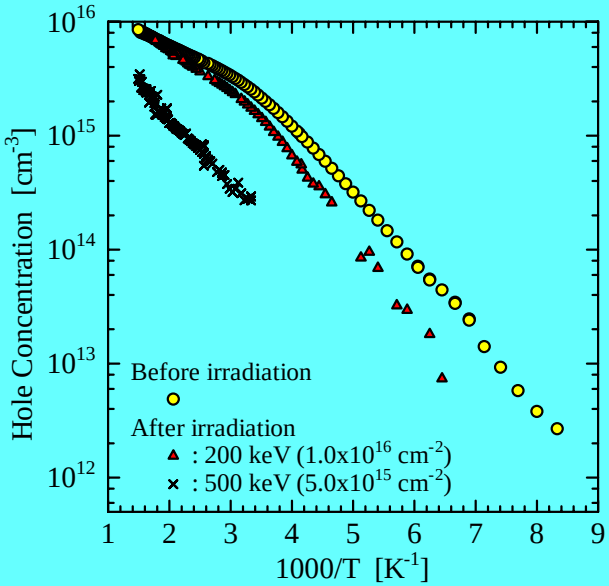
Mechanisms of Decrease in Hole Concentration in Al-doped 4H-SiC by Irradiation of 200 keV Electrons

Hideharu Matsuura[1)], Nobumasa Minohara[1)], Yusuke Inagawa[1)], Miyuki Takahashi[1)],
Takeshi Ohshima[2)], and Hisayoshi Itoh[2)]
[1)]*Osaka Electro-Communication University*, [2)]*Japan Atomic energy Agency*

Abstract. From the temperature dependence of the hole concentration p(T) in lightly Al-doped 4H-SiC epilayer irradiated with several fluences of 200 keV electrons, the density (N_{Al}) of Al acceptors with E_V+0.2 eV decreases significantly with increasing fluence, whereas the density (N_{Defect}) of unknown acceptors (or defects) with E_V+0.37 eV increases with fluence at first and then decreases slightly. Although only C vacancies increases with fluence because 200 keV electrons can displace only C atoms, only the increase in the density of C monovacancies (V_C) located at midgap cannot explain the changes of p(T) by 200 keV electron irradiation. In order to explain the fluence dependences of N_{Al} and N_{Defect}, it may be necessary to consider the relationship between C vacancies and Al acceptors.

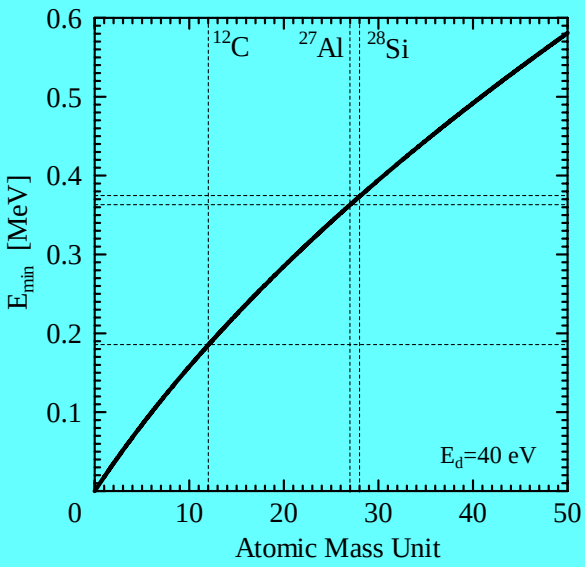
Introduction

Irradiation-energy dependence of p(T) (Refs. 1,2)



