SHJ太陽電池における水素起因界面欠陥の発生機構

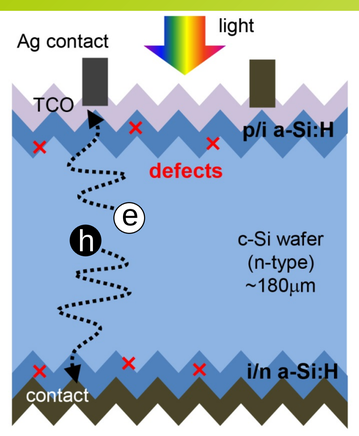
布村 正太[1]、坂田 功[1]、Mickaël Lozac'h[2]、松原 浩司[3]

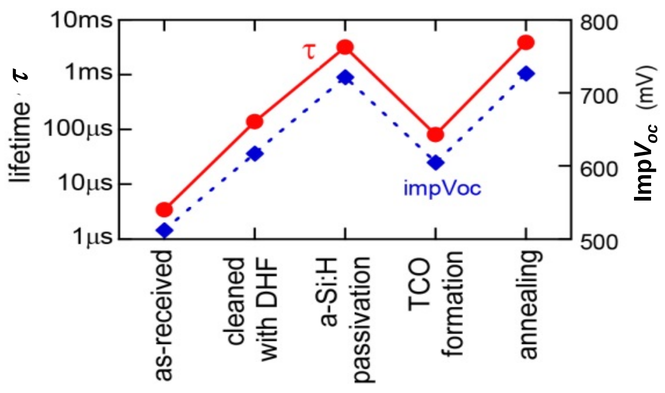
産業技術総合研究所　[1]電子光基礎技術研究部門、
[2]デバイス技術研究部門、[3]エネルギー・環境領域

Abstract

- **Hydrogen plasma-induced defects** in crystalline silicon have been studied, by using in-situ photocurrent measurement and spectroscopic ellipsometry.
- A hydrogen (H_2) plasma treatment causes **surface defects**, **bulk defects** and **surface disordered layer (DSL),** depending on the treatment time.
- The defect formation strongly depends on the treatment time & treatment temperature.

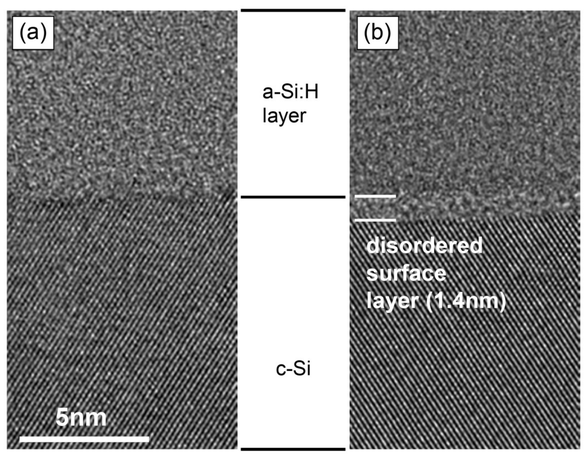
SHJ solar cell structure & minority carrier lifetime

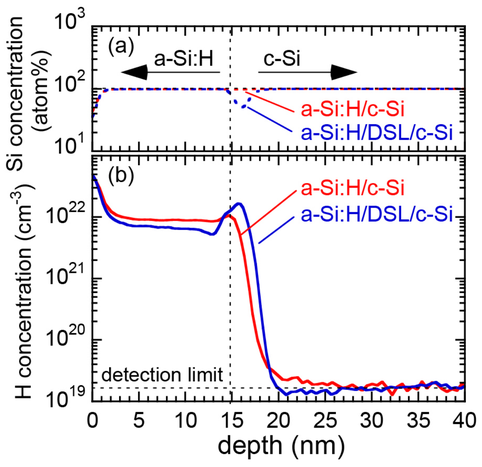




- In SHJ solar cells, a-Si:H layer plays important roles in surface passivation & carrier selection.
- The lifetime, i.e., a measure for the surface passivation, varies throughout the fabrication process of SHJ solar cells

