Integrated divergent beam for FinFET Conformal Doping

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***Abstract*—In order to achieve high performance finFET devices, it is important to achieve a high concentration and conformal doping within the Fin. In this paper, a solution for conformal finFET doping method is demonstrated. We present a novel implantation condition called Integrated Divergent Beam (IDB) that consists of various implant angle distribution. We perform the IDB Arsenic implantation by Monte-Carlo simulation.**

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

I. INTRODUCTION

FinFETs or multigate transistors exhibit excellent control of short-channel effects, device variation and power consumption. It has been adopted at the 22nm technology node and beyond [1]. However, it is difficult to use beam line tool to perform conformal dopant distribution in vertical sidewall structure. One of the concerns with high tilt implantation is retained dose loss due to the cosine effect at higher tilt angles. Another issue is tilt angle restrictions due to shadowing effect in tight pitch structures. In order to boost the performance of finFET devices, it is important to achieve a high concentration and conformal doping within the Fin. However, it is difficult to obtain the ion dopant profiles in FinFET structure by commercial analysis tool [2-4]. Monte Carlo simulation is widely used for predicting ion implantation profiles. We present the IDB that consists of various implant angles distribution and perform the IDB Arsenic implantation in fin structure silicon by Monte-Carlo simulation.

II. EXPERIMENT

The simulation structures of Si fin on bulk with tapered and rectangular profile in this study. We used a extreme condition with Si fin height of 100 nm and fin bottom width of 16 nm to evaluate the performance of new implant condition.

The implant condition is 3keV Arsenic with different tilt angles and beam conditions. The IDB consists of various implant angles within the beam condition. The ion beam is compressed and crossed by multiples, as showed in Fig. 1. Comparing with conventional spot beam, the IDB shows a horn beam shape. We could modify the angle distribution by tuning the beam shape and beam height, as showed in Fig. 2.

Fig. 1. Schematic diagram of IDB.

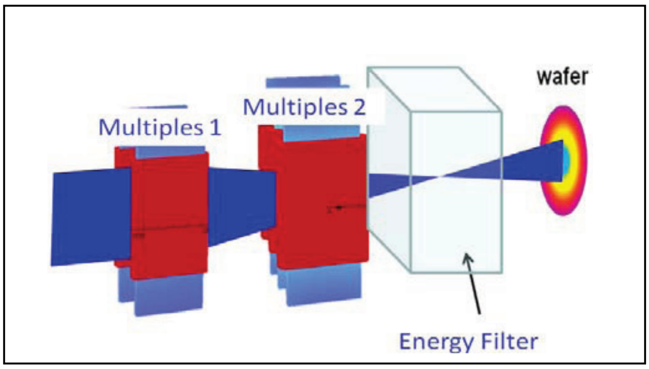
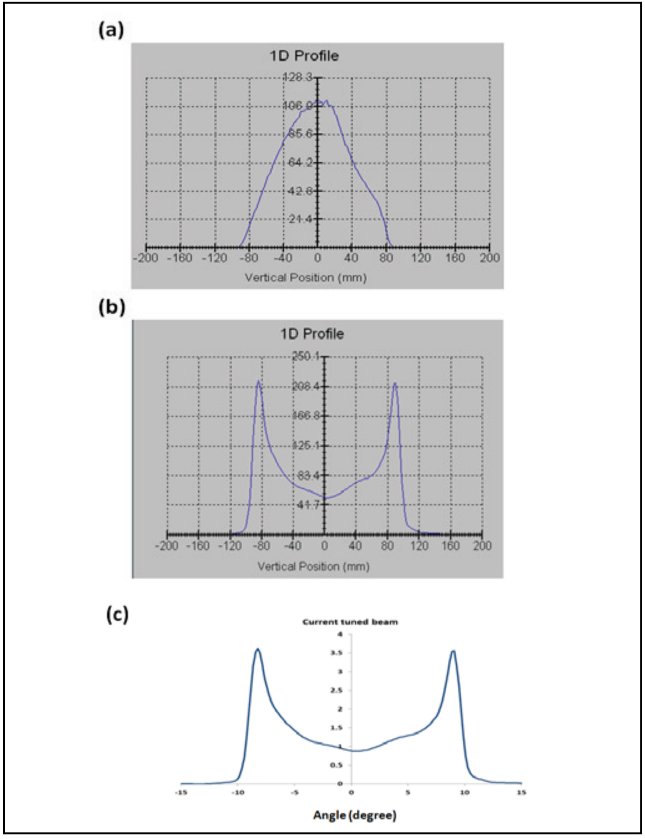


Fig. 2. Beam shapes of (a) conventional spot beam and (b) IDB. (c) The angle distribution of Fig. 2(b).



