The SC – RISE Summit Meeting

Ohmi Laboratory – UCR Collaboration

Silicon Thin Film Solar Cell Having High Conversion Efficiency

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Introduction

★Global Heating Issues will be overcome by developing New Solar Cells where the total generation energy of the Solar Cell must be completely larger than the entire energy required to produce the solar cells !! Very high productivity manufacturing equipment is strictly required such as,

★Different thin film continuous deposition in the same process chamber only by changing process gases, and different thin film continuous etching in the same process chamber only by changing process gases must be established to achieve this requirement.

★To generate all the electrical power in the world (25 trillion kWh/year, 2020), solar cells (efficiency 30%) of 80,000km^2 (1/4.5 of area of Japan) is required.

★**Si is unique material to solve the energy issue of the entire world !!**

Recoverable reserves

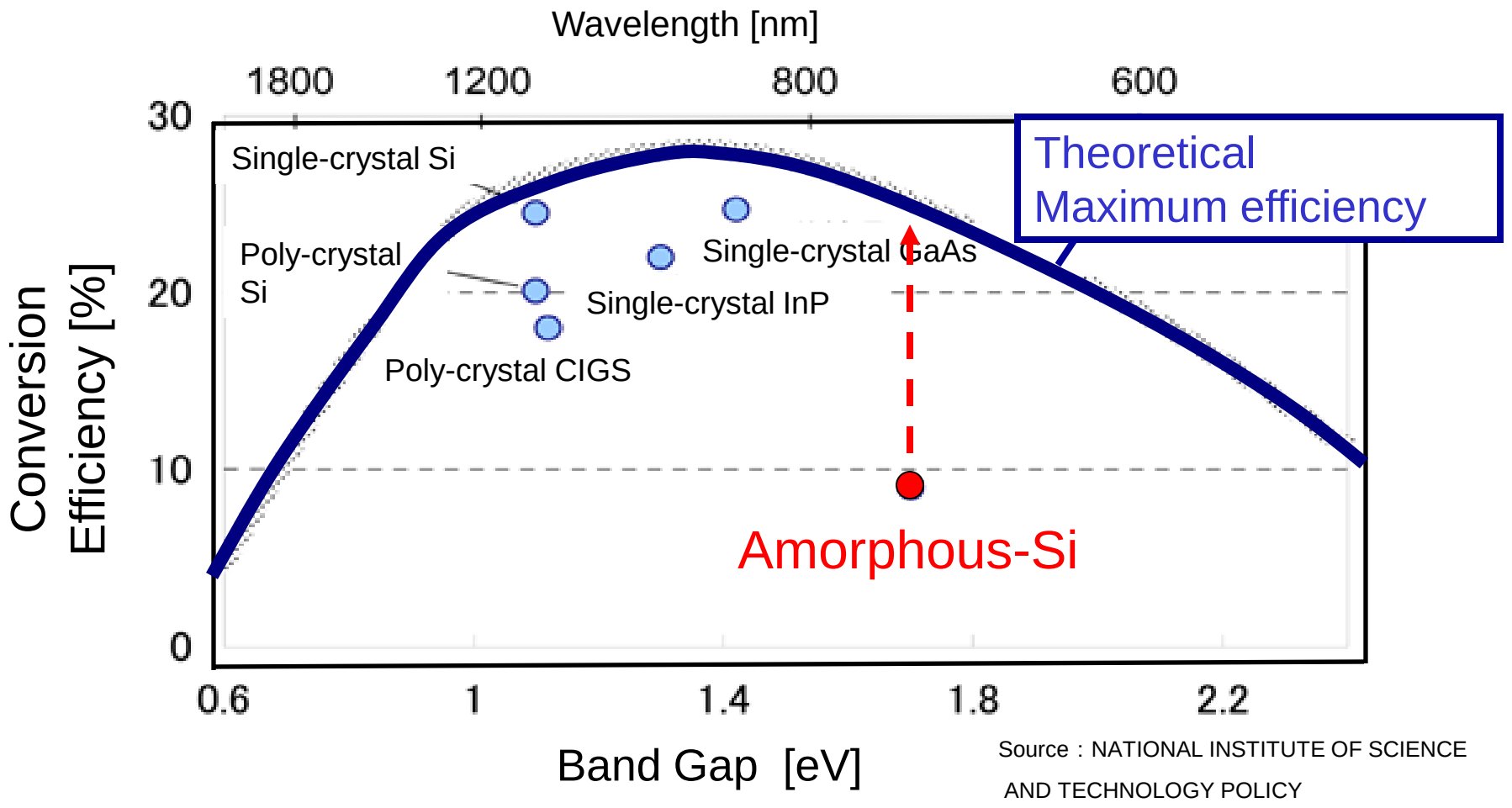
	Recoverable reserves [ton]	Requirement [ton]	Cost [$/ton]
Si	Enough	140,000 ~ 466,000 (20% a- Si Solar cell) (30% a-Si/μc- Si Solar cell)	2,000
Ge	500	160,000	130,000
Cd	600,000	3,460,000	2,000
Te	21,000	2,500,000	100,000
In	2,800		1,000,000
Zn	220,000		2,000
Se	82,000	5,748	30,000