TEM and SIMS analysis

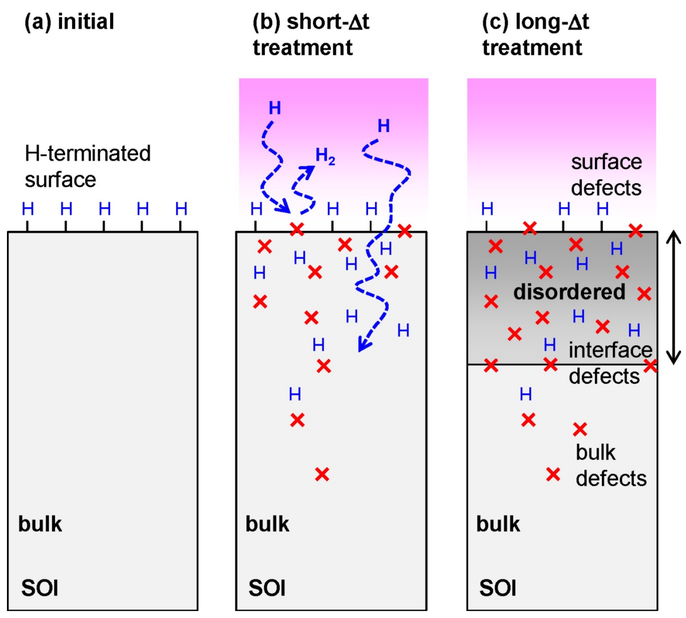




- TEM: (a) Normal sharp Interface of a-Si:H/c-Si. (b) Formation of the disordered surface layer (DSL). The DSL is formed by a sufficiently long-Δt H_2 plasma treatment.
- SIMS: H atoms concentrate at the interface. The concentration is increased at the interface with DSL.

S. Nunomura et al., Jpn. J. Appl. Phys. 59, SHHE05 (2020).
S. Nunomura et al., J. Appl. Phys. 128, 033302 (2020).

Model: Formation of H atom-induced defects & DSL



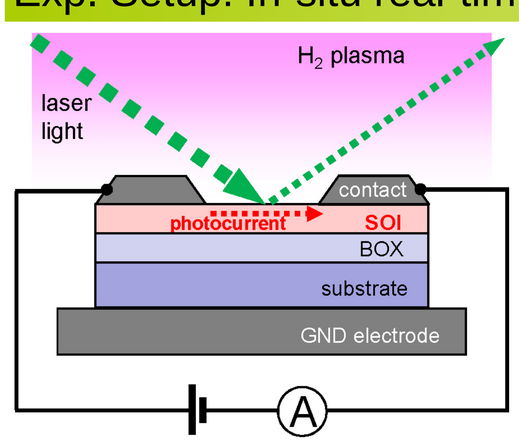
(a) Initially, the surface is terminated with H atoms.

(b) H atoms react with **surface Si-H bonds**, yielding H_2 molecules as a reaction product, leaving **surface DBs**. Besides, H atoms penetrate into the bulk, and generate the **bulk defects** via reaction with lattice bonds.

(c) If H atoms are sufficiently penetrated into c-Si bulk, and a large amount of defects are generated, then the **DSL** can be created.

S. Nunomura et al., *AIP advances.* **9**, 045110 (2019).

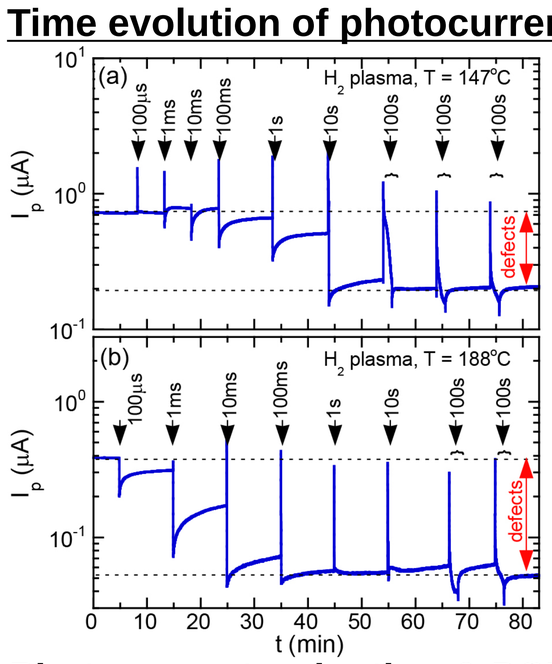
Exp. Setup: In-situ real-time photocurrent measurement



