Reduction in Al Acceptor Density by Electron Irradiation in Al-Doped 4H-SiC

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Abstract

The influence of electron irradiation on the hole concentration in Al-doped 4H-SiC epilayers is investigated using the temperature dependence of the hole concentration p(T).

By 4.6-MeV electron irradiation, the p(T) is reduced in the whole temperature range.

In the unirradiated and irradiated samples, ~200 meV Al acceptors and ~370 meV unknown defects are detected.

By irradiation, only the density of Al acceptors is reduced from 6.2×10^{15} cm^{-3} to 8.2×10^{14} cm^{-3}.

The main reduction in p(T) by electron irradiation results from the decrease of the Al acceptor density , not from the creation of defects.

Motivation

Electron Irradiation

In the case of Si

The creation of vacancy-related defects.

↓

The controlled generation of intrinsic defects in Si for using high power devices.

The decrease of the acceptor density in p-type Si.

↓

The degradation of the conversion efficiency of Si solar cells used in space.

What happens in Al-doped p-type SiC?

Experimental

Al-doped 4H-SiC epilayer

Al-doped 4H-SiC epilayer
(thickness: 10 μm, Al-doping density: ~$5x10^{15}$ cm^{-3})

n-type 4H-SiC wafer
(thickness: 375.9 μm, resistivity: 0.02 Ωcm)