*Se thickness : 10nm

1$=100yen

Si is unique material to solve the energy issue of the entire world !!

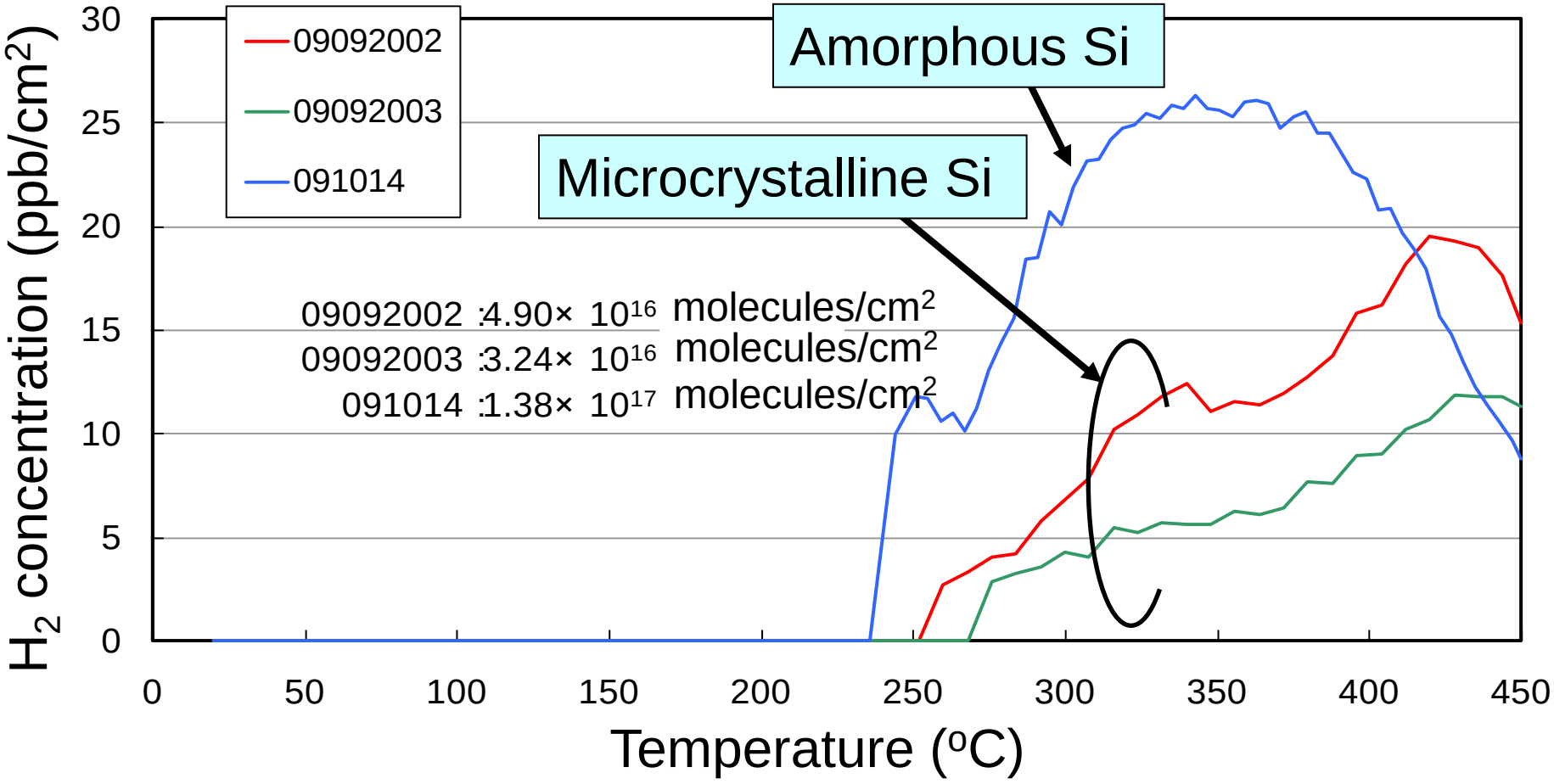
Theoretical Solar Cell Conversion Efficiency vs Band Gap



