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Cross-sectional distribution of phonon-limited electron mobility in rectangular silicon nanowire field effect transistors

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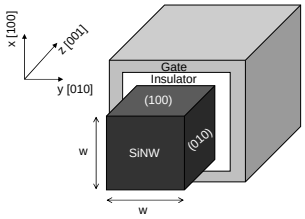
Introduction

The silicon nanowire field effect transistor (SiNW FET) is one of the promising devices because of its good immunity for short channel effects.

In rectangular SiNW FETs, electron states at corner and side consist of differently occupied subband states since spatial probability density of each subband is different. Therefore, the mobility would be different at the corner and the side.

Methods[1,2)]

Self-consistent solution of 2D Schrödinger and Poisson equations were used for electron state calculation.



Intra- and inter-valley acoustic and inter-valley optical phonon scattering mechanisms were considered.

The Kubo-Greenwood formula were used for the mobiliy calculation

Results and discussion

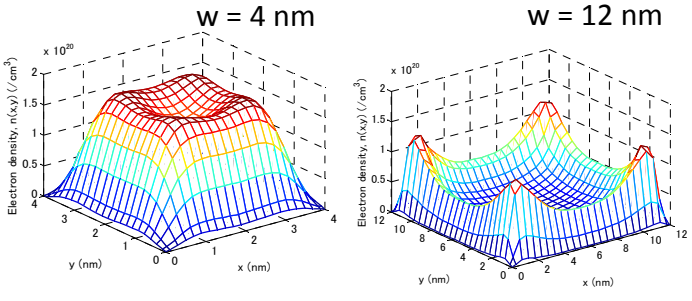
Input parameters $\begin{cases} n_p = 10^{16}\ /\mathrm{cm}^3 & T = 300\ \mathrm{K} \\ t_{ox} = 1\ \mathrm{nm} & V_G = 1\ \mathrm{V} \end{cases}$

Width dependence of phonon-limited mobility, μ_{ph}

w (nm)	N_{inv} (/cm^2)	μ_{ph} (cm^2/V·s)
4	1.1 x 10^{13}	557
12	1.1 x 10^{13}	725

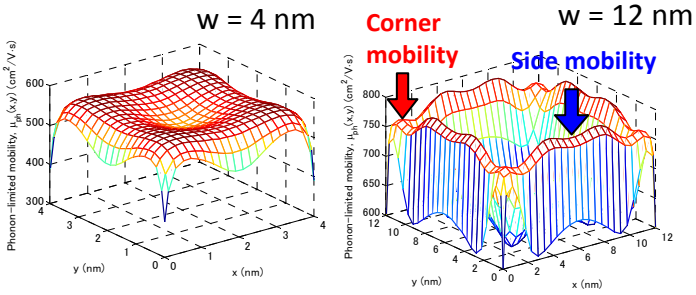
The small SiNW FET shows low mobility because of large wave function overlap.[1,2)]

Cross-sectional distribution of electron density



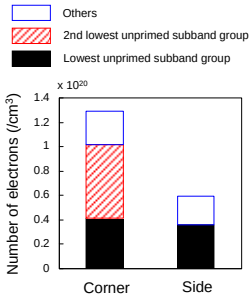
In *w* of 12 nm, corner electron density is approximately twice of planar electron density

Cross-sectional distribution of mobility



In *w* of 12 nm, corner mobility is lower than side mobility.

Subband composition at corner and side

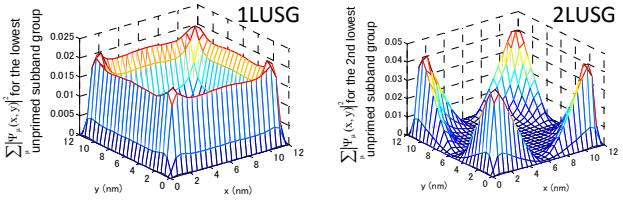


Mobility for each subband type

Subband type	μ_{ph} (cm^2/V·s)
Lowest unprimed subband group (1LUSG)	898
2nd lowest unprimed subband group (2LUSG)	783

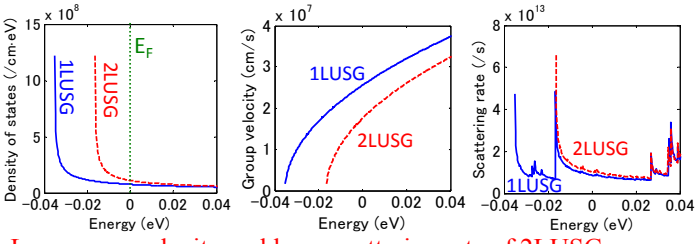
The low corner mobility is due to a large number of 2LUSG electrons with low mobility.

Probability density: |Wave function|^2



Probability density for the 2LUSG concentrates at corner. Hence, at the corner, there are a large number of electrons occupying the 2LUSG.

Origin of the 2LUSG mobility lower than 1LUSG mobility



Low group velocity and large scattering rate of 2LUSG causes the low mobility of the 2LUSG.

Conclusions

The corner mobility was lower than the side mobility because of the large rate of the electrons occupying the 2nd lowest unprimed subband group (2LUSG) with the lower group velocity .

1) R. Kotlyar, B. Obradovic, P. Matagne, M. Stettler, and M. D. Giles: Appl. Phys. Lett. 84 (2004), 5270.

2) S. Jin, M. V. Fischetti, and T.-w. Tang: J. Appl. Phys. 102 (2007), 083715.

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