Molecular Dopants and High Mass Dopants for HALO and Extension Implantation

Akira Mineji[1], John Borland[2], Seiichi Shishiguchi[1], Masami Hane[1], Masayasu Tanjyo[3] and Tsutomu Nagayama[3]

[1]NEC Electronics Corp., 1120, Shimokuzawa, Sagamihara, Kanagawa, 229-1198, Japan
[2]J.O.B. Technologies, 98-1204 Kuawa St. Aiea, Hawaii 96701
[3]Nissin Ion Equipment, 575, Kuze-Tonoshiro-Cho, Minami-Ku, Kyoto, 601-8205, Japan
E-mail : JohnOBorland@aol.com

1.Introduction

Enhanced dopant activation with molecular dopant species when using diffusion-less activation by msec Flash or laser annealing and low temperature 650°C SPE annealing was reported in our earlier paper [1]. Those results suggested the potential of lowering Flash and spike temperatures as well as increasing SPE temperatures. Also these advanced annealing techniques must not only activate USJ but must also activate the HALO/pocket implants simultateously to achieve high quality junctions in the device channel region. Therefore this paper will describe our results to achieve high quality engineered junctions in the device channel region by optimizing both HALO and SDE implantation with various diffusion-less anneals comparing standard dopants to both molecular dopants and high mass dopants.

2.Experimentation

Table 1 shows the various nSDE, pSDE, nHALO and pHALO implants used in this study. All the SDE and HALO implants were performed at Nissin on either the Exceed-3000AH medium current implanter or Exceed-Cluster implanter. Also, the 650°C 30 sec SPE, 900°C Spike and 1050°C Spike anneals were performed at Nissin using the Mattson 3000 annealer while the 1300°C Flash annealing was performed at Mattson Technology using the Arc-lamp Flash annealer.

3.Results

The effects of each annealing condition on $B_{10}H_{14}$ dopant diffusion is shown in Fig.1. The 1050°C Spike anneal resulted in 23nm of boron diffusion, the 1300°C Flash anneal resulted in 2nm of diffusion while both the 900°C Spike and 650°C SPE anneals resulted in zero diffusion. All the boron SIMS results are shown in Fig. 2 and similar to what we reported before with the 1050°C Spike anneal BF_2 diffusion was +13nm, $B_{10}H_{14}$ was +23nm and $B_{18}H_{22}$ was +28nm. With Flash anneal $B_{18}H_{22}$ diffusion was +4nm. The pSDE boron dopant activation levels were determined by sheet resistance (Rs) measurements as shown in Fig. 3. Ploting Rs versus SIMS Xj is shown in Fig. 4. Similar to before, enhanced boron dopant activation is observed with $B_{10}H_{14}$ and $B_{18}H_{22}$ compared to BF_2 for SPE and 900°C annealing. With Flash annealing $B_{18}H_{22}$ had a lower Rs value but the juction was 2nm deepers so the net Bss activation level was still 1.5E20/cm^3. Fig. 5 also shows results for comparing retained dose after annealing condition for each pSDE dopant species. BF_2 always had the lowest retained dose after annealing. Fig. 6 is a plot of Rs versus retained dose and note that the retained dose and Rs for the 1050°C Spike and 1300°C Flash annealing are the same for both $B_{10}H_{14}$ and $B_{18}H_{22}$.

Activation Rs results for the pHALO implants are shown in Fig. 7 comparing BF_2, $B_{10}H_{14}$ and In. No significant difference was seen between BF_2 and $B_{10}H_{14}$ HALO boron activation Rs values for all 4 annealing conditions. With the 1050°C spike, 900°C spike and 1300°C Flash anneals the 3E13/cm^2 HALO implant dose resulted in about 300ohms/sq. Rs value. With the 650°C SPE anneal the Rs increased up to 1000 ohms/sq. for all 3 dopant species (BF2, B10Hx and In). Most surprising was that the In HALO Rs value remained at about 1000 ohms/sq all the 4 anneals including the Flash anneal which is opposite to what Ito of Toshiba [2] observed in their 2002 IWJT paper where Flash annealing resulted in a 3x increase in In dopant activation. The pHALO junction leakage results are shown in Fig. 8. Only In dopant showed evidence of leakage degradation and the Flash anneal was 100x worse, 900°C spike was 300x worse and the SPE anneal was 2,000x worse than BF_2 or $B_{10}H_{14}$ HALOs.

