Application Of Fin Shaping On Silicon And Germanium FinFET

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Abstract
The short channel effects at the 22-nm technology node and beyond can be overcome by Finfets. The studies on fin shaping of finfets shows that a triangular fin reduces leakage current over a rectangular fin with the same base fin width. First we made a study on Silicon Finfets with varying fin widths, their leakage, on state current etc. Then we made a study on germanium finfets. The germanium finfets showed a decrease in leakage current. So when applying fin shaping on germanium finfets, it shows improved performance than silicon finfets.

Keywords: Finfet, semiconductor device modelling

1. Introduction
The FinFET is a transistor design, first developed by Chenming Hu and colleagues at the University of California at Berkeley, which attempts to overcome the worst types of short-channel effect encountered by deep submicron transistors, such as drain-induced barrier lowering (DIBL). Feature of FinFET is the fin thickness, which needs to be smaller than or equal to the gate length. Their scaling does not depend on oxide thickness, which is a big advantage. Furthermore, only one extra mask is required to create the silicon fin. Designers also have a choice of extending the width in third dimension in trigate FinFET without affecting layout area; as a result the effective channel width can be significantly enhanced relative to a planar transistor.

Some papers reported that leakage increased in silicon on insulator FinFETs as the fin cross-sectional shape changes from rectangular to triangular to trapezoidal. In their study, the width of the fin base changed from 13 (rectangular) to 92 (triangular) to 140 nm (trapezoidal). We believe that the increase in leakage is due to the increase in fin width, not the change in cross-sectional shape.

Here we are dealing with bulk silicon FinFETs and bulk Germanium FinFETs. By varying the fin width we are achieving trapezoidal fin shape and triangular fin shapes. We show in this paper that fin shape significantly impacts leakage in bulk tri-gate nFinFETs with thin fin widths when the fin body doping is optimized to minimize leakage.

2. Silicon FinFET
Here we are using partially cylindrical FinFETs (PC-FinFET). The fig2 shows Partially Cylindrical FinFET (PC-FinFET), as the corners are rounded, the heat can flow easily, which reduces the self heating phenomenon thereby improving the mobility of the carriers. This reduces the series resistance of the PC-FinFET, which results in increase of on state current. Thus, PC-FinFET results in higher Ion/Ioff ratio by increasing the on state current and decreasing the off state current. The rounding of the corners also helps in reduction of the off state leakage current, as the premature
inversion is avoided. The fig 1 shows Conventional FinFET. We made our analysis on the 22-nm bulk nFinFET Technology Computer Aided Design (TCAD) model. We used the Atlas Silvaco tool for our analysis. The key geometries shown in Table I. The corner radius of the rounded fin is set to \( \frac{1}{2} \) Wtop to minimize corner effects. All other model parameters take the default value unless otherwise specified.

We made our study by varying the fin widths from 15nm(trapezoidal) to 1nm(triangular). We take the values 15nm,13nm,11nm,9nm,7nm,5nm,3nm and 1nm. By varying the fin shapes we are analyzing the leakage current, \( I_{on}/I_{off} \) ratio, threshold voltage and subthreshold swing. The doping is changed from 1e18 1/cm\(^3\) to 5e17 1/cm\(^3\). To evaluate the impact of fin shape on Ioff, we sweep Wtop over the range of 1–15 nm (Fig.4). We simulate both the rectangular and triangular optimal doping profiles. Ioff decreases as Wtop decreases except for the nFinFET with 1e18 1/cm\(^3\) fin body doping when Wtop is less than 5 nm. The leakage current is more sensitive to Wtop with the lower doping profile. To obtain the optimal leakage performance for various fin shapes, the doping concentration and fin shape must be selected jointly to optimize performance. A doping concentration of 1e18 1/cm\(^3\) is selected when Wtop is greater than or equal to 5 nm and a doping concentration of 5e17 1/cm\(^3\) is selected when Wtop is less than 5 nm. For these Wtop and doping selections, Vth is within the range of 435-472 mV, SS is less than 85mV/dec, and \( I_{on}/I_{off} \) monotonically increases as Wtop decreases.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>L</td>
<td>Gate Length</td>
<td>34nm</td>
</tr>
<tr>
<td>H</td>
<td>Fin Height</td>
<td>35nm</td>
</tr>
<tr>
<td>Wbottom</td>
<td>Width of the bottom of active fin</td>
<td>15nm</td>
</tr>
<tr>
<td>Wtop</td>
<td>Width of the top of active fin</td>
<td>15nm</td>
</tr>
</tbody>
</table>

Table1:nFinFET model geometry parameters

Fig2:Partially cylindrical bulk Silicon FinFET

Fig3 FinFETs with fin width 1nm, 7nm and 15nm respectively
3. Germanium FinFET

Germanium FinFETs were made and the Ioff current and Ion/Ioff current ratio were analysed for different fin widths varying from 15nm to 1nm.
It is found that leakage current has been reduced for germanium FinFETs when compared to silicon FinFETs. Ion/Ioff ratio has also been improved.

4. Conclusion

Silicon and Germanium FinFETs have been compared. Fin shaping is done for both FinFETs. Fin widths are varied for FinFETs. Then the analysis of leakage current and on state current has been done for both silicon and germanium FinFETs. The study shown that germanium FinFETs has shown an improved characteristics compared to silicon FinFETs.