ヘテロ接合型結晶シリコン太陽電池における アモルファスシリコン界面層の物性と発電性能の相関

Effects of a-Si:H bilayers in a-Si:H/c-Si heterojuncion solar cells

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Research Background

■a-Si:H/c-Si heterojunction (SHJ) solar cells

- Excellent surface passivation by using a-Si:H [1]
- High efficiency (> 25%), high V_{OC} and low T-coefficient
- Suitable to bi-facial modules
- Applicable to thin wafers thanks to low-T process

■Key issue – (i)a-Si:H/c-Si interface

□Surface passivation

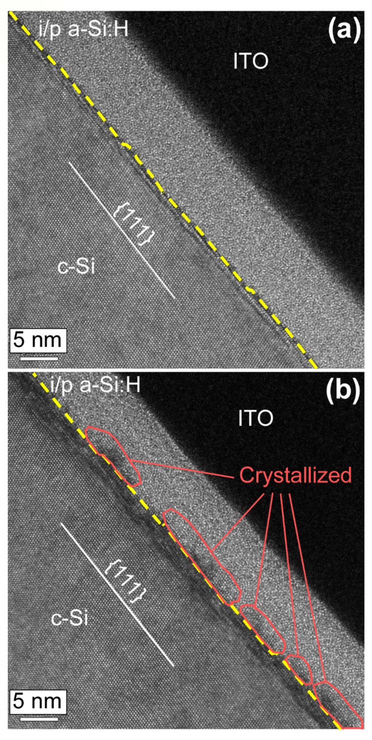
- Abrupt a-Si:H/c-Si interface is preferable. Epitaxial growth is detrimental (either as-grown or post-growth).
- Overlying p-layer deteriorates the passivation

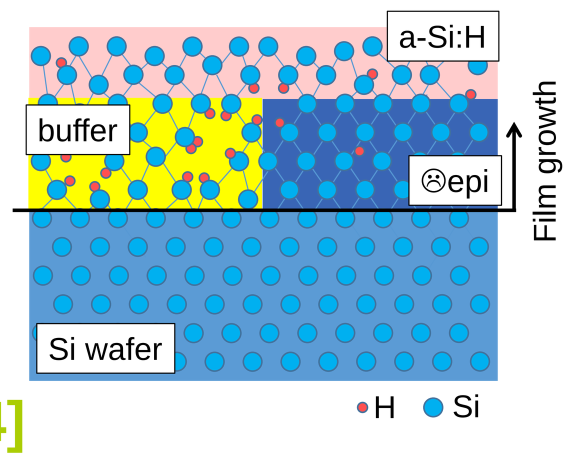
□Carrier transport channel

- Series resistance should be minimized.

■2-step growth of (i)a-Si:H [2-4]

- Interfacial layer (i_1) + bulk layer (i_2) is effective for improving surface passivation.
- Record-efficiency (25.1%) cell has been achieved.[4]





Research Objective

■ Our previous study [3] clarified:

- Porous and H-rich a-Si:H layers are suited for the interfacial layer (i_1).
- Such layers are grown with pure SiH_4 plasma at high-pressure and high-power conditions.
- Microstructure factor R* determined by FT-IR is useful to optimize the i_1-layer.

■ However,

- Material properties of a-Si:H can be tuned by various process (PECVD) parameters.

Objective:
How do the growth parameters affect the R* of a-Si:H and the photovoltaic performance of SHJ solar cells?

Parameters considered in this work:
・Substrate temperature (T_S)　・Gas pressure (P)
・Precursor gases (SiH_4 and Si_2H_6)