Results for the nSDE implants are shown in Fig. 9 for As, As_2, P_2 and Sb. With the Flash anneal only the P implant showed lower Rs by about 25% while As, As_2 and Sb were about the same in Rs value. With SPE annealing Sb had the lowest Rs value. Results for nHALO are shown in Fig. 10 and similar to the boron HALO results in Fig. 7 no significant change in Rs values are seen for all the annealing conditions except for the SPE were a 2x increase in Rs were observed. However, doubling the As_2 dose reduced the SPE Rs by 2x.

4.Summary

Diffusion-less activation were realized for the 650°C SPE, >1300°C Flash and 900°C Spike anneals. For pSDE all boron dopant species (BF_2, $B_{10}H_{14}$ and $B_{18}H_{22}$) achieved high quality junctions with Flash annealing. With 900°C Spike either $B_{10}H_{14}$ or $B_{18}H_{22}$ can be used while with 650°C SPE annealing only $B_{18}H_{22}$ can be used. For pHALO using In no difference in activation level could be seen but significant differences in junction leakage was observed. No difference between BF_2 and $B_{10}H_{14}$ HALO activation could be seen for each annealing condition and SPE annealing resulted in the worse activation level. For nSDE with Flash annealing As, As_2 and Sb activation levels were similar while P_2 was 25% better. With SPE and 900°C Spike Sb gave the best activation. For nHALO As, As_2 and Sb activation levels were similar for all annealing conditions

with SPE resulting in 2x lower activation. Doubling the As_2 dose improved SPE activation by 2x.

Acknowledgements

The authors are grateful to Mattson for the Flash anneal processing.

References

[1] J. Borland, S. Shishiguchi, A. Mineji, W. Krull, D. Jacobson, M. Tanjo, W. Lerch, S. Paul, J. Gelpey, S. McCoy, J. Venturini, M. Current, V. Faifer, R. Hillard, M. Benjamin, T. Walker, A. Buczkowski, Z. Li and J. Chen, "45nm Node p+ USJ Formation with High Dopant Activation and Low Damage", IWJT 2006, p. 4.

[2] T. Ito, K. Suguro, M. Tomura, T. Taniguchi, Y. Ushiku, T. Iinuma, T. Itani, M. Yoshioka, T. Owada, Y. Imaoka, H. Murayama and T. Kusuda, "Flash Lamp Annealing Technology for Ultra-shallow Junction Formation", IWJT 2002, p. 23.

Table 1 : Summary of SDE and HALO implant matrix.

	Ion	Energy	Dose (Equiv.)		Ion	Energy	Dose (Equiv.)
N-SDE	As	3keV	1e15	P-SDE	BF2	3keV	1e15
	As2	6keV	1e15		B10Hx	7.5keV	1e15
	P2	3keV	1e15		B18Hx	15keV	1e15
	Sb	5keV	1e15				1e15
N-Halo	As	40keV	3E13	P-Halo	BF2	20keV	3E13
	As2	80keV	3E13		B10Hx	50keV	3E13
	Sb	65keV	3E13		In	45keV	3E13

