バリスティック n^+-i-n^+ダイオードのドレイン領域内のフォノン発生が電子伝導に与える影響

Influence of Heat Generation in Drain of Ballistic n^+-i-n^+ Diode on Electrons Transport

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1. Introduction

Recently, advanced semiconductor device have been scaled down to the nanoscale size. When the channel length is further shortened less than or comparable to a carrier's mean free path, the frequency of scattering events in channel of these nanoscale devices is diminished, so that the near ballistic or full ballistic transport is expected at the room temperature operation [1]. In the conventional MOSFETs, the influence of scattering in the drain on the carriers transport could be negligible because scattering is dominant in the channel and carriers have released their energy [2]. If the channel is ballistic, the electrons injected from the source flow into the drain become hot electrons since electrons do not suffer any scattering in the channel region. Kurusu and Natori discussed the influence of these hot electrons on ballistic transport during elastic/inelastic scattering by Monte Carlo method [3]. However, the role of heat generation in ballistic transport is not clearly distinguished there.

2. Simulation Method

We employed the 2D silicon ballistic n^+-i-n^+ diode in this research. The channel region is assumed to be intrinsic and perfectly uniform. We denote the n^+ doped regions as the source and the drain, respectively, and the doping concentration is 10^{18} cm^{-3}. The length of the source, drain and channel is 40nm. The diode width is 40nm. As for the scattering mechanism, acoustic/optical phonon scattering is taken into account in the investigation. We assumed that channel is ballistic and ignore all scatterings. We treat source and drain contacts is ideal *Ohmic* contacts. The lattice temperature is assumed to be 300K. We employed an analytical non-parabolic band model for the band structure of silicon. To distinguish the influence of heat generation rate on electrons transport, we will choose two different cases to perform the investigation. In case A, only intervalley optical phonon scattering is considered inside the drain region; in case B, only intravalley acoustic phonon scattering is considered inside the drain region. For the source region, acoustic/optical phonon scattering are considered in both case.

3. Results and Discussion

In this paper we have investigated and discussed the effect of heat generation inside drain region of ballistic n^+-i-n^+ diode on electrons transport using the semiclassical Monte Carlo method. Distributions of the electrons mean velocity and heat generation rate along X-axis for each of the case at V_D=0.3V is shows in Figure 1 (a), (b), respectively. We found that influence of phonon scattering in drain on electrons transport is seriously depended on heat generation of hot electrons. In case A, optical phonon scattering has high peak value of mean velocity in channel due to heat generation rate is high, and hot electrons have low energy flow back into channel. In case B, acoustic phonon scattering severely degrade the mean velocity of electrons in channel because it has less heat generation rate and hot electrons have high energy flow from drain back into channel. We conclude that heat generation of hot electrons in drain seriously influence the electrons transport in ballistic n^+-i-n^+ diode. This conclusion could be extending to source, channel and other different devices.

4. References

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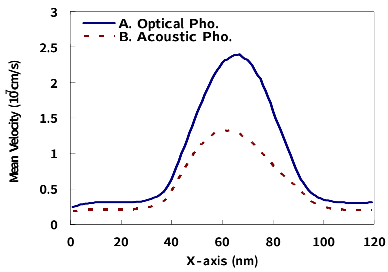
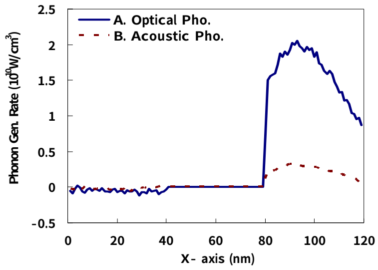


(a)



(b)

Fig. 1. Distribution of (a) velocity, (b) heat generation rate inside ballistic n^+-i-n^+diode at V_D=0.3V.