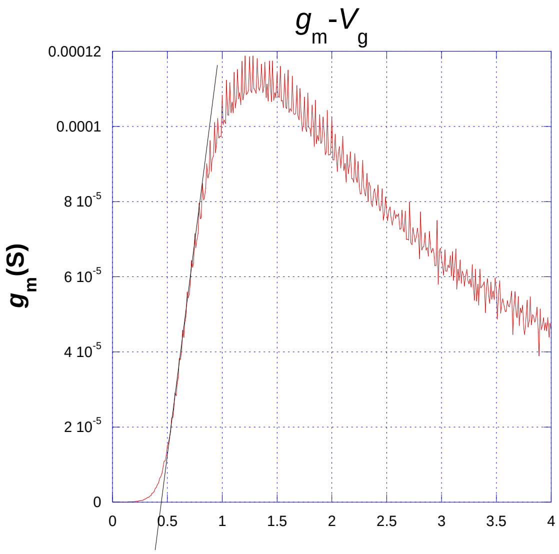

Fig. 2. Measured g_m versus gate voltage and the way how threshold voltage was determined.

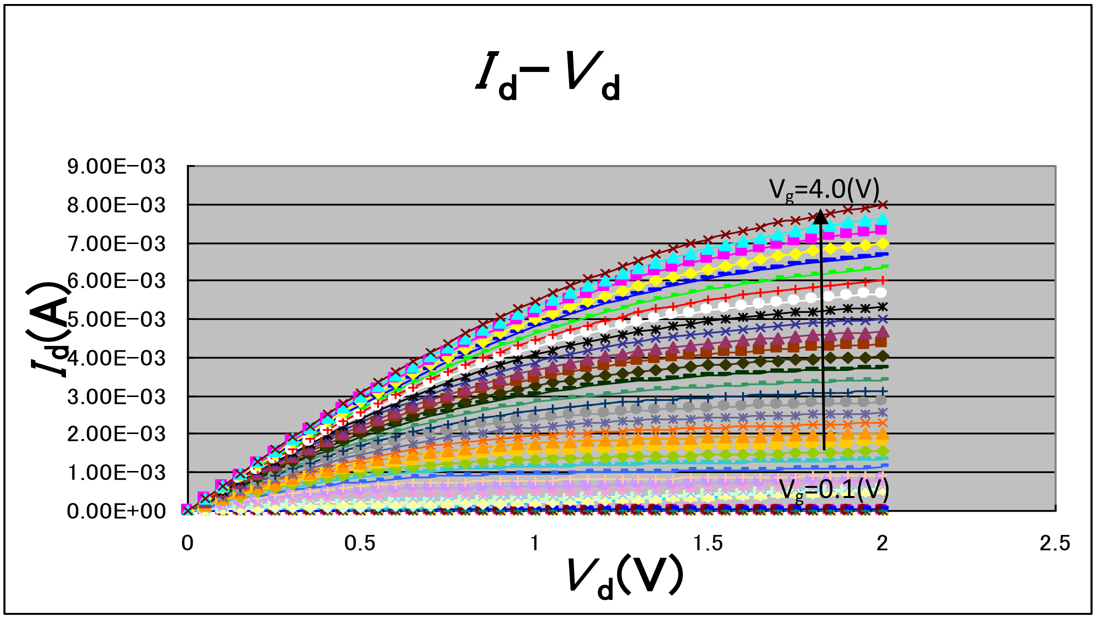

Fig.. 3. Measured drain current versus drain voltage as a parameter of gate voltage.