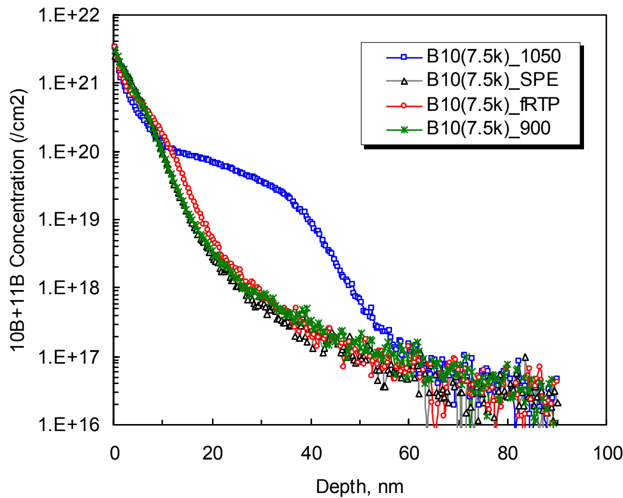
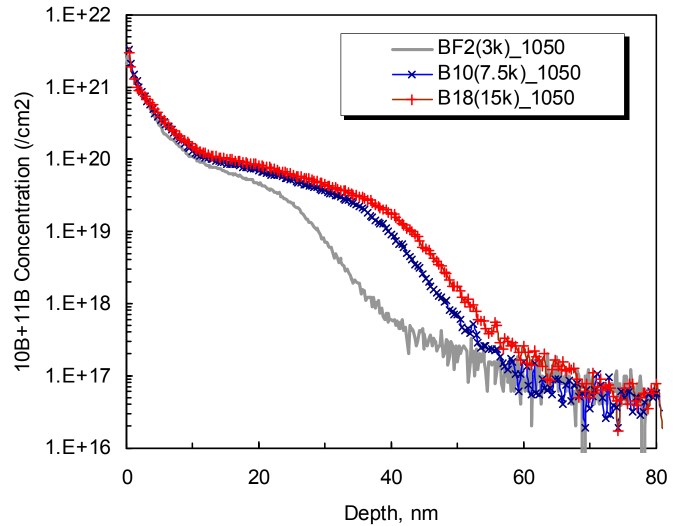
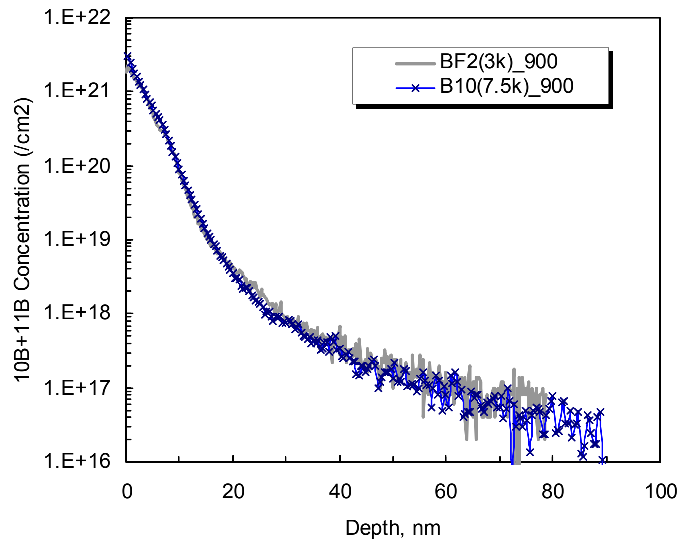


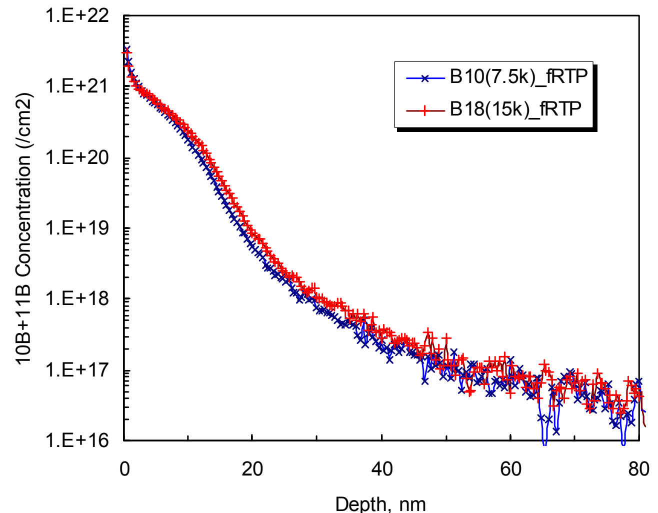
Fig. 1 : SIMS boron dopant profiles for $B_{10}H_{14}$ after the various 4 different anneals.