III. RESULTS AND DISCUSSION

We checked the fin shape effect on retained dose with 3keV Arsenic parallel beam at tilt angle of 3º. Fig. 3 shows the cross-section dopant distribution after implant. The retained dose loss of rectangular fin is obvious in sidewall surface. It is supposed that the higher incidence angle and more ion reflection on sidewall surface occurred in tapered fin.

Fig. 3. The cross-section dopant distribution of (a) rectangular fin and (b) tapered fin.

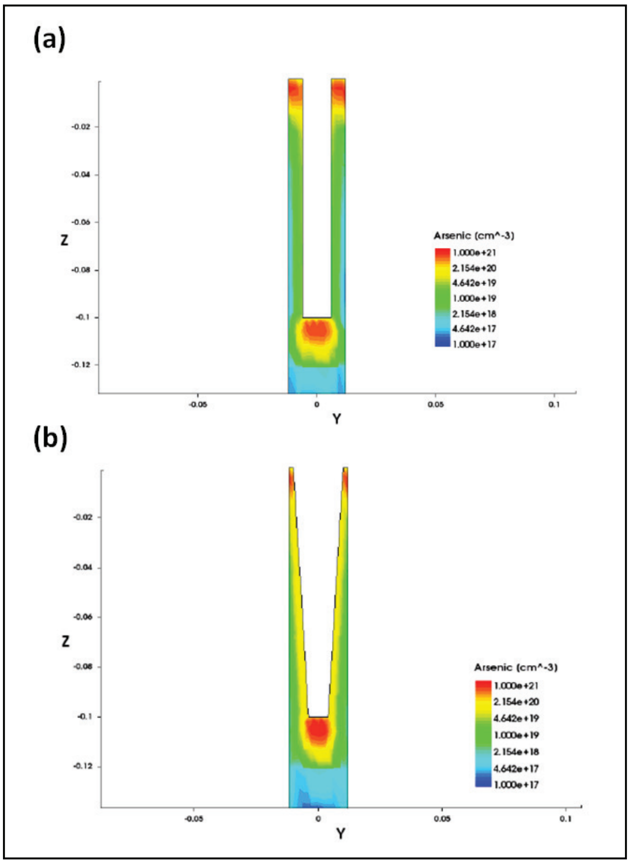


Fig. 4 shows the cross-section dopant distribution of parallel beam and IDB in tapered fin with 3keV Arsenic at tilt angle of 3º. The IDB shows higher dopant concentration in the fin surface. Fig. 5 shows the dopant profile along the fin surface. We extracted the dopant profile from the cross-section planes at 1 nm below the fin surface, as showed in Fig. 4 (a). The IDB shows 10% higher surface concentration and better dopant uniformity. It was also observed in horizontal dopant profile showed in Fig. 6.

We implement the IDB into the source drain extension of FinFET nMOS device simulation and found that the performance (I_{on} /I_{off}) of IDB is about 2% higher than parallel beam, as showed in Fig. 7. It was supposed that IDB could increase the retained dosage and better dopant uniformity. The IDB is extendable to 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.

Fig. 4. The cross-section dopant distribution of (a) parallel beam and (b)IDB.

