Analysis of Lateral Superjunction Silicon Power Device with Multiple Layers by TCAD Simulation

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[Introduction] One of the advantages of a lateral power device over a vertical one is that it is easier to integrate with other transistors [1]. The lateral superjunction (SJ) device is promising as a future integrated power device with high breakdown voltage (V_{BD}) and low specific on-resistance ($R_{ON,\,sp}$) [2,3]. However, one of the demerits of SJ devices is that V_{BD} is very sensitive to the balance of p/n concentrations (N_A and N_D). In this work, the device characteristics of SJ devices with two layers and multiple layers were simulated and analyzed. **[Simulation results]** Ideal SJ diode structures with N_D=N_A=N are assumed (Fig.1) in the simulation, where N is the doping concentration. First, a 30um long SJ diode with two layers (Fig.1(a)) was simulated. V_{BD} significantly depends on N and the thickness (T_d) (Fig.2). When N increases, V_{BD} decreases, but V_{BD} starts to decrease at higher N as T_d is smaller. This is because the layers are fully depleted more easily as T_d is smaller. When the thickness is too thin (T_d=0.2μm), the maximum breakdown voltage slightly drops, which is caused by the superposition of electric fields near the electrodes. Fig.3 compares SJ devices with two, three, and four layers (Fig.1) for T_d=0.5μm, where it is assumed that the concentrations of the middle layers is N and that of top/bottom layers is N/2 in the 3- and 4-layer devices because the depletion layer expands only one side in the top/bottom layers. It is found that high V_{BD} remains until higher N in the 3- and 4-layer devices. Low $R_{ON,\,sp}$ in the 3- and 4-layer devices is confirmed at the fixed V_{BD} (Fig.4). On the other hand, V_{BD} is very sensitive to the balance of the p/n concentration [2]. When the doping is uneven, V_{BD} is rapidly degraded in the two-layer devices (Fig.5(a)). It is found that the 4-layer structure has better resistance to uneven doping of p/n (Fig.5(b)) at the fixed N. **[Conclusion]** The lateral SJ power device with multiple layers shows better tradeoff between V_{BD} and $R_{ON,\,sp}$ and improves resistance to performance degradation caused by uneven doping. **[Reference]** [1] AW. Ludikhuize, ISPSD, p.11, 2000. [2] T. Fujihira, JJAP, 36, 6254, 1997. [3] F. Udrea et al., IEEE TED, 64, 713, 2017.

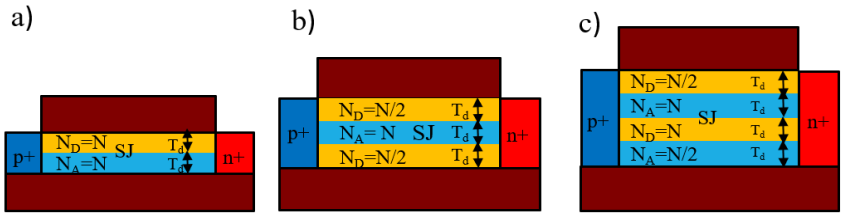

Fig.1. Schematics of SJ diodes with a) 2 layers, b) 3 layers, and c) 4 layers, where T_d is the thickness of n/p layers and N is the concentration.

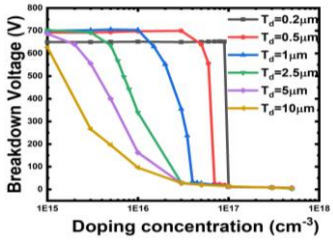

Fig.2. Dependence of V_{BD} on T_d and doping concentration (N) in 2-layer device.

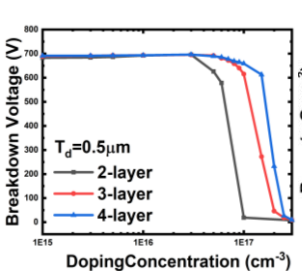

Fig.3. Dependence of V_{BD} on N in 2-layer, 3-layer, and 4-layer devices.

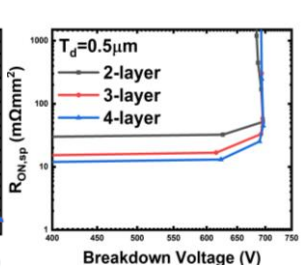

Fig.4. Tradeoff between $R_{ON,\,sp}$ and V_{BD} in 2-layer, 3-layer, and 4-layer devices.

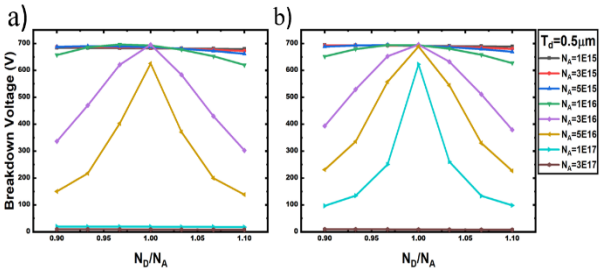

Fig.5. Dependence of breakdown voltage on uneven doping. a) 2 layers. b) 4 layers.