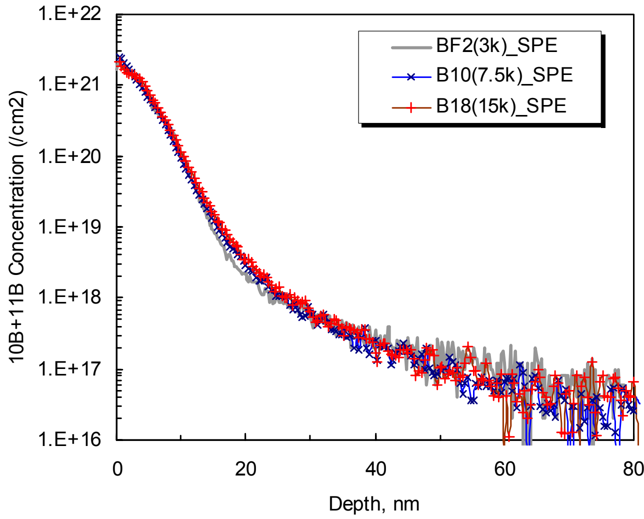
a) 1050°C Spike



b) 900°C Spike



c) 1300°C Flash



d) 650°C SPE

Fig. 2 : SIMS boron diffusion comparison for each anneal.

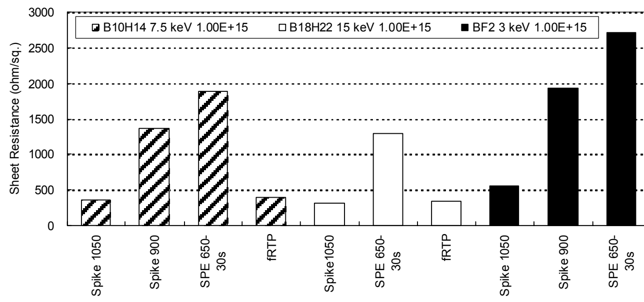


Fig. 3: Boron Rs for pSDE implants and anneals.

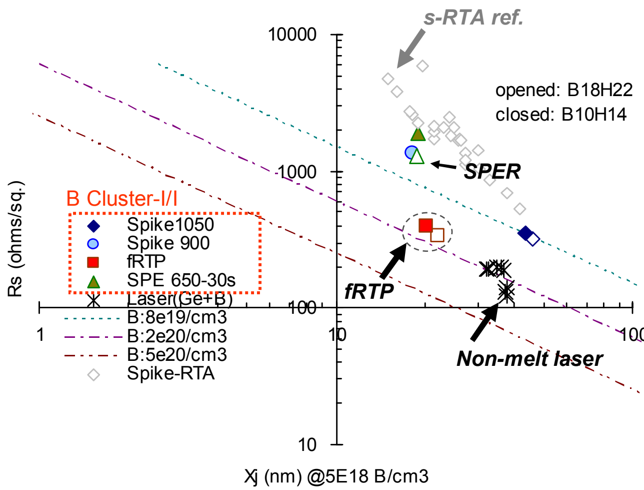


Fig. 4 : Rs versus Xj plot.

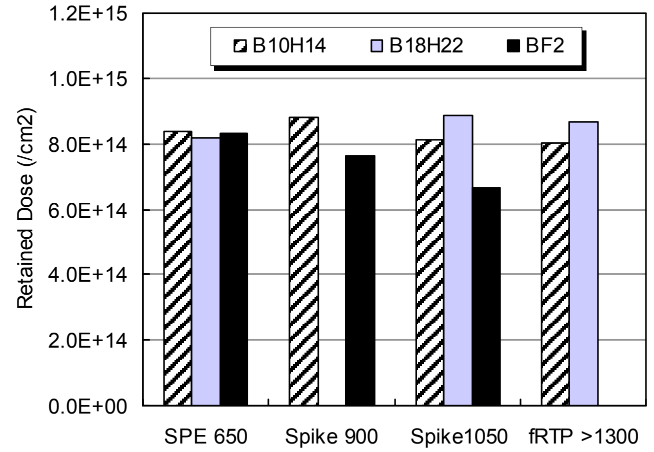


Fig. 5: Retained dose comparison for the various pSDE implants.

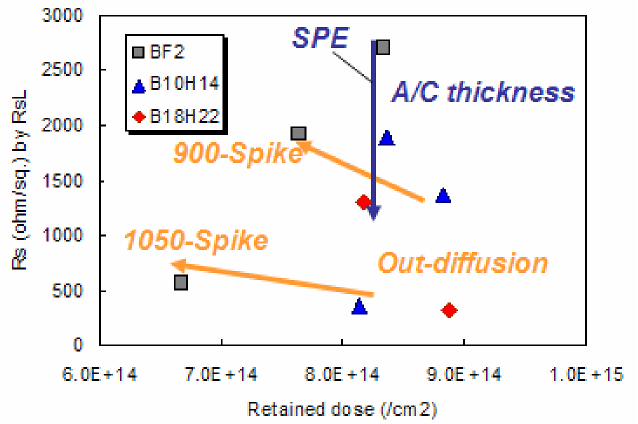


Fig. 6: Retained dose versus Rs for various anneals.

