Novel implantation mode application in FinFET structure

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***Abstract*—Multiple-gate FETs such as FinFETs would be adopted at the 22nm technology generation and beyond, owing to the better control of short-channel effects (SCEs) in high-volume manufacturing. In this paper, we present a novel implantation mode called "FlexScan" that consists of a series of various rotated angles. We perform the implant with FlexScan mode by Monte-Carlo simulation. FlexScan shows more conformal doping distribution in the fin structure. We expect that it could reduce device leakage and device variation caused from random doping distribution. The FlexScan mode could be used for 3D device doping process needed conformal doping profile.**

Keywords—FinFET; conformal; ion implant; Monte-Carlo simulation

I. INTRODUCTION

Due to the aggressive scaling of the semiconductor devices in integrated circuit manufacturing, device technology is confronted by several difficulties such as short channel effects, device variation and power consumption. Multiple-gate FETs such as FinFETs has been a promising candidate and adopted at the 22nm technology generation and beyond, owing to the better control of short-channel effects (SCEs) than conventional planar CMOS devices. In order to achieve high performance FinFET devices, it is crucial to produce conformal and accurate junctions. Ion implantation is a standard technology to dope devices in VLSI processes. However, the ion dopant profiles in FinFET structure is difficult be obtained by commercial analysis tool such as secondary ion mass spectrometry (SIMS) [1]. Therefore, theoretical evaluation of dopant profiles is adopted. Monte Carlo simulation is widely used for predicting ion implantation profiles. In this paper, we present a novel implantation mode called "FlexScan" that consists of a series of various rotated angles. We perform the implant with FlexScan mode by Monte-Carlo simulation. The FlexScan mode could be used for 3D device doping process needed conformal doping profile, like Source/Drain doping, Source/Drain extensions, halo implant, anti-punch through implant etc.

II. EXPERIMENT

Fig. 1 shows the 3-D simulation structures of Si FinFET on bulk with tapered profile in this study. The Si transistor has a gate length of 22 nm, poly-silicon height of 69.3 nm, fin bottom width of 15 nm, and fin height of 34 nm.

The implant condition is 3KeV BF2 at tilt angle of 7^o. We simulated dopant distribution of the FlexScan and conventional quad mode with the fin structure. The conventional quad-mode is the method which implant with 4 rotations at 90 degrees each. The FlexScan mode is a continuous rotated mode. It completes 360 degree rotation within one recipe. The recipe used in this study consists of 40 scans. In order to simplify the simulation procedure, the 40 continuous rotated angles was replaced by 40 discrete rotated angles. The FlexScan mode used in this study consists of 40 rotated angles at 9 degrees each, as showed in Fig. 2.

Fig. 1. Fin structure used for Monte-Carlo simulation

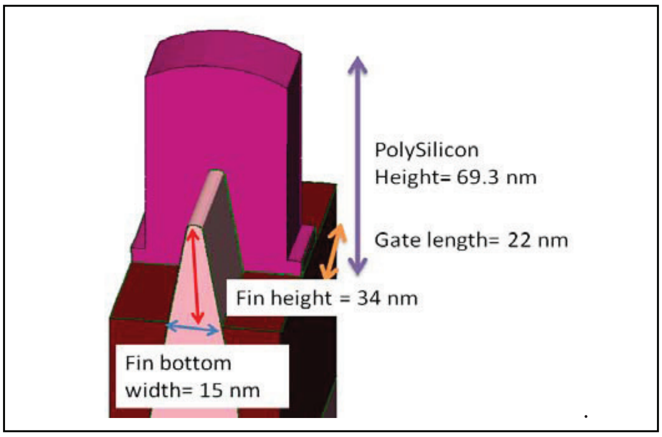
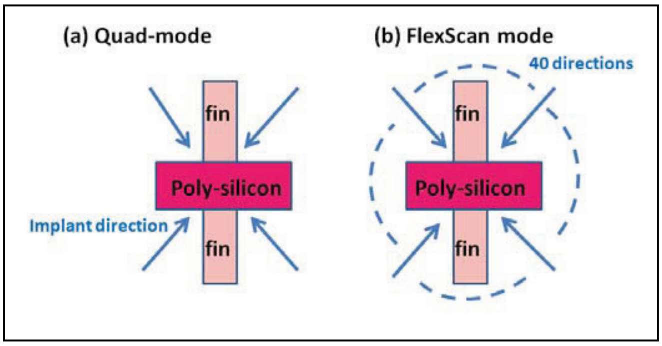


