Si Substrate Suitable for Radiation-Resistant Space Solar Cells

Hideharu Matsuura, Shirou Kawakita,[1] Takeshi Ohshima[2] and Hisayoshi Itoh[2]

Osaka Electro-Communication University,
1) Japan Aerospace Exploration Agency,
2) Japan Atomic Energy Agency

Abstract.

Irradiating group-III (B, Al, Ga)-doped Czochralski (CZ)-grown Si substrates as well as B-doped magnetic Czochralski (MCZ)-grown and floating-zone (FZ)-grown Si substrates with 10 MeV protons or 1 MeV electrons, we investigate both the reduction in the hole concentration and the conversion of p-type to n-type using Hall-effect measurements. In all the 10 Ωcm CZ-Si, the density of each acceptor species is reduced by irradiation, and finally the conversion occurs with 1.0×10^{17} cm^{-2} fluence of 1 MeV electrons or with 2.5×10^{14} cm^{-2} fluence of 10 MeV protons. In 10 Ωcm MCZ-Si and 10 Ωcm FZ-Si, on the other hand, the conversion does not occur under the same condition. Moreover, the reduction in the hole concentration for FZ-Si is much less than the others. From these results, it is elucidated that the conversion as well as the reduction in the hole concentration is strongly dependent on the concentration of oxygen in Si, not on the type of acceptor species in Si. Therefore, the p-type FZ-Si substrate is the most appropriate for radiation-resistant space solar cells such as $n^+/p/p^+$ Si solar cells and upcoming III-V tandem solar cells on n^+/p Si substrates.

Introduction

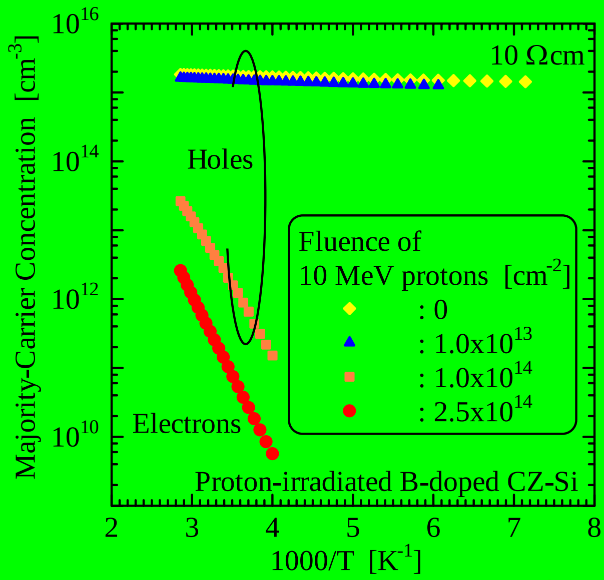
Until approximately 7 years ago, prime space solar cells were $n^+/p/p^+$ Si solar cells. Recently, a thin III-V compound tandem cell on a thick Ge bottom cell (i.e., Ge substrate) has replaced Si solar cells. However, the Ge substrate is heavier, more fragile and more expensive than the Si substrate. Therefore, Si is expected as a bottom cell material.

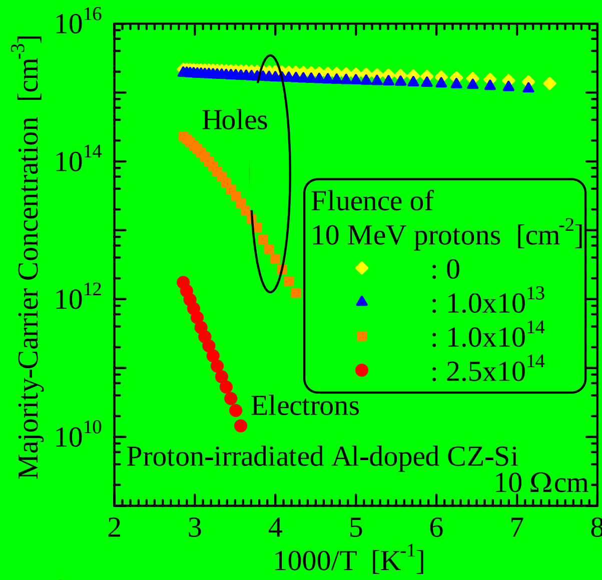
Why have we investigated the defects induced by irradiation using Hall-effect measurements instead of DLTS?

