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Low Temperature Impurity Diffusion in 6H-SiC: Planar Quantum-Well P-N Junctions and N-P-N Transistor Structures

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Abstract. Low temperature diffusion of boron and phosphorus has been realized for the first time in monocrystalline 6H-SiC through controlled surface injection of silicon vacancies. By varying the parameters of the surface oxide overlayer during the boron/phosphorus diffusion process, it was possible to obtain the SiC planar quantum–well p–n junctions and transistor structures featuring low values for dark leakage currents. Use of the SiC quantum-well transistor structures in both bipolar and FET variations has been found to result in the generation of the negative resistance due to avalanche current processes.

Dopant diffusion in semiconductors is known to be amenable to control by adjusting the fluxes of self-interstitials and vacancies emerging from the monocrystalline surface. Use of thin oxide overlayers deposited on semiconductor wafers in combination with high diffusion temperatures has been found to result predominantly in the generation of self–interstitials by the oxidized surface, and hence, in increased rates of impurity diffusion by the kick-out mechanism,[1] while the dissociative vacancy diffusion mechanism is associated with thick oxide overlayers and low diffusion temperatures.[2] Therefore, the present work was aimed at the realization of the SiC planar quantum–well p–n junctions and transistor structures using thick oxide overlayers in combination with boron/phosphorus low temperature diffusion (<1000°C) which are responsible for the domination of the dissociative vacancy diffusion mechanism.

The diffusion experiments involving boron and phosphorus diffusion were performed at 900°C and 950°C, respectively, from gas phase into 520 mm thick n–type 6H–SiC (0001) wafers containing the high concentration of nitrogen ($2{\cdot}10^{18}$ cm^{-3}). The working and back side of the wafers were previously oxidized using the pyrolysis of silane.The parameter that was varied in the course of experiment was the oxide overlayer thickness. Diffusion profiles were measured using the SIMS technique (figs.1 and 2). It can be seen that use of thick oxide overlayers leads to an increased depth for the p^+n junction. The direct I–V characteristics of the sample with thick oxide overlayer exhibits the classical type of the SiC p–n junction (figs. 3 and 4). The behavior of the I–V characteristics as a function of oxide overlayer thickness correlates with the SIMS data (figs.1–4). A quantum–well n^+–p^+–n structure can operate depending on the circuit configuration as a bipolar or a field–effect transistor, the I–V characteristics of which reflectes the occurrence of the conditions for both the emitter-base and base-collector tunneling. For example, the recombination of holes in 2D base with the electrons tunneling from the emitter can cause a hysteresis of the I_{bc}–U_{bc} dependence (fig. 5). In order to demonstrate the avalanche properties of the 6H–SiC transistor structure the p^+n base–collector junction has been studied as a single diode structure (fig. 5). The reverse base–collector voltage U_{bc} results in a sharp increase in the $I_{bc}=f(U_{bc})$ because of impact ionization (figs. 5 and 6) and demonstrates the realization of the negative induced resistance due to avalanche current process, the presence of which is necessary to produce UHF devices.[3]

REFERENCES

1) N.T. Bagraev, L.E. Klyachkin, V.L. Sukhanov, *Semicond.Sci.Technol.* **6** (1991) 577
2) N.T. Bagraev, L.E. Klyachkin, V.L. Sukhanov, *Defect and Diffusion Forum* **103–105** (1993) 201
3) N.T. Bagraev, L.E. Klyachkin, V.L. Sukhanov, *Sol. St. Electronics* **36** (1993) 1741

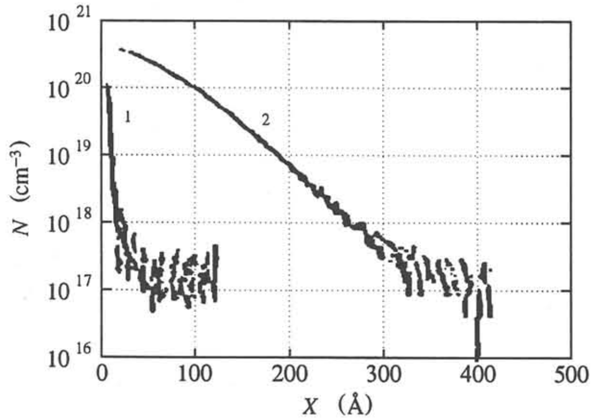

Figure 1. SIMS data for quantum–well diffusion profiles obtained for the boron dopant in n-type monocrystalline 6H–SiC with thin (1) and thick (2) oxide overlayer at diffusion temperature of 900°C.