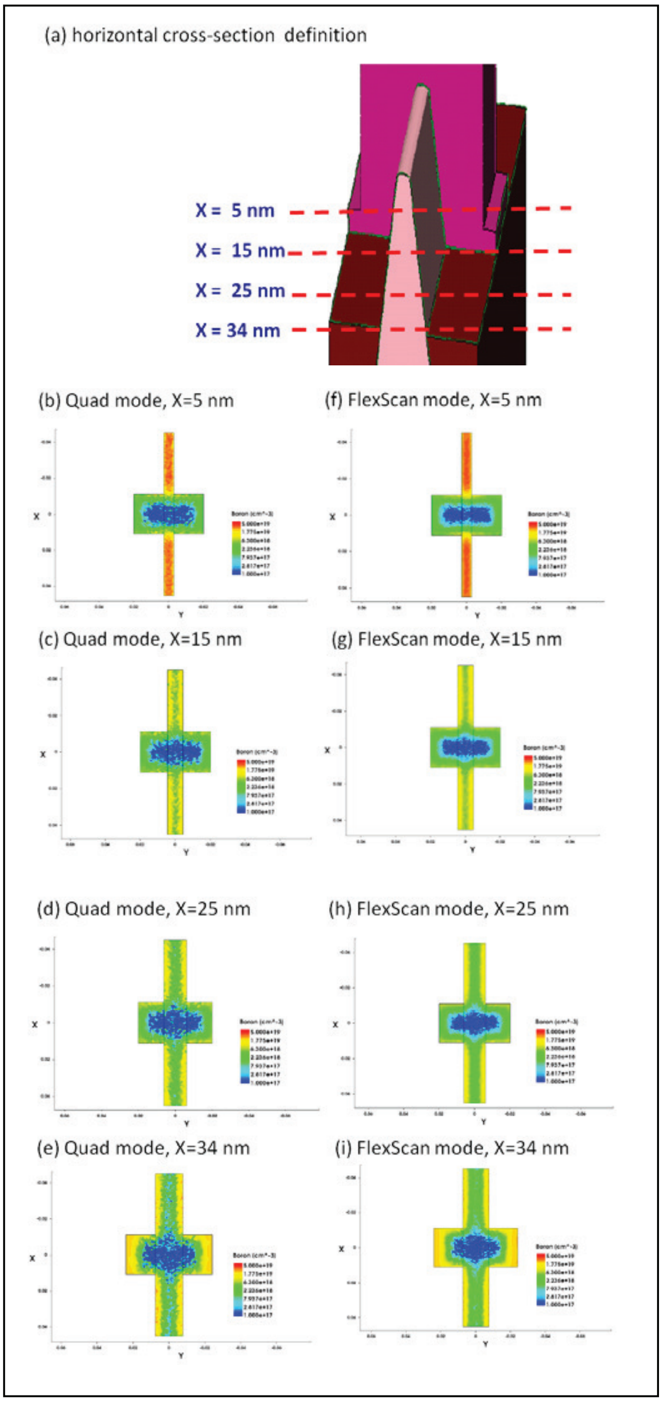
Fig. 2. Schematic diagram of implant mode.(Top-view of Fig.1)



III. RESULTS AND DISCUSION

Fig. 3 shows the horizontal cross-section dopant distribution after implant. We extracted the cross-section plane at 5, 15, 25 and 34 nm below from fin tip. The FlexScan mode shows more uniform dopant distribution in the fin surface and under the poly-silicon.