Source：NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY POLICY

Conversion Efficiency of amorphous Si solar cell is far from theoretical value , why? There exist huge amount of defects from current plasma CVD equipment and laser scribing. Theoretical conversion efficiency of amorphous Si solar cell is 22 ~ 23%.

H_2 Emission from Deposited Si as a Function of Temperature



When the temperature of the amorphous Si film is higher than 250^{0}C, hydrogen (H) terminating dangling bond of Si in the amorphous Si film is eliminated, so that the amorphous Si film deposition must be carried out at the temperatures less than at least 200^{0}C, i.e., the plasma process is essentially required to produce the high quality amorphous Si films at such low temperatures.

Current Plasma Process Equipment

: Accompanies various disadvantages such as

☆ Very severe substrate surface plasma induced damages, i.e. charge-up damage and ion bombardment induced damages, so that the amorphous Si solar cell exhibits very poor conversion efficiency less than 10%.

☆ Plasma uniformity in the process chamber can be maintained at only one process chamber condition, i.e., only one process can be carried out in the same process chamber at present. Very frequent substrate transportations between different process chamber are required, i.e., very poor productivity productions.

☆ Terrible gas flow pattern in the process chamber completely far from uniform and laminar gas flow pattern, resulting in reaction products too much adhesion to the inner surface of the process chamber, the inner surface of the gas pump and the inner surface of the exhaust ducts. Surface cleaning is frequently required. The productivity is very poor, so that huge amount of energy is used for the solar cell productions!!

