第一回複合創造領域シンポジウム

Remote Coulomb and roughness scatterings in gate oxide scaling

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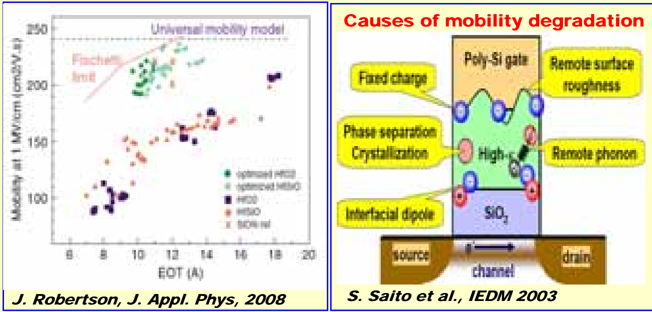
Background

Mobility degradation is one of the main concerns in the high-k gate stacked MOSFETs.

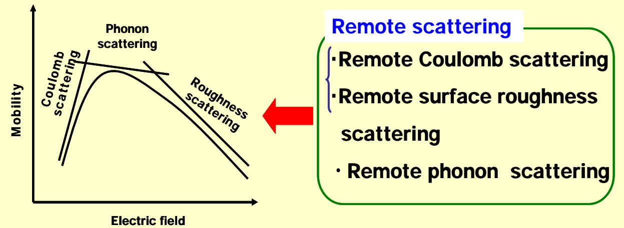


J. Robertson, J. Appl. Phys, 2008

S. Saito et al., IEDM 2003

Purpose

Importance of Remote scattering for direct contact MOSFETs



Aim

•Remote surface roughness (RSR) scattering effect on electron mobility in La_2O_3 gate stacked MOSFETs

Model

RCS scattering model:

Definition

Scattering from fixed charges at the gate/high-k interface, and at the high-k/ silicate interface

La_2O_3
La-sil
Si

RSR scattering model:

Definition

Scattering from Roughness at the gate /high-k interface, and at the high-k/silicate interface

Metal gate
L
Δ(r)
La_2O_3
T_{ox}
Substrate

La_2O_3/Si interface supposed as an ideal smooth surface。

● **Calculation method**

Scattering potential
⇩
< Relaxation time >
⇩
Carrier mobility

Parameters

Roughness Δ, roughness correlation length L, roughness distribution R

$$R(r)=\Delta e^{-\sqrt{2}r/L}$$

The RCS, and RSR limited mobility can be solved by Schrödinger equation and Self-consistent Poisson equation.

Experiment

Fabrication Process and structure of Sample

Fabrication process

- p-type Si substrate
- SPM, HF last treatment
- Deposition of high-k (La_2O_3 , CeO_2/La_2O_3)
- Metal gate deposition (W by RF sputtering)
- Gate patterning
- PMA (500℃, 30min) F.G. (N_2:H_2=97%:3%)
- S/D holing and Al wiring
- Back side Al contact

Measurement

Sample structure

W / La_2O_3 / Si

W / CeO_2 / La_2O_3 / Si

Results

RCR limited electron mobility simulation and experimental result

Scattering potential

Effective electric field (MV/cm)

Effect of Ce capping

	V_{th} (V)	SS (mV/dec)	peak m_{eff} (cm^2/V.s)
With Ce capping	-0.12	70.8	205
Without CeO_x	-0.41	81.6	169

Mobility in CeO_2/La_2O_3 gate stack MOSFET is larger than in single La_2O_3 layer MOSFET。

Experimental result for RCS limited mobility

Experimental and analytic result

Experimental value
Analytic(Nfix=4E12)
Analytic(Nfix=6E13)
Effective electric field(MV/cm)
RCS limited mobility($cm^2V^{-1}s^{-1}$)

RSR limited electron mobility simulation result

T=35K, L=4nm, T_{ox}=3nm (Delta=0.3nm, Delta=0.4nm, Delta=0.5nm)

T=35K, Δ=0.5nm, T_{ox}=3nm (L=2nm, L=3nm, L=4nm)

T=35K, L=3nm, Δ=0.5nm (Tox=3nm, Tox=4nm, Tox=5nm)

T=300K, L=4nm, Δ=0.2nm (Universal curve, Effective mobility(Expo))

Inversion charge density ($10^{13}cm^{-2}$)

RSR-limited mobility ($10^5cm^2V^{-1}s^{-1}$)

Conclusion

➤ *Capping of the CeO_2 on La_2O_3 layer can control the amount of the fixed charges in the gate. Therefore the RCS limited mobility can be improved by proper capping of CeO_2 on La_2O_3 layer MOSFETs。*

➤ *For a larger value of the roughness correlation length and for a larger value of the oxide thickness, the remote Coulomb scattering play dominant role than RSR scattering.*