# Reduction in Majority-Carrier Concentration in Lightly-Doped 4H-SiC Epilayers by Electron Irradiation

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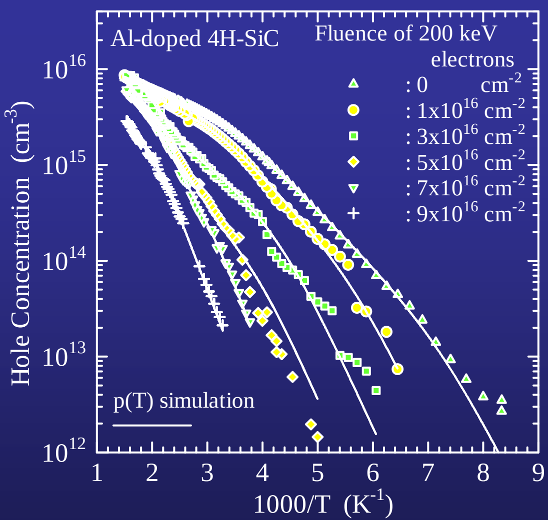
**Abstract.** The mechanisms for the reduction in the hole concentration in lightly Al-doped p-type 4H-SiC epilayers by electron irradiation as well as in the electron concentration in lightly N-doped n-type 4H-SiC epilayers by electron irradiation are investigated.

In the p-type 4H-SiC epilayers, the temperature dependence of the hole concentration, p(T), is not changed by 100 keV electron irradiation, while the p(T) is decreased by 150 keV electron irradiation. The density of Al acceptors with energy level $E_V$+0.22 eV decreases with increasing fluence of 150 keV electrons, whereas the density of deep acceptors with energy level $E_V$+0.38 eV increases.

In the n-type 4H-SiC epilayers, the temperature dependence of the electron concentration, n(T), is decreased by 200 keV electron irradiation. The density of N donors located at hexagonal C-sublattice sites decreases significantly with increasing fluence of 200 keV electrons, whereas the density of N donors located at cubic C-sublattice site decreases slightly.

## Back Ground of This Study

### 200 keV electron irradiation

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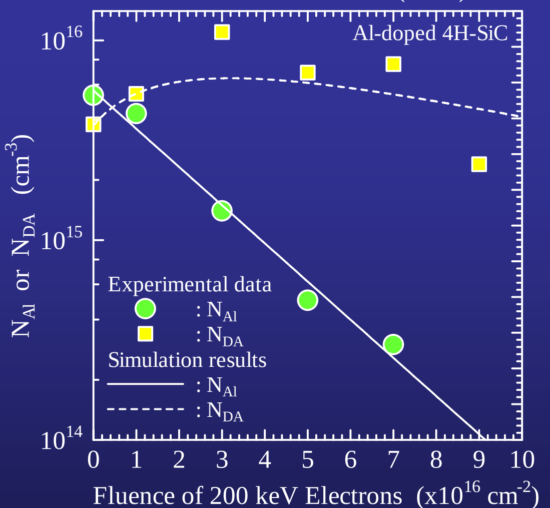



Fluence dependence of Al acceptor density

$$\frac{dN_{Al}}{d\Phi} = -\kappa_{Al200} N_{Al}$$

Fluence dependence of deep acceptor density

$$\frac{dN_{DA}}{d\Phi} = -\frac{dN_{Al}}{d\Phi} - \kappa_{DA200} N_{DA}$$

$$\kappa_{Al200} = 4.4\times10^{-17}\ \text{cm}^2$$
$$\kappa_{DA200} \cong 1\times10^{-17}\ \text{cm}^2$$

## Experimental

Samples

1) 10 μm-thick Al-doped 4H-SiC
2) 10 μm-thick N-doped 4H-SiC

Electron irradiations

Irradiation at room temperature

Hall-effect measurements

van der Pauw configuration
Magnetic field: 1.4 T

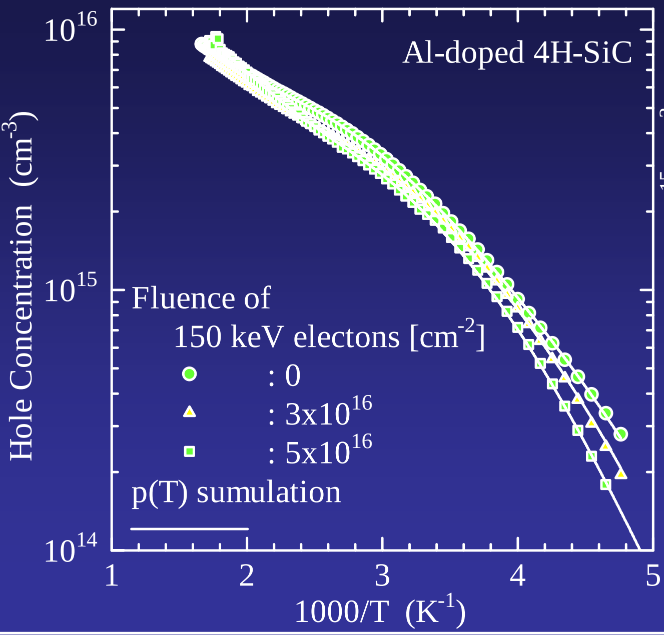
Analysis of temperature dependence of majority-carrier concentration