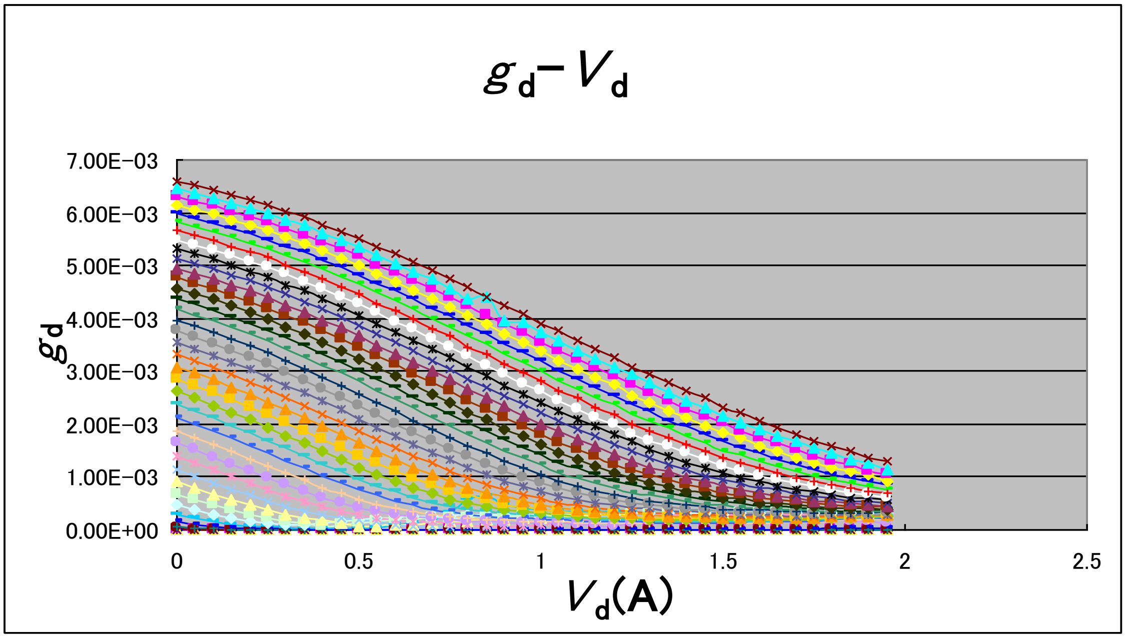

Fig. 4. Measured g_D versus drain voltage as a parameter of gate voltage.

3.2 *C-V* Measurement

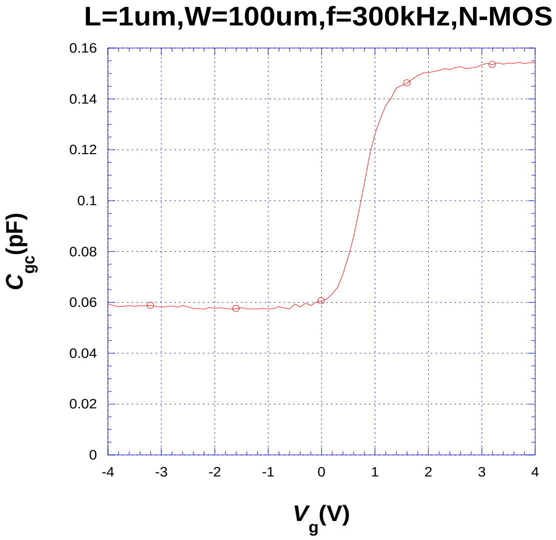

Fig. 5. Measured gate-capacitance, C_{gc} versus gate voltage.

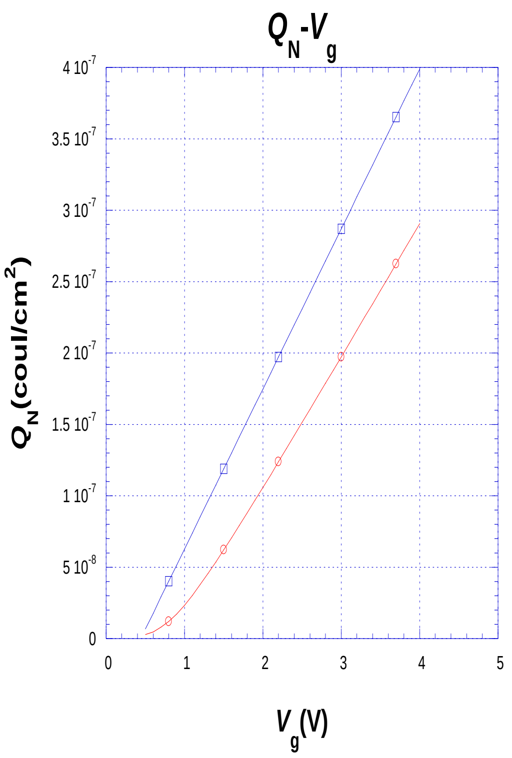

Fig.. 6. Calculated (blue line) and measured (red line) channel charge versus gate voltage is plotted on a linear scale.

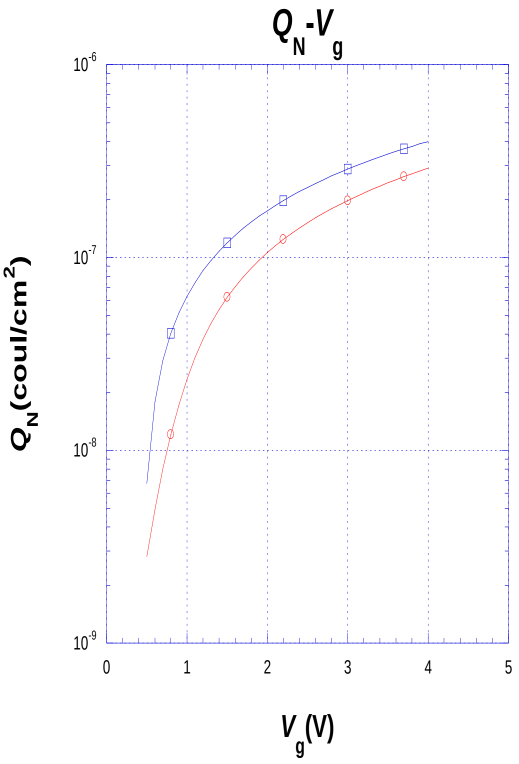

Fig. 7. Calculated (blue line) and measured (red line) channel charge versus gate voltage is plotted on a logarithmic scale.