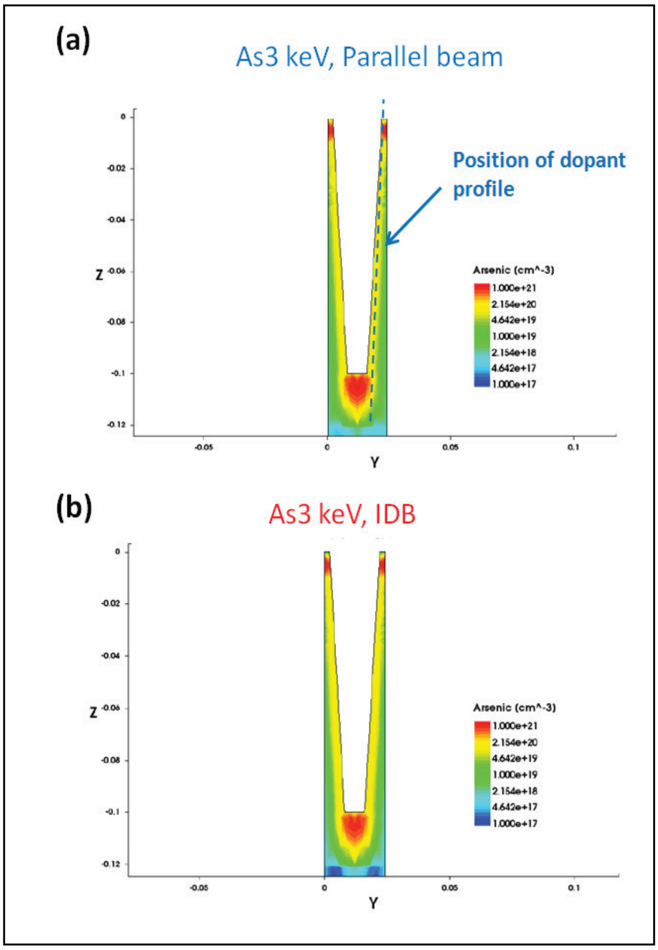


Fig. 5. The dopant profile along the fin surface.

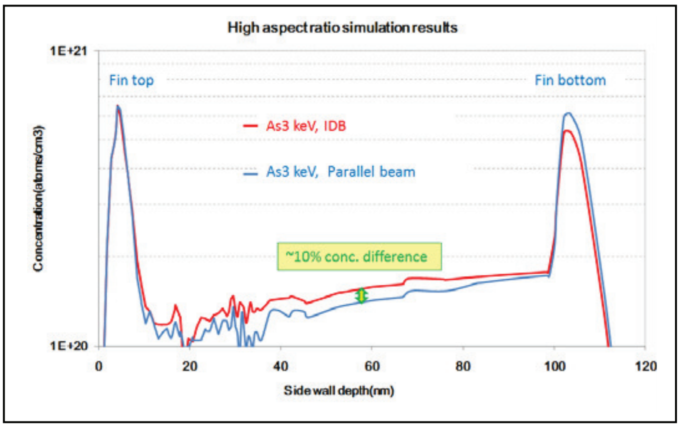


Fig. 6. The horizontal dopant profile.

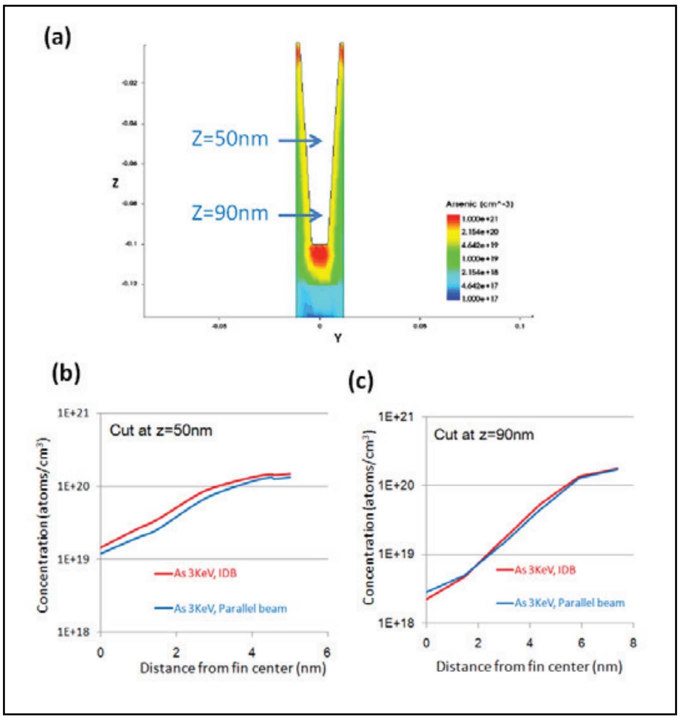
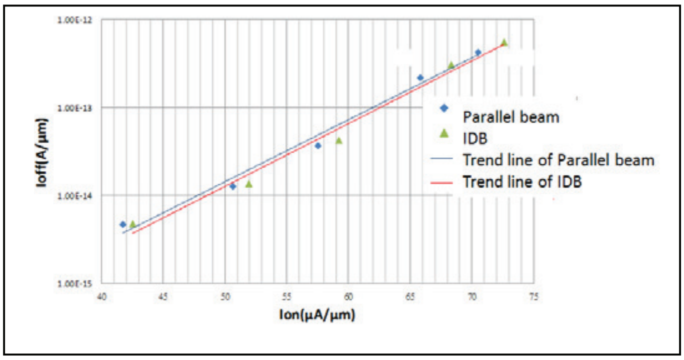


Fig. 7. FinFET device simulation of parallel beam and IDB.



IV. CONCLUSION

In this study, we presented IDB that consists of various implant angle distribution. It could produce a higher concentration and more uniform dopant profile. The FinFET device simulation shows about 2 % performance (I_{on} /I_{off}) improvement for FinFET nMOS device. The IDB is a feasible method to be used for 3D device doping process needed conformal doping profile.

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