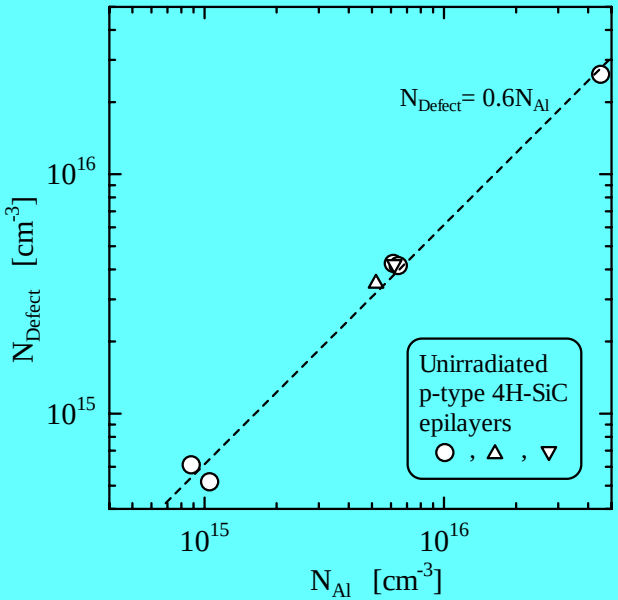
Although the fluence of 200 keV electrons is higher, the p(T) decreases less than due to 500 keV electron irradiation.

Atomic-mass-unit dependence of minimum electron energy required for displacement of substitutional atom in SiC (Ref. 1)



Energy		Displaced atoms
200 keV	→	only C atoms
500 keV	→	C, Al and Si atoms

Relationship between N_{Al} and N_{Defect} (Refs. 1,3)



$$N_{Defect} = 0.6 \times N_{Al}$$

Unknown acceptors with E_V+0.37 eV are related to Al.

Experiment

Unirradiated Al-doped 4H-SiC epilayer

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Hall-effect measurement

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Irradiation of $1x10^{16}$ cm^{-2} fluence of 200 keV electrons

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Hall-effect measurement

↓

Irradiation of $2x10^{16}$ cm^{-2} fluence of 200 keV electrons

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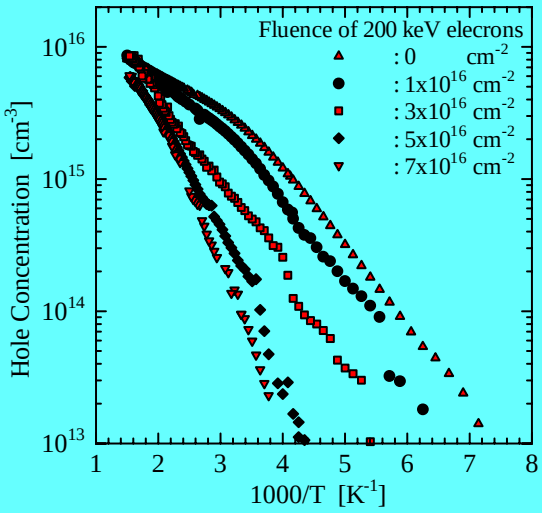
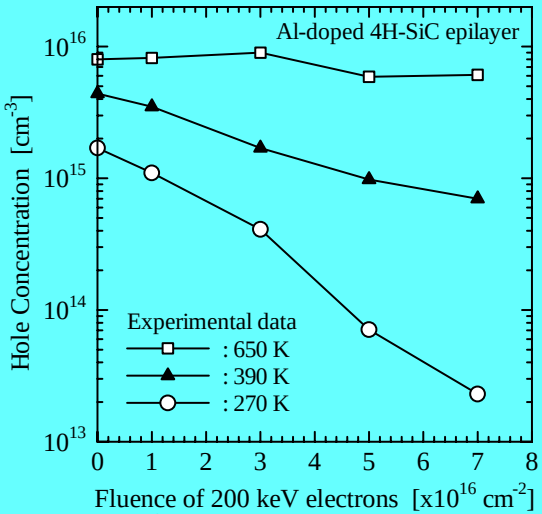
Hall-effect measurement