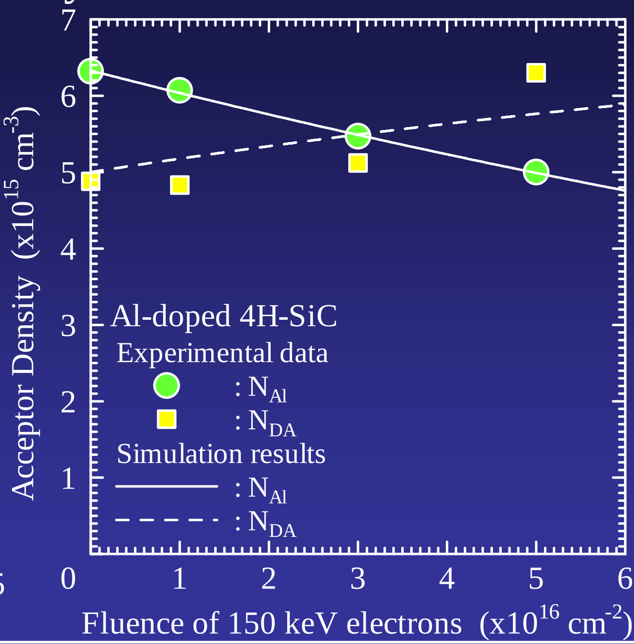
Free Carrier Concentration Spectroscopy (FCCS)

## Results

A) p(T) was unchanged by 100 keV electron irradiation.

## Al-doped p-type 4H-SiC irradiated by 150 keV electrons




$N_{Al}$ : Density of Al acceptors with $E_V + 0.22$ eV

$$\frac{dN_{Al}}{d\Phi} = -\kappa_{Al150} N_{Al}$$

$$\kappa_{Al150} = 4.8\times10^{-18}\ \mathrm{cm}^2$$

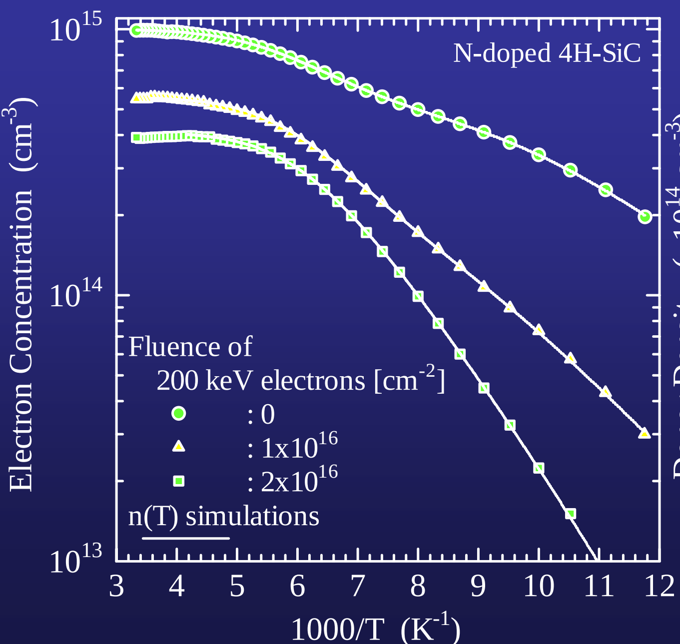
$N_{DA}$ : Densuty of deep acceptors with $E_V + 0.38$ eV

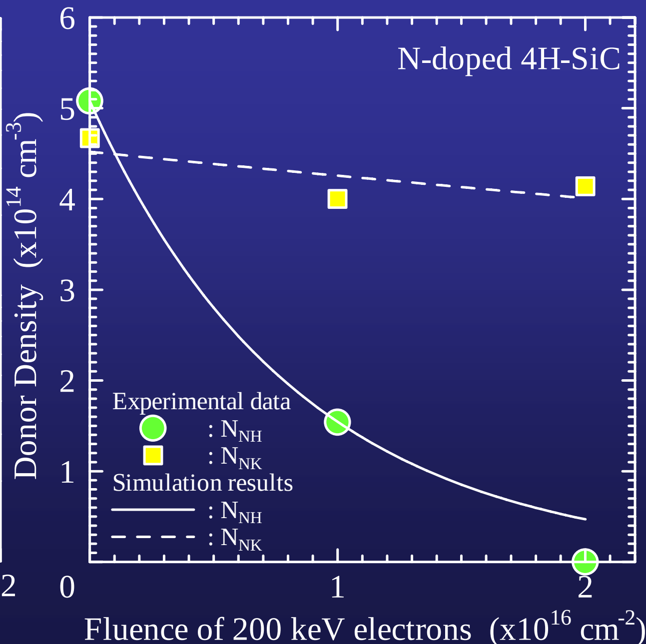
$$\frac{dN_{DA}}{d\Phi} = -\frac{dN_{Al}}{d\Phi} - \kappa_{DA150} N_{DA}$$

$$\kappa_{DA150} \cong 1\times10^{-18}\ \mathrm{cm}^2$$

B) 150 keV electron irradiation may transform Al acceptors into deep acceptors.

## N-doped n-type 4H-SiC irradiated by 200 keV electrons




$N_{NH}$ :Density of N donors at hexagonal sites with $E_C - 0.07$ eV

$$\frac{dN_{NH}}{d\Phi} = -\kappa_{NH200} N_{NH}$$

$$\kappa_{NH200} \cong 1.2\times10^{-16}\ \mathrm{cm}^2$$

$N_{NK}$ :Density of N donors at cubic sites with $E_C - 0.12$ eV

$$\frac{dN_{NK}}{d\Phi} = -\kappa_{NK200} N_{NK}$$

$$\kappa_{NK200} \cong 6.0\times10^{-18}\ \mathrm{cm}^2$$

C) N donors at hexagonal sites are less radiation-resistant than N donors at cubic sites.