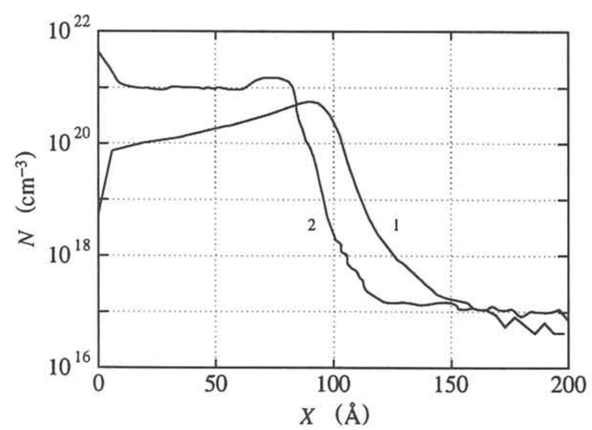

Figure 2. SIMS data for quantum–well diffusion profiles of boron (1) and phosphorus (2) obtained using successive diffusion into n-type monocrystalline 6H-SiC at diffusion temperatures of 900°C (boron) and 950°C (phosphorus).

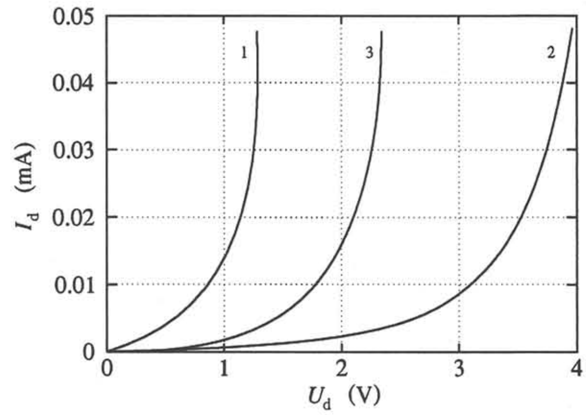

Figure 3. The direct I–V characteristics for the 6H–SiC planar p–n junctions (0.8 mm^2) obtained using low temperature diffusion of boron (900°C) at thin (1), medium (2) and thick (3) oxide overlayer.

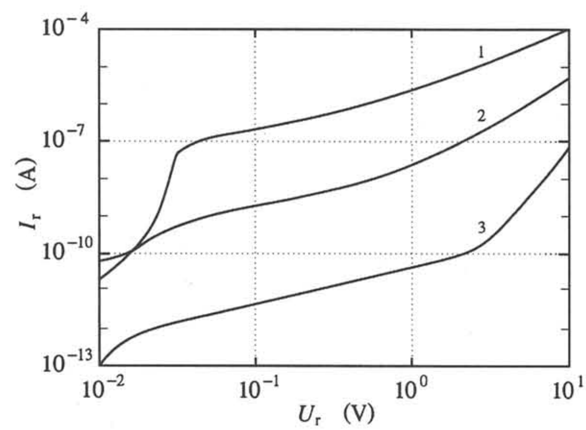

Figure 4. The reverse I–V characteristics for the 6H–SiC planar p–n junctions (0.8 mm^2) obtained using low temperature diffusion of boron (900°C) at thin (1), medium (2) and thick (3) oxide overlayer.