Experimental

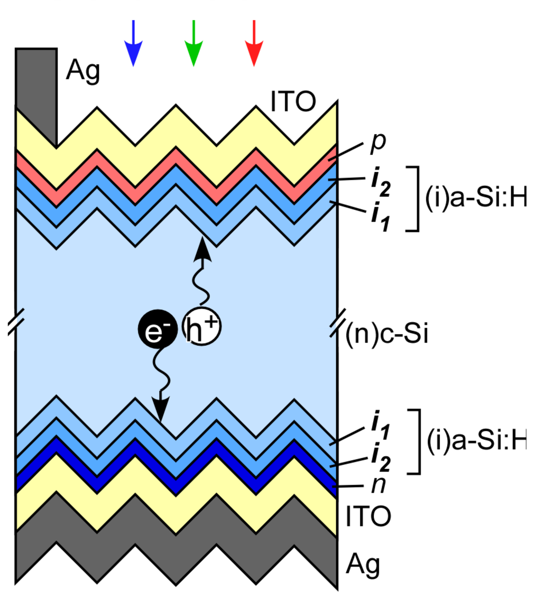
■ Growth of (i)a-Si:H layers

- PECVD, CCP, 13.56MHz
- Characterization: Ellipsometry, FT-IR

Table: Growth conditions for (i)a-Si:H layers

Layer	i_1			i_2
Series	Si_2H_6	T_S	P	
Si precursor	SiH_4, Si_2H_6	SiH_4	SiH_4	SiH_4
Si_2H_6 concentration, C_{Si2H6} $[Si_2H_6]/([SiH_4]+[Si_2H_6])$	0 – 75%	0	0	0
Hydrogen dilution $[H_2]/[SiH_4]$	0	0	0	10
Substrate temperature, Ts (°C)	200	30 – 400	200	200
Pressure, P (Pa)	13, 40	13	13-40	13
Power density (mW cm^{-2})	11	11	11	11