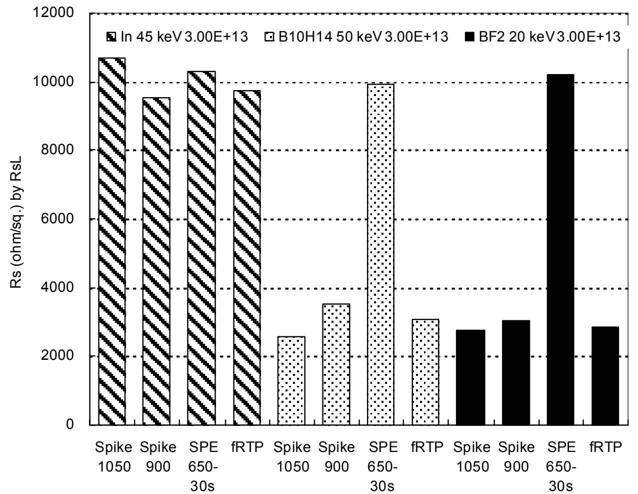


Fig. 7: pHALO implant Rs results.

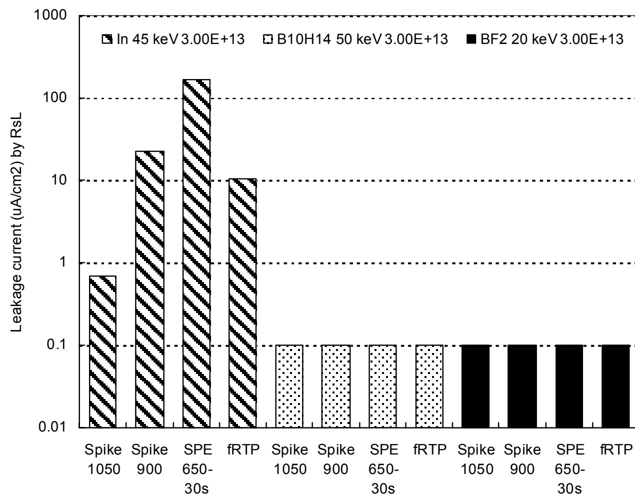


Fig. 8: Junction leakage results for the different pHALO implants.

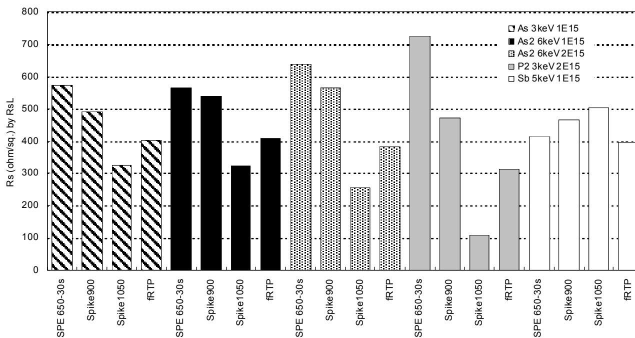


Fig. 9: Rs results for the various nSDE implants and anneals.

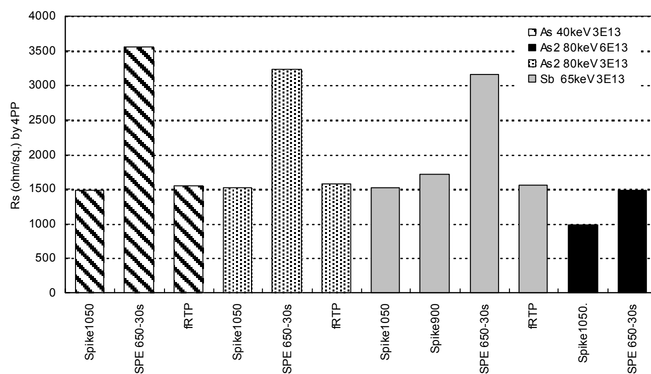


Fig. 10: Rs results for the various nHALO implants and anneals.