

## FLUORINE CO-IMPLANTATION SCHEMES FOR 65 NM AND BELOW ULTRA-SHALLOW JUNCTIONS

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The source/drain extension of CMOS devices must scale below 17 nm by 2007 and eventually below 6 nm by 2016 with sheet resistance values below 760 and 1210 Ohms/sq. respectively. This presents challenges on all fronts of the implant/anneal process flow. The 6 nm junction depth requirement for as-implanted boron profiles demands a very low energy implant with minimal channeling or energy contamination. The obvious drawbacks of low energy, high dose implantation that is free of energy contamination, are low throughput and high cost [1]. While Ge or Si pre-amorphization helps alleviate problems associated with channeling, the number of implant steps double and post-anneal residual damage becomes an issue. From an anneal perspective, obtaining good activation with acceptable amounts of residual damage requires a high temperature anneal, but current spike-RTP anneals yield unacceptably high levels of diffusions. Anneals that produce little or no diffusion, such as, SPE or flash RTP still have obstacles to overcome with residual damage issues, especially when pre-amorphizing implants such as Si or Ge are used. A potential solution to these problems is co-implantation of F with low energy  $\text{BF}_3$  P<sup>2</sup>LAD where issues related to channeling, energy contamination, low throughput, and residual damage all can be eliminated. Figure 1 depicts an as-implanted profile of a 300V  $\text{BF}_3$  P<sup>2</sup>LAD [1] into a F pre-amorphized substrate. The as-implanted junction at a boron concentration of  $1 \times 10^{18}/\text{cm}^3$  is 9 nm and at  $3 \times 10^{19}/\text{cm}^3$  (where the 22 nm node requirement for an activated junction of 6 nm is determined) is 4.6 nm.

Implementing a F co-implantation scheme is not a straight-forward process. First, the chemical effect of F on the diffusion mechanism of B in crystalline and amorphous Si [2,3] must be analyzed in each kinetic regime (e.g. furnace; rapid spike RTP, millisecond flash RTP etc.). In addition, the post-implant damage will be very different and the addition of F complicates the analysis of damage driven diffusion. The damage affects not only the diffusion of B, but also the diffusion of F. If the two species interact chemically, then the result of damage on the diffusion of B is necessarily tied to the damage driven diffusion of F. Further, it has been shown that F slows the re-crystallization of amorphized silicon [3], altering the medium through which boron diffuses. The effect of F placement, with respect to the location of B, as well as the location of post-implant damage are important. Hence separating the F and B implants into two separate steps, so that the as-implanted profile and dose of each can be controlled, is an excellent way to control diffusion during the anneal process. An added benefit to F is that it can enhance activation [4]. As a result, the retention of F, which is dependent on the anneal and the anneal ambient, affects the ultimate activation of the dopant. Fluorine co-implantation doping and activation schemes that satisfy the 65 nm to 22 nm

node requirements with minimal residual damage are possible and will be discussed.

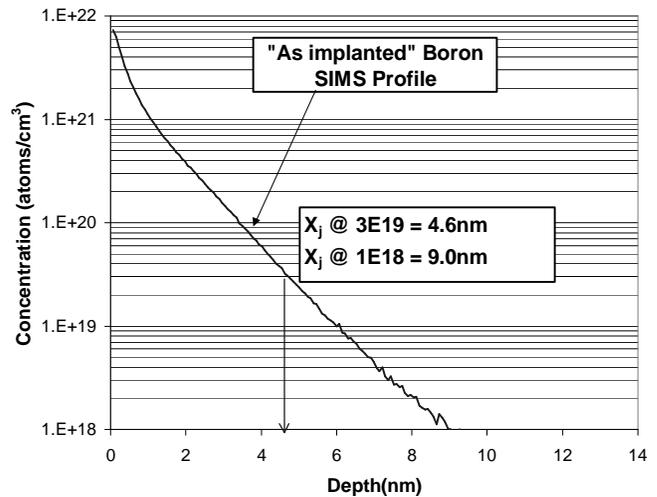


Fig. 1  $\text{BF}_3$ , 300V, P<sup>2</sup>LAD Implant into F Pre-amorphized Silicon

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<sup>4</sup> D.F. Downey, C.M. Osburn, and S. Marcus, Solid State Technology 71, Dec. 1997