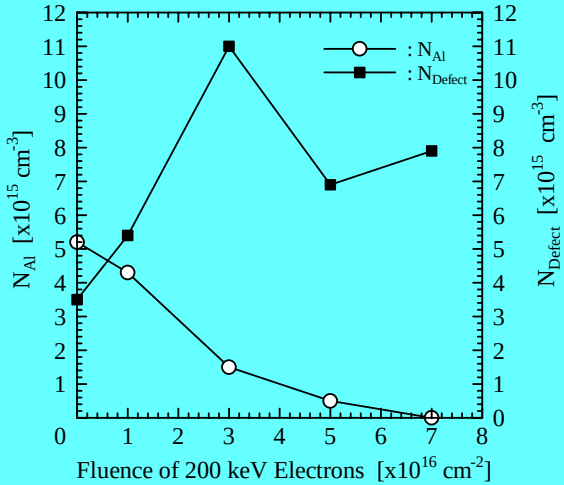
Total fluences
- 0 cm^{-2}
- $1x10^{16}$ cm^{-2}
- $3x10^{16}$ cm^{-2}
- $5x10^{16}$ cm^{-2}
- $7x10^{16}$ cm^{-2}

Results





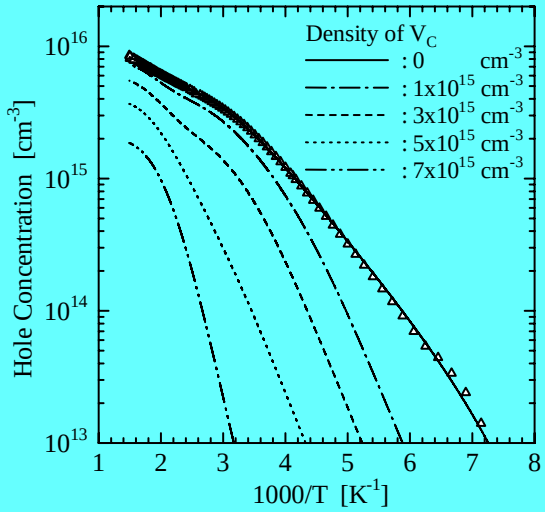
p(T) at low T decreases with fluence, whereas p(T) at high T seems unchanged.



N_{Al} decreases monotonously with increasing fluence, whereas N_{Defect} increases at first and then decreases.

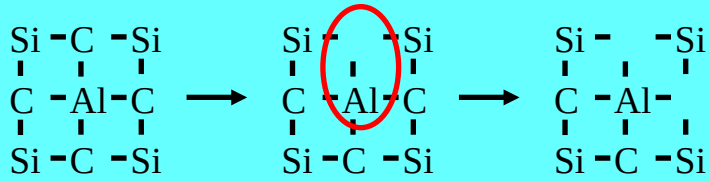
Discussion

Under the assumption that only V_C is increased by 200 keV electron irradiation



p(T) at all the T decreases with increasing V_C density.

Under the assumption that the unknown acceptor is a complex of Al and V_C



Al acceptor → **N_{Al} decreases, Al-V_C increases** → **Al-V_C decreases**

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N_{Al} decreases monotonously with fluence, whereas the density of Al-V_C increases at first with fluence and then decreases.

Summary

The unknown deep acceptors with E_V+0.37 eV may be related to Al and C vacancy.

References

1) Hideharu Matsuura, et al.: “Relationship between defects induced by irradiation and reduction of hole concentration in Al-doped 4H-SiC”, Physica B 376-377 (2006) 342-345.
2) Hideharu Matsuura, et al.: “Decrease in Al acceptor density in Al-doped 4H-SiC by irradiation with 4.6 electrons”, Appl. Phys. Lett. 83 (2003) 4981-4983.
3) Hideharu Matsuura, et al.: “Dependence of acceptor levels and hole mobility on acceptor density and temperature in Al-doped p-type 4H-SiC epilayers”, J. Appl. Phys. 96 (2004) 2708-2715.