## Improvement of electrical characteristics of junctionless transistor with BF<sub>2</sub><sup>+</sup> implanted poly-Si channel by boron segregation and fluorine passivation

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**[Introduction]** Fluorine (F) passivation on grain boundaries in poly-Si is considered as effective way to improve the quality of poly-Si due to its high Si-F bonding energy [1]. Recently, a junctionless (JL) transistor has been spotlighted due to the simple process and volume conduction [2]. For better performances, thin and highly doped JL channel should be desired for full depletion and high on-current, respectively. Nonetheless, highly doped thin channel usually suffer from some damages and defects during ion implantation, and produces degradation of mobility, subthreshold slope (SS), and variation characteristics. Hence, ion implantation of JL channel should be optimized for better understanding of the electrical properties. In this work, we investigated the dependence of dopant types (P<sup>+</sup>, B<sup>+</sup>, BF<sub>2</sub><sup>+</sup>) on the poly-Si JL transistors and observed superior electrical characteristics in  $BF_2^+$  implanted poly-Si JL transistor thanks to the effect of F passivation as well as B segregation.

**[Experimental]** The fabrication processes basically follow our previous work [3]. P<sup>+</sup>, B<sup>+</sup>, BF<sub>2</sub><sup>+</sup> ions were implanted for n- and p-type channel. The channel thinning process was performed by oxidation at 1100°C, in which grain size becomes larger [3]. The channel width W, length L, and thickness T are 40µm, 40µm, and 5nm, respectively. For comparison, IM p-type transistors (T=10nm) with P<sup>+</sup>poly-Si gate were also fabricated as shown in Fig.1. In JL\_B and JL\_BF2, the B concentration in the channel was reduced due to the segregation of B ions during channel thinning process, resulting in P<sup>+</sup>/P/P<sup>+</sup> structure. In contrast, the N<sup>+</sup>/N<sup>+</sup>/N<sup>+</sup> structure is formed in JL\_P because P concentration is not changed during oxidation process.

**[Results and Discussion]** Fig.2 shows the I<sub>D</sub>-V<sub>G</sub> and transconductance (g<sub>m</sub>) curves of four devices at V<sub>D</sub>=|0.05|V. Apparently, JL\_B and JL\_BF2 exhibit superior current drivability compared to others. Higher g<sub>m</sub> of JL\_B and JL\_BF2 compared to IM can be explained by smaller electric field due to the volume conduction. Poor g<sub>m</sub> of JL\_P comes from high impurity scattering due to high channel concentration. Fig.3 shows the extracted SS as a function of I<sub>D</sub> at  $|V_D|=0.05V$ . Fig.4 displays cumulative distributions of threshold voltage  $|V_T|$  from ~50 transistors of each devices at  $|V_D|=0.05V$ . The  $|V_T|$  of JL\_B and JL\_BF2 are higher than that of JL\_P due to the lower channel concentration by B segregation. In addition, the B segregation produces small variations due to reduced channel concentration, whereas severe variations are observed in JL\_P even at large-size planar device. Table I summarizes key parameters of four devices, clearly showing that JL\_BF2 exhibits superior performances. To examine the origins, SIMS depth profiles of JL\_B and JL\_BF2 after channel thinning were measured as shown in Fig.5. It is clearly seen that the F concentration of JL\_BF2 is over 10 times higher than that of JL\_B at the bottom interface, which is driving force of improved performances because the bottom interface mainly affects the subthreshold characteristics of JL transistor owing to the unique volume conduction.

**[Conclusion]** Improved electrical performances as well as small variations of  $BF_2^+$  implanted poly-SI JL transistor have been experimentally characterized and demonstrated thanks to the B segregation and F effect.

[Reference] [1] S. K. Kwon *et al.*, JEDS, 6, p.808, 2018. [2] J. P. Colinge *et al.*, Nature Nanotech., 5, p.225, 2010. [3] M. J. Ahn et al., IEEE SNW, p. 51, 2020.



four poly-Si JL transistors.

Fig.5: F concentration profiles