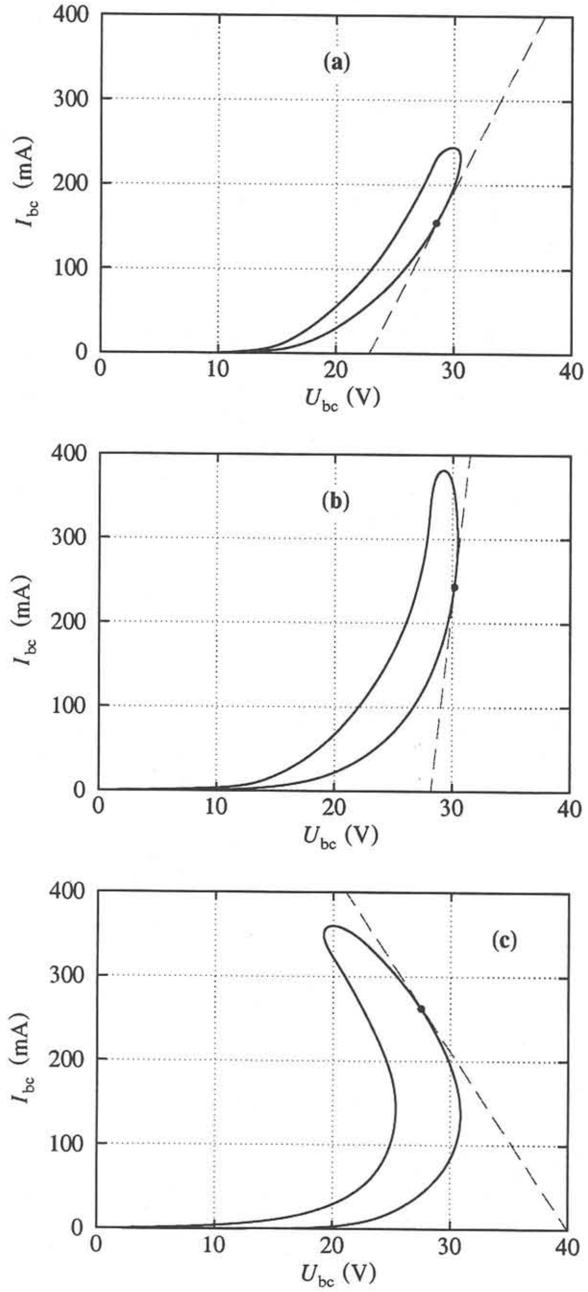

Figure 5. Avalanche collector current vs U_{bc} in the case of the 6H–SiC bipolar transistor mode. The value of the modulation for the base–collector voltage is:
(a) $U_{bc}=5$ V, $dU_{bc}/dI_{bc}>0$;
(b) $U_{bc}=10$ V, $dU_{bc}/dI_{bc}=0$;
(c) $U_{bc}=15$ V, $dU_{bc}/dI_{bc}<0$.

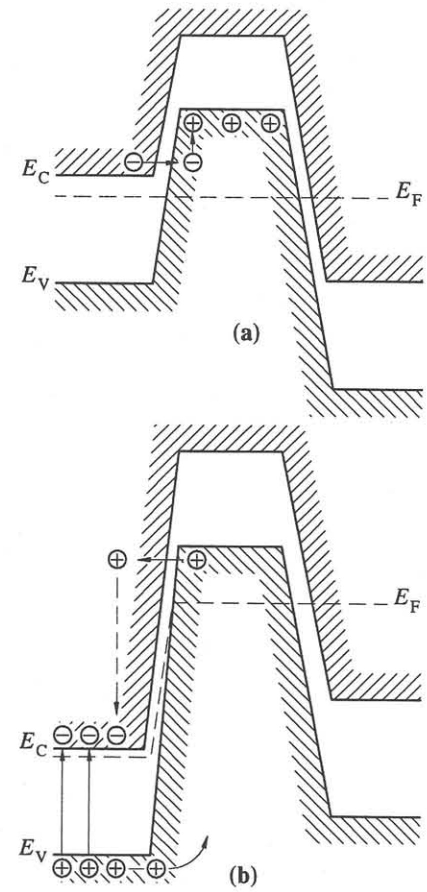

Figure 6. The one–electron band scheme of a transistor with the two–dimensional base: **(a)** — $U_{bc}=0$; **(b)** — $U_{bc}<0$.