■ Solar cell

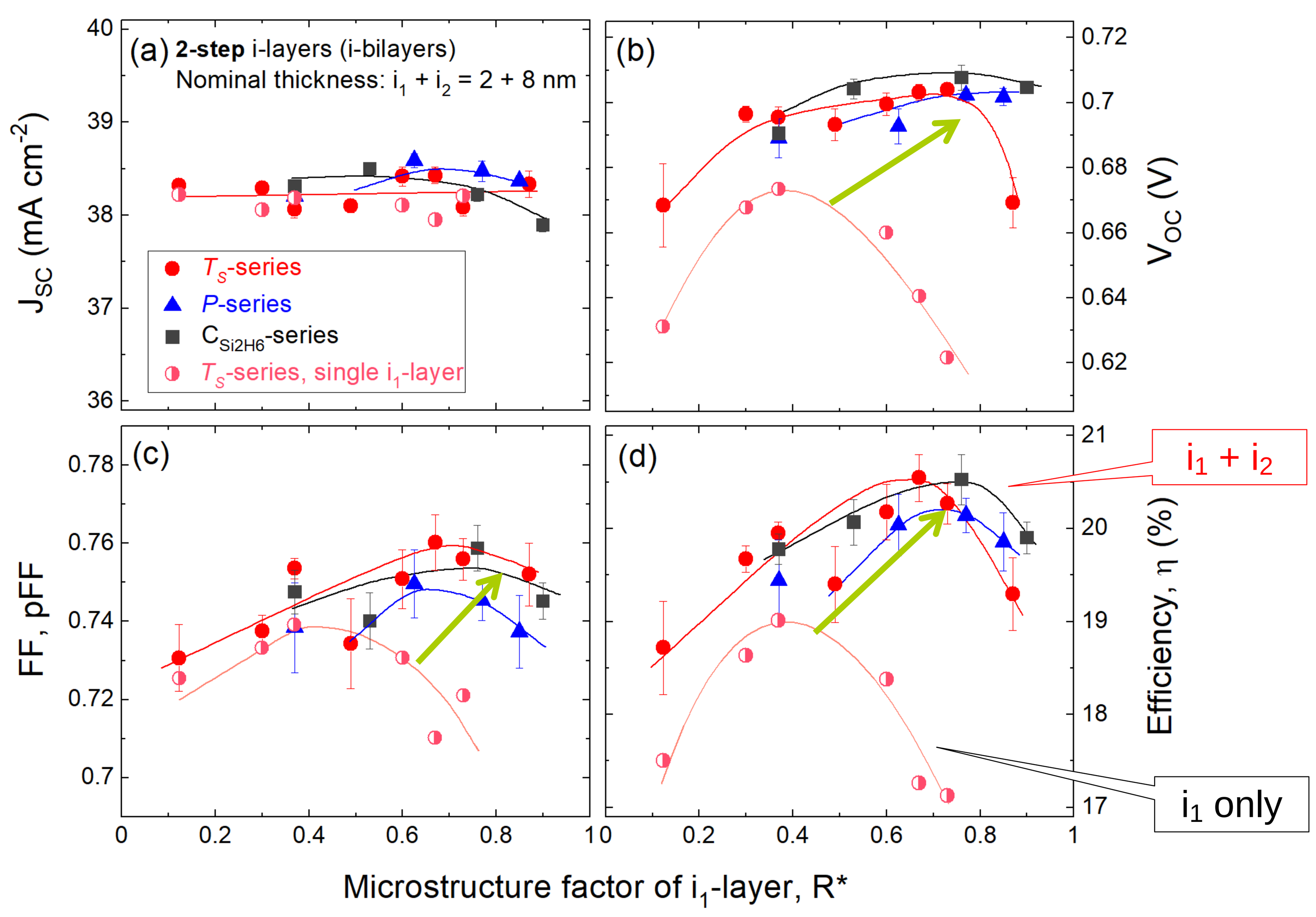


- Front emitter
- (n)FZ-Si, 270μm
- Pyramid texture
- (i)a-Si:H bilayer
- ITO/Ag by SP

SHJ cells with (i)a-Si:H bilayers (i1 + i2) [6]

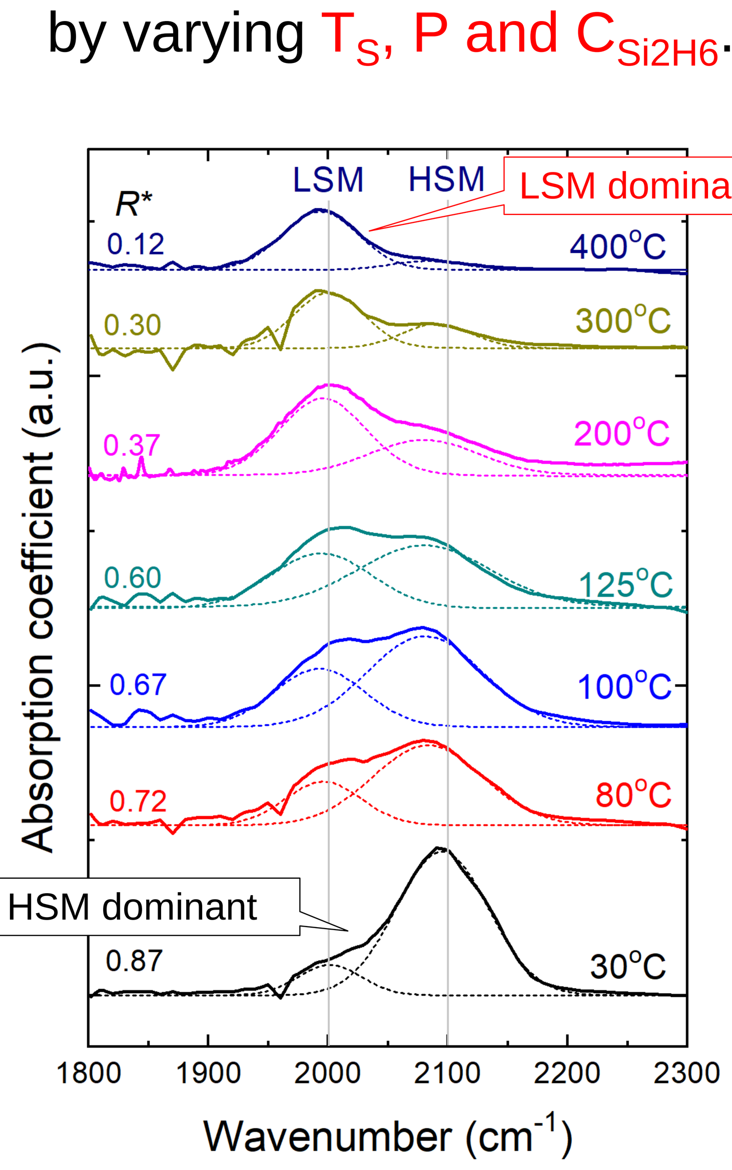
■ Effect of (i)a-Si:H bilayer: i_1- and i_2-layers (2 + 8 nm)