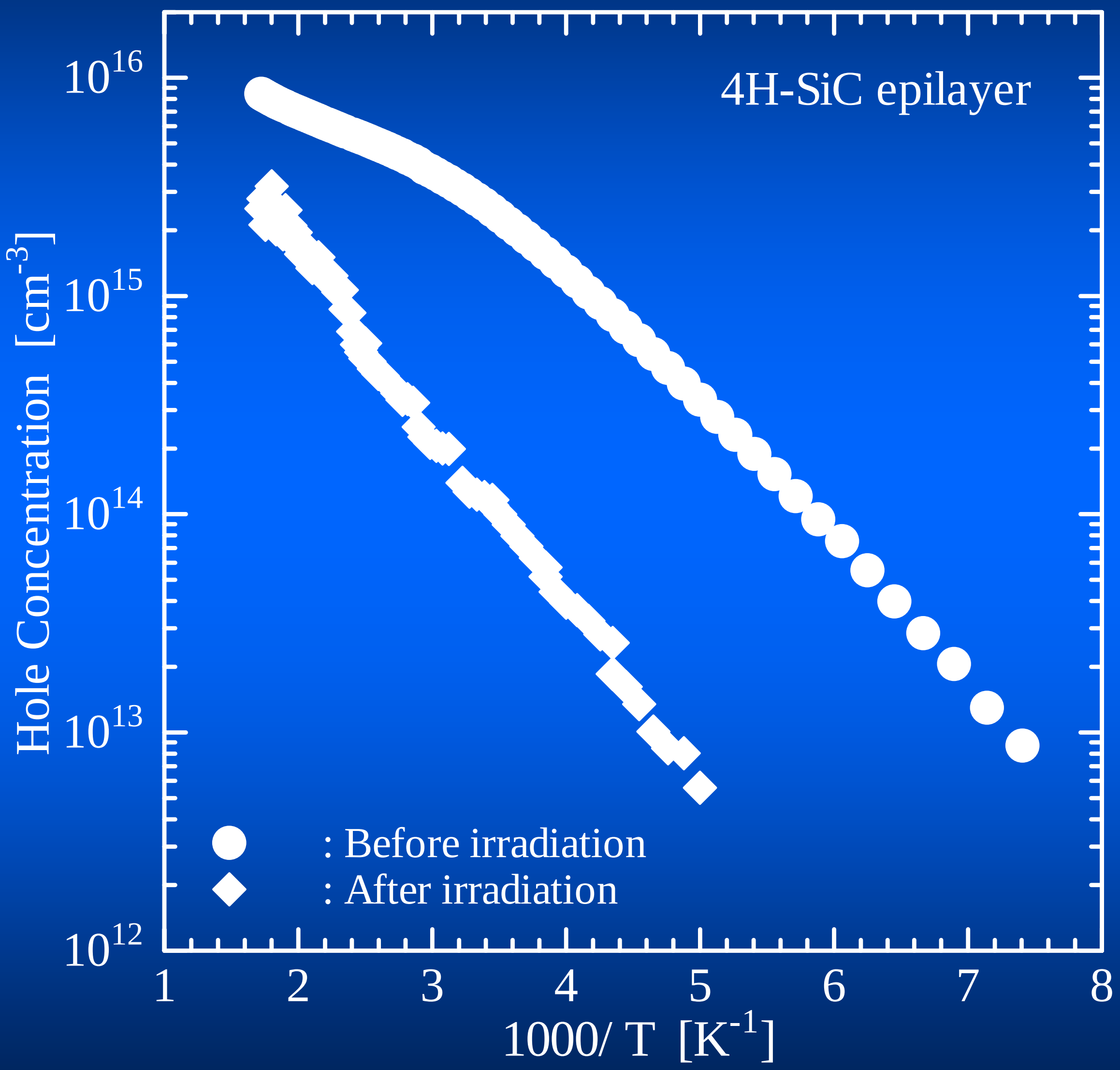
Irradiation

4.6 MeV electrons with $2.6x10^{14}$ cm^{-2} at room temperature

Hall-effect measurement

Temperatures: 135 K to 580 K
Magnetic field: 1.4 T

Change of temperature dependence of hole concentration



p(T) is reduced by electron irradiation

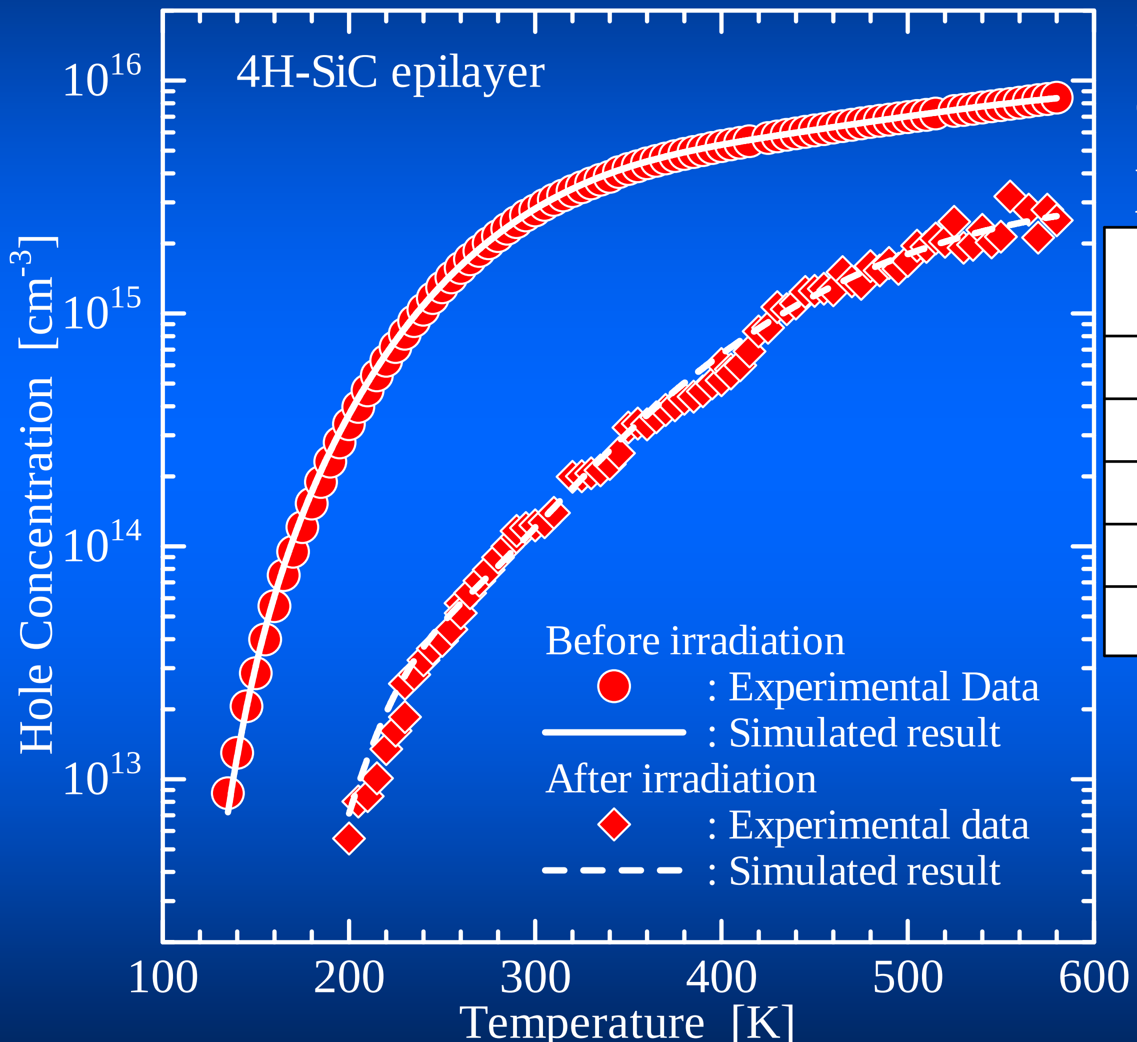
↓ The possible reason

1. The creation of defects (hole traps or donor-like defects)

or

2. The decrease in acceptor density

Verification of obtained values



Comparison between experimental and simulated p(T)

	Before irradiation	After irradiation
ΔE_{A1} [meV]	203	206
N_{A1} [cm^{-3}]	6.2×10^{15}	8.2×10^{14}
ΔE_{A2} [meV]	365	383
N_{A2} [cm^{-3}]	4.2×10^{15}	3.4×10^{15}
N_{comp} [cm^{-3}]	3.4×10^{13}	7.4×10^{14}

The p(T) simulations are in good agreement with the experimental p(T).

Origins of these energy levels

	Before irradiation	After irradiation
ΔE_{A1} [meV]	203	206
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Al acceptors (ΔE_{A1}, N_{A1})

Unknown defect (ΔE_{A2}, N_{A2})

The main reason for the reduction in p(T) by electron irradiation

The Al acceptor density (~200 meV level) is decreased from $6.2\text{x}10^{15}$ cm^{-3} to $8.2\text{x}10^{14}$ cm^{-3}.

The unknown defect density (~370 meV level) appears unchanged.

Therefore, the decrease in the Al acceptor density results in the reduction in p(T).

The cause of the decrease in Al acceptor density by electron irradiation

1) The movement of the substitutional Al atoms into the interstitial sites
2) The bond-breaking between the substitutional Al atom and the nearest neighbor atom

Further research in this area is in progress.

Summary

1) The effect of electron irradiation on Al-doped 4H-SiC was investigated with Hall-effect measurements.
2) p(T) was reduced by 4.6-MeV electron irradiation.
3) ~200 meV Al-acceptor density was decreased.
4) ~370 meV unknown defects appeared unchanged.
5) The main reduction in p(T) by irradiation resulted from the decrease in Al acceptors, not from the creation of hole traps or donor-like defects.