- **Silicon on insulator (SOI)** is used as a sample for the photocurrent measurement.
- SOI is illuminated with a **semiconductor laser** (520nm, 1mW).
- The **photocurrent** is measured during H_2 plasma treatment and subsequent postannealing.
- In experiments, **the treatment time (Δt)** and **temperature (T)** are varied.

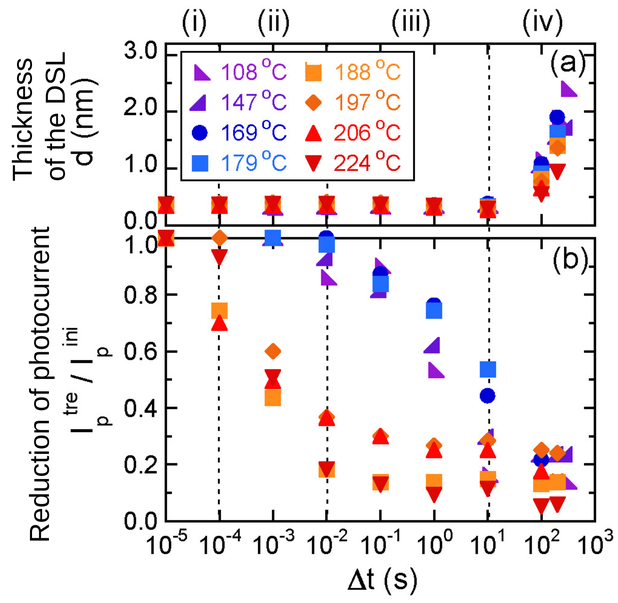
Experimental results

Time evolution of photocurrents



- The photocurrent (I_p) is reduced by a H_2 plasma treatment, indicating generation of defects (**defect generation**).
- The reduction of I_p is enhanced for a long-Δt treatment; more defects are generated.
- The generation of defects are pronounced for a short-Δt treatment under high-T conditions.
- During postannealing, I_p is increased, indicating the annihilation of defects. (**defect annihilation**)

Photocurrent reduction & DSL



- (a)The **DSL** is formed only for long-Δt treatment. No DSL formation for short-Δt treatment.
- (b) The reduction tendency of I_p is classified into two groups: low-T and high-T groups.
- In the high-T group, I_p is decreased once Δt exceeds 10^{-4} s.
- In the low-T group, a longer-Δt treatment is required for generation of defects, possibly due to impurity adsorption.
- **Before formation of DSL, the H-induced electronic defects are created.**

S. Nunomura et al., *AIP advances.* **9**, 045110 (2019).
S. Nunomura et al., *Appl. Phys. Express.* **12**, 051006 (2019).

Summary

- **The generation and annihilation of H-induced defects** in crystalline silicon has been studied during **H_2 plasma treatments**, by using in-situ photocurrent measurement and spectroscopic ellipsometry.
- The H-induced defects are generated by a H_2 plasma treatment, and annihilated/recovered by postannealing.
- The generation of defects depends on treatment time and temperature.
- The electronic defects are created before the formation of DSL, i.e., nanometer-scale amorphized surface layer.
- The **surface and/or bulk defects** are partially recovered, but the **DSL** is not recovered.

Acknowledgements

This work was supported by JSPS KAKENHI (Grant Numbers 15K04717 & 18K03603) and New Energy and Industrial Technology Development Organization (NEDO).