Fig. 3. Horizontal cross-section dopant distribution of boron after implant: (b)~(e)quad mode; (f)~(i) FlexScan mode

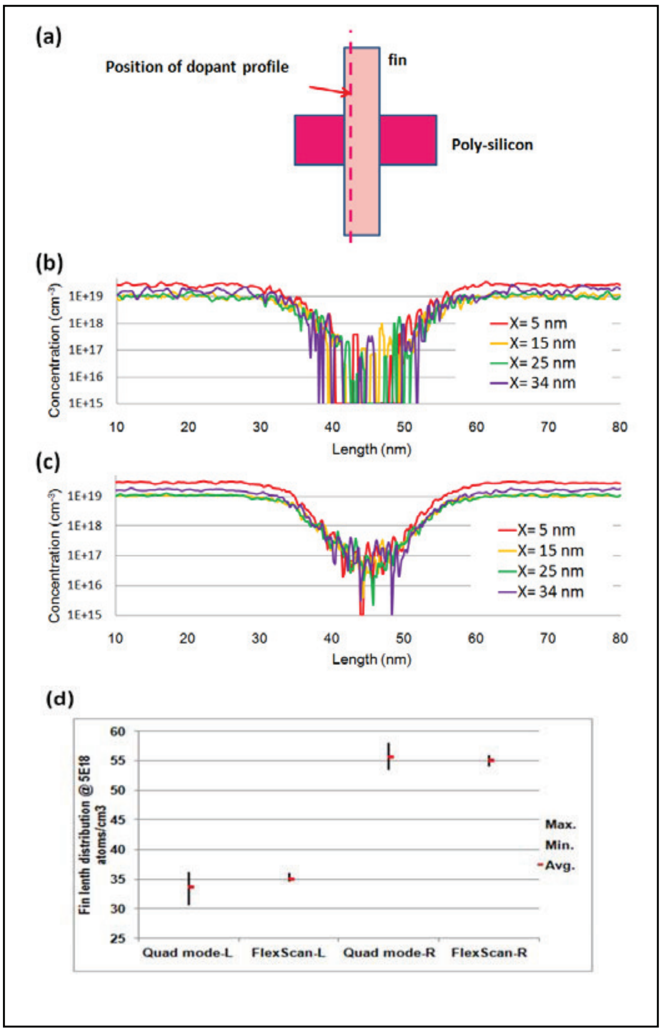


Otherwise, there is more randomly positioned dopant in the channel area of quad mode implant. The random and discrete dopant distribution in the channel will cause significantly random dopant fluctuations, such as the deviation of threshold voltage, drive current mismatch, and so on [2]-[3]. Therefore, we expected the FlexScan mode could reduce the device mismatch and fluctuation.

Fig. 4 shows the dopant profile along the fin direction. We extracted the dopant profile from the cross-section planes showed in Fig. 3. The profile location is at 1 nm below the fin surface, as showed in Fig. 4(a).

The ranges of profile depth at 5E18 of quad mode are 5.6 nm (from 30.6 to 36.2 nm) at left side and 4.6 nm (from 53.4 to 58 nm) at right side. The depth ranges of FlexScan mode are 1.5 nm (from 34.5 to 36 nm) at left side and 1.9 nm (from 54 to 55.9 nm) at right side, as showed in Fig. 4(b)~(d).

Fig. 4. (a) Position of extracted dopant profile in horizontal cross-section plane. (b) dopant profile of quad mode . (c) dopant profile of FlexScan mode. (d) dopant depth distribution.



The average depth range reduction is about 66%. The FlexScan mode shows more conformal dopant distribution under the poly-silicon. The FlexScan mode has potential benefit to reduce the device variability.

IV. Conclusion

The FinFET has been adopted at the 22nm technology generation and beyond. It is important to produce conformal and accurate junctions. We perform the implant with FlexScan mode by Monte-Carlo simulation. The FlexScan mode shows more uniform dopant distribution in the fin surface and less randomly positioned dopant in the channel area. It also showed about 66% of profile depth variation reduction. This new implant mode will be the excellent compatible doping method for 3D device needed conformal dopant profile.

Reference

[1] A.K. Kambham, J.Mody, M.Gilbert , S.Koelling, and W.Vandervorst, “Atom-probe for FinFET dopant characterization,” Ultramicroscopy, vol. 111, 2011, pp. 535–539.

[2] Y. Li, S. Yu, J. Hwang, and F. Yang, “Discrete Dopant Fluctuations in 20-nm/15-nm-Gate Planar CMOS,” IEEE TRANSACTIONS ON ELECTRON DEVICES, vol. 55, no. 6, 2008, pp. 1449–1455 .

[3] V. Moroz, “TCAD eases FinFET design and variability analysis,” Synopsys Inc., 2012.