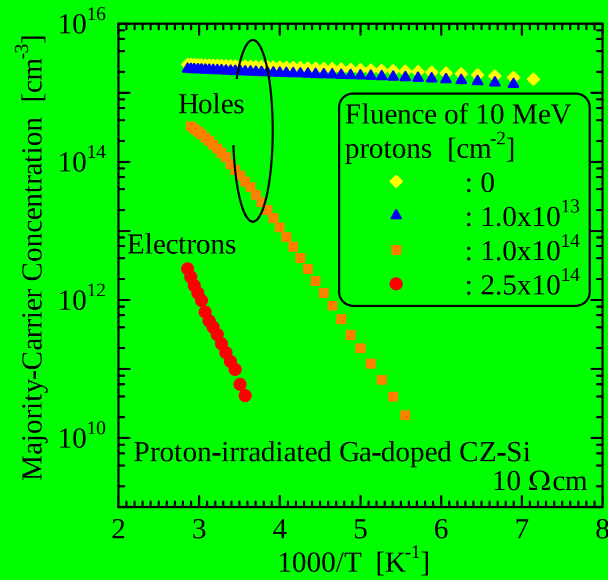
1. **Hole concentration in p-type Si substrate is reduced by irradiation.**
2. **DLTS (deep level transient spectroscopy) cannot determine the densities and energy levels of defects whose densities are close to or higher than the acceptor density.**
3. **We would like to investigate the quantitative relationship between the hole concentration and the densities of defects induced by irradiation.**

Results and Discussion

1. Dependence of reduction in p(T) on type of acceptor species.

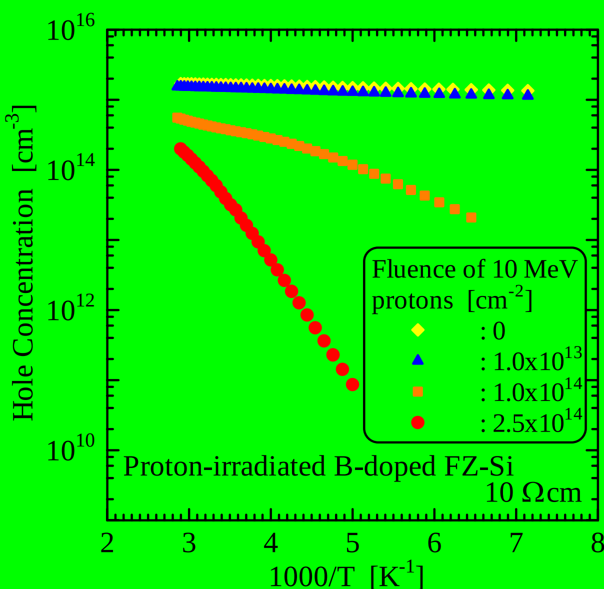


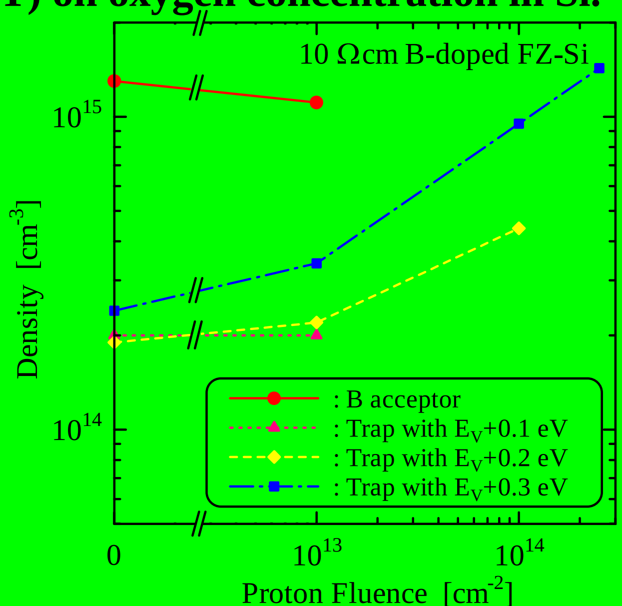




By irradiation with 2.5×10^{14} cm^{-2} fluence of 10 MeV protons, the type conversion occurred in the 10 Ω cm CZ-Si with any acceptor species (B, Al, Ga).

2. Dependence of reduction in p(T) on oxygen concentration in Si.





1. **In FZ-Si that has the lowest oxygen concentration among these Si, the type conversion did not occur.**
2. **By irradiation with 2.5×10^{14} cm^{-2} fluence of 10 MeV protons, the density of trap with E_V+0.3 eV exceeded the B acceptor density.**

Conclusion

p-type FZ-Si substrate is the most appropriate for space Si solar cells.