3.3 Universal Relationship in N-channel Poly-Si TFT's

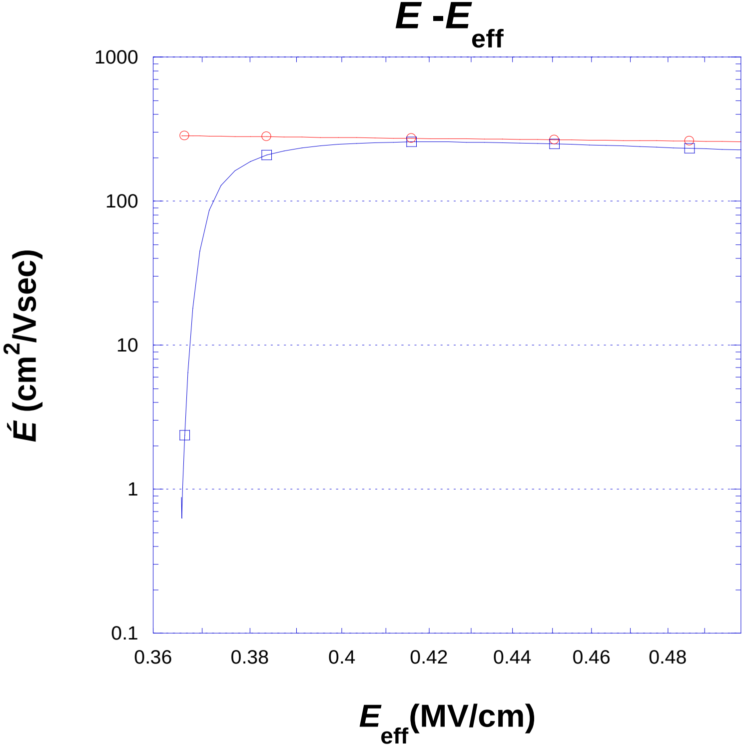

Fig. 8. Effective electron mobility μ_{eff} in n-channel Poly-Si TFT's versus effective field $E_{eff.}$

Figure 8 shows the E_{eff} dependence of the inversion-electron mobility at about 300K(room temperature). It should be notice concerning electron mobility in Figure 8 that the E_{eff} dependence of electron mobility is in proportion to $E_{eff}^{-0.3}$ at E_{eff} from 0.4(MV/cm) to 0.45(MV/cm),over the one order of magnitude E_{eff} range. But electron mobility starts to decrease steeply at E_{eff} higher than 0.45(MV/cm),though the universality is maintained. Besides, the electron mobility value is degraded to a single figures lower than MOSFET's mobility.

As is well known, the dominant scattering mechanism in the Si inversion-layer is phonon scattering at high temperature and surface roughness at low temperature and high normal field. Therefore, it can be considered that the mobility which has $E_{eff}^{-0.3}$ dependence in figure is limited by phonon scattering [6] and also if E_{eff} higher than 0.45(MV/cm) the mobility value starts to decrease steeply .Hence , the significant decrease in mobility is thought to be caused by surface roughness scattering[7]. But in Poly-Si TFT, the effect by surface roughness is faster because of the grain- boundaries in channel region. This is also can be explained by electrons trap and de-trap phenomenon(Figure 9).

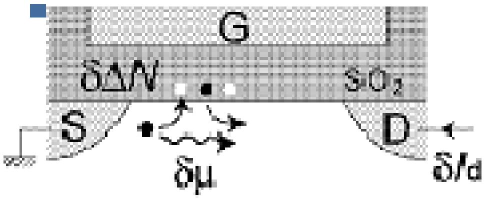

Fig. 9. Trap and de-trap phenomenon image

IV. CONCLUSION

This paper reports the studies on the inversion-layer mobility behaviors in n-channel Poly-Si TFT's, from the universal relationship viewpoint. A significant mobility lowering has been observed at low N_s(low effective field), which is due to Coulomb scattering /screen effect. Also, in n-channel Poly-Si TFT's the significant decrease in mobility is thought to be caused by surface roughness scattering which is faster because of the grain- boundaries in channel region. Besides, the degradation of carrier-mobility in Poly-Si TFT's has been found. This is thought to be caused by grain-boundaries.

From these facts, it can be concluded that, by adding the term of surface roughness and Coulomb scattering to the universal curves, a more accurate description of inversion-layer motilities can be realized.

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