Interband Tunneling in Si Lateral Nano-\textit{pn} Junctions

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Introduction
Recently, nanometer-scale \textit{pn} junctions have been extensively studied.1-6 In particular, tunneling in nano-\textit{pn} junctions is important for future nanoelectronics. For the conventional heavily-doped (degenerated) \textit{pn} diodes, it is known that interband tunneling occurs, which is the basis of Esaki tunneling diodes.7 The tunneling in forward-bias mode can be seen as negative differential conductance (NDC) in current-voltage (\textit{I-V}) curve. In this work, we fabricated heavily doped nanoscale Si lateral \textit{pn} junctions and studied \textit{I-V} characteristics in forward-bias mode. As a result, we found similar NDC behavior at low temperatures even for the nanowire-\textit{pn} junctions.

Device structure
We fabricated lateral nanowire silicon-on-insulator (SOI) \textit{pn} junctions, with structure schematically shown in Fig. 1. Nanowires were patterned on the SOI layer by an electron beam (EB) lithography technique. Then, a selective doping technique was used to create the \textit{n}-type (phosphorus-doped) and \textit{p}-type (boron-doped) regions. A 10-nm-thick thermally grown SiO$_2$ layer was used as a mask for phosphorus doping process, while for boron doping mask, we used a 15-nm-thick ECR-deposited Si$_3$N$_4$ layer. After final process, doping concentration was estimated on the order of $5.0 \times 10^{19}$ cm$^{-3}$. The nanowire thickness and length are about 15 nm and 1000 nm, respectively, while the nanowire width is varied as parameters. The \textit{p}-type region is connected to a voltage source, while \textit{n}-type region and substrate are grounded.

I-V characteristics
We measured current versus applied bias (\textit{I-V}) characteristics at room (\textit{T} = 300 K) and low temperature (\textit{T} = 10 K) in dark condition. Preliminary results are shown in Fig. 2. It was found that, at low temperature, \textit{I-V} characteristics exhibit NDC. This behavior is similar to the conventional Esaki diode characteristics, suggesting that the observed features are most likely a signature of interband tunneling. However, more investigation is necessary to be done before fully clarifying this event.

References