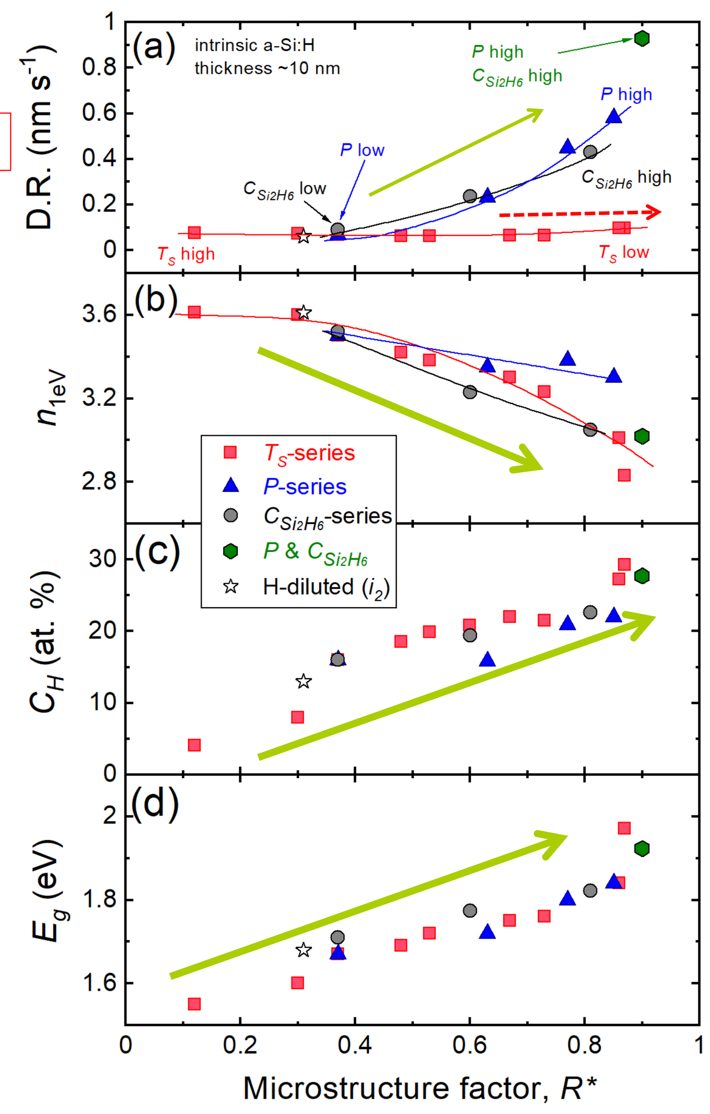
- The V_{OC}, FF, and efficiency are significantly improved by applying i-bilayers.
- The best efficiency is obtained by using i_1 layer with R* ~ 0.7, regardless of the process conditions.



Properties of (i)a-Si:H for interfacial layer [6]

- Microstructure factor [5]: $R^* = I_{HSM}/(I_{LSM} + I_{HSM})$
- D.R., refractive index (n_{1eV}), hydrogen content (C_H), and bandgap energy (Eg) as well as R* are controlled widely by varying T_S, P and C_{Si2H6}.





Conclusions

■ Material properties of a-Si:H layers can be tuned widely by controlling various PECVD parameters: temperature, pressure, mixing of SiH_4 and Si_2H_6 etc.

■ Microstructure factor R* of interfacial a-Si:H layers is a good measure to improve the surface passivation at a-Si:H/c-Si, regardless of the PECVD parameters.

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