Activation of Al Implants in SiC

K.A. Jones, P.B. Shah, M.H. Ervin, and M.A. Derenge
Army Research Lab -SEDD
2800 Powder Mill Road, Adelphi, MD 20783
J. A. Freitas
Naval Research Lab
Code 6877, 4555 Overlook Ave., Washington, DC 20375
R.D. Vispute and V. Kulkarni
University of Maryland, Physics Department, College Park, MD 20742

Aluminum is the acceptor of choice for SiC because its acceptor energy is the smallest, and its solubility is greater than 10^{20} cm^{-3}. It can be readily incorporated during growth, but like all other dopants it cannot be diffused in at technologically useful rate even at temperatures as high as 1800 °C. Thus, for applications that require localized doping, the Al must be implanted.

Before the Al can become electrically active, the sample has to be annealed at temperatures as high as 1700 °C. As seen in Fig. 1, this temperature can be lowered a little by co-implanting C, and as seen in Fig. 2, the temperature can be raised a little by co-implanting Si. This can best be explained by the Al being more easily incorporated into the SiC lattice by reacting with the implanted C, or being blocked somewhat by the implanted Si from reacting with the C in the SiC.

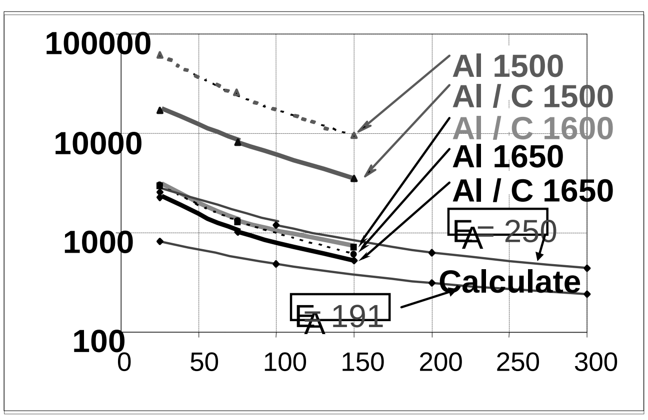

Fig. 1. The sheet resistivity of SiC implanted with Al or co-implanted with Al and C and annealed at different temperatures plotted as a function of the measurement temperature.

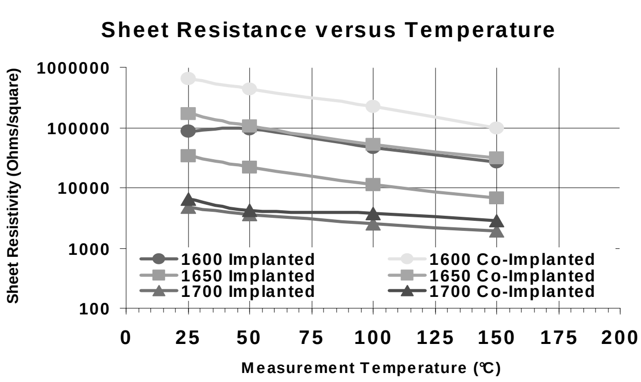

Fig. 2. The sheet resistivity of SiC implanted with Al or co-implanted with Al and Si and annealed at different temperatures plotted as a function of the measurement temperature.

However, all of the implant damage is not annealed out, and this results in a lower mobility and possibly trapping out some of the acceptors as is indicated by resistivity, cathodoluminescence, (CL) electron paramagnetic resonance (EPR), and Rutherford backscattering spectroscopy (RBS) measurements. The CL measurements in Fig. 3 show peaks around 2.9 eV that are identified with the D_I defect, and the RBS data in Table 1 shows that the lattice appears to become more defective at the higher annealing temperatures because χ_{min} begins to increase at the higher annealing temperatures.

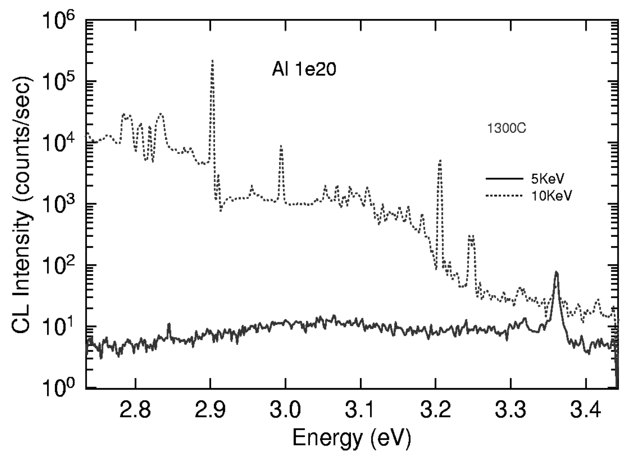

Fig. 3. The cathodoluminescence peaks created by 10 keV electrons in Al implanted SiC annealed at 1300 °C for 30 min.

Sample	χ (min) **Al 10^{20}**	χ (min) **Al/C 10^{20}**	χ (min) **Al 10^{20}**	χ (min) **Al/Si 10^{20}**
As Grown	1.9			
As Implanted	6.1	6.8	21.0	16.6
Annealed 1300°C	4.3	5.0		
Annealed 1400°C	4.3	4.3	4.5	4.35
Annealed 1500°C	4.1	4.5	4.4	4.35
Annealed 1600°C		5.1		9.8
Annealed 1650°C	6.2	7.7	5.6	6.3
Annealed 1700°C			7.9	7.8

Table 1. The RBS χ_{min} for SiC implanted with Al, Al and C, or Al and Si and annealed at various temperatures.

The D_I defect can best be attributed to the formation of dislocation loops. One possible source of this thermally stable defect are the σ bonds that could be formed between neighboring dangling C bonds in the 60° basal plane dislocations forming the dislocation loops.