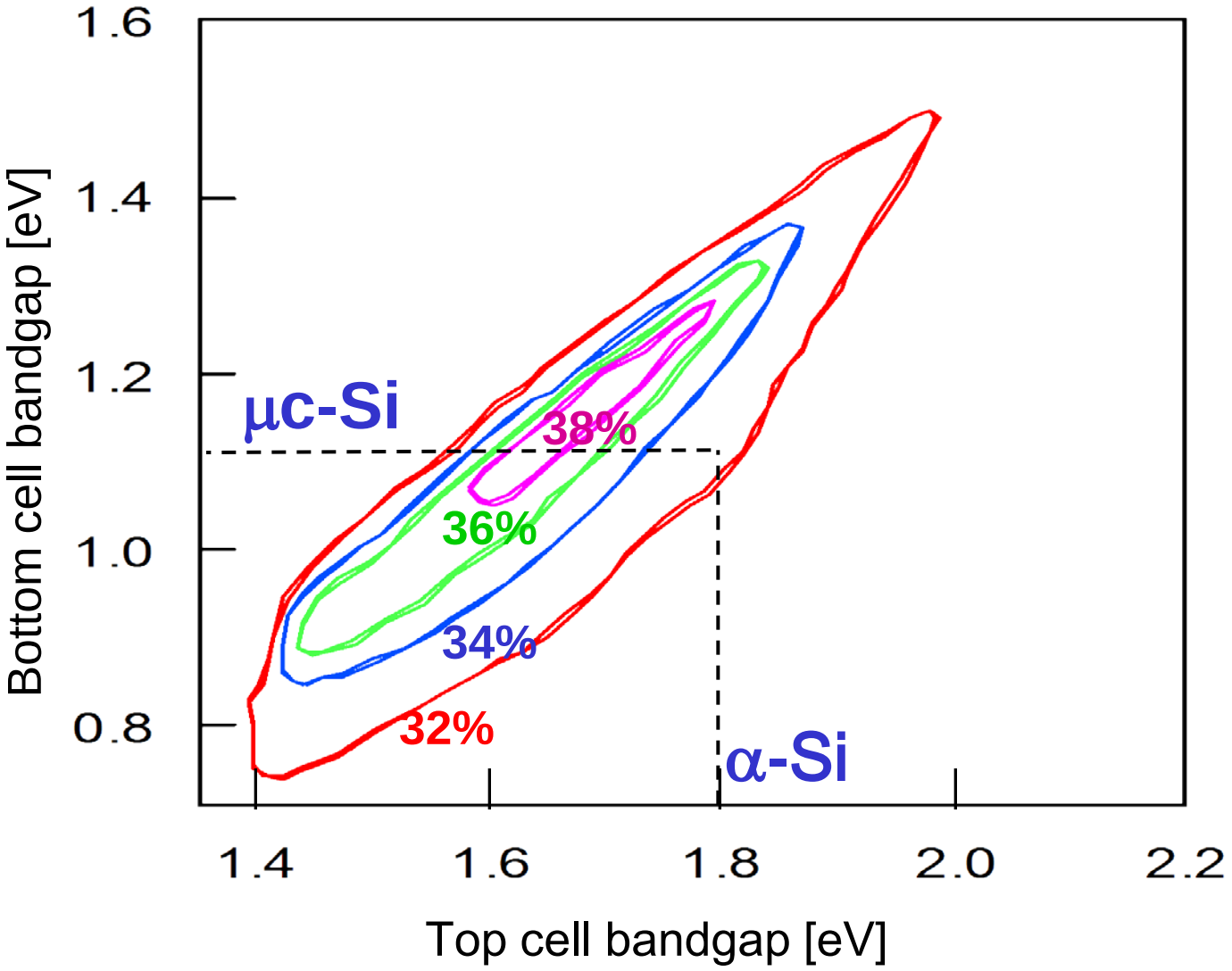
Different Thin Film Continuous Deposition and Different Thin Film Continuous Etching Completely Free From Damages in the Same Process Chamber Only By Changing Process Gas

☆ Plasma uniformity must be maintained for entire different process gases!!, and

☆ Completely uniform and laminar gas flow pattern in the process chamber without accompanying reaction product deposition on the inner surface of the process chamber, resulting in very high productivity productions of thin film Si solar cells.

- Completely Damage Free 915MHz Metal Surfacewave Excitation Plasma (MSEP) with the Upper Shower Plate Supplying Plasma Excitation and Radical Generation Gases and The Lower Shower Plate for Process Gases.
- Very High Quality and High Efficiency Thin Film Depositions by Completely Damage Free Rotation Magnet Sputtering.
- Al_2O_3 Complete Passivation Film Treatment on Al Alloy
- New Gas Supply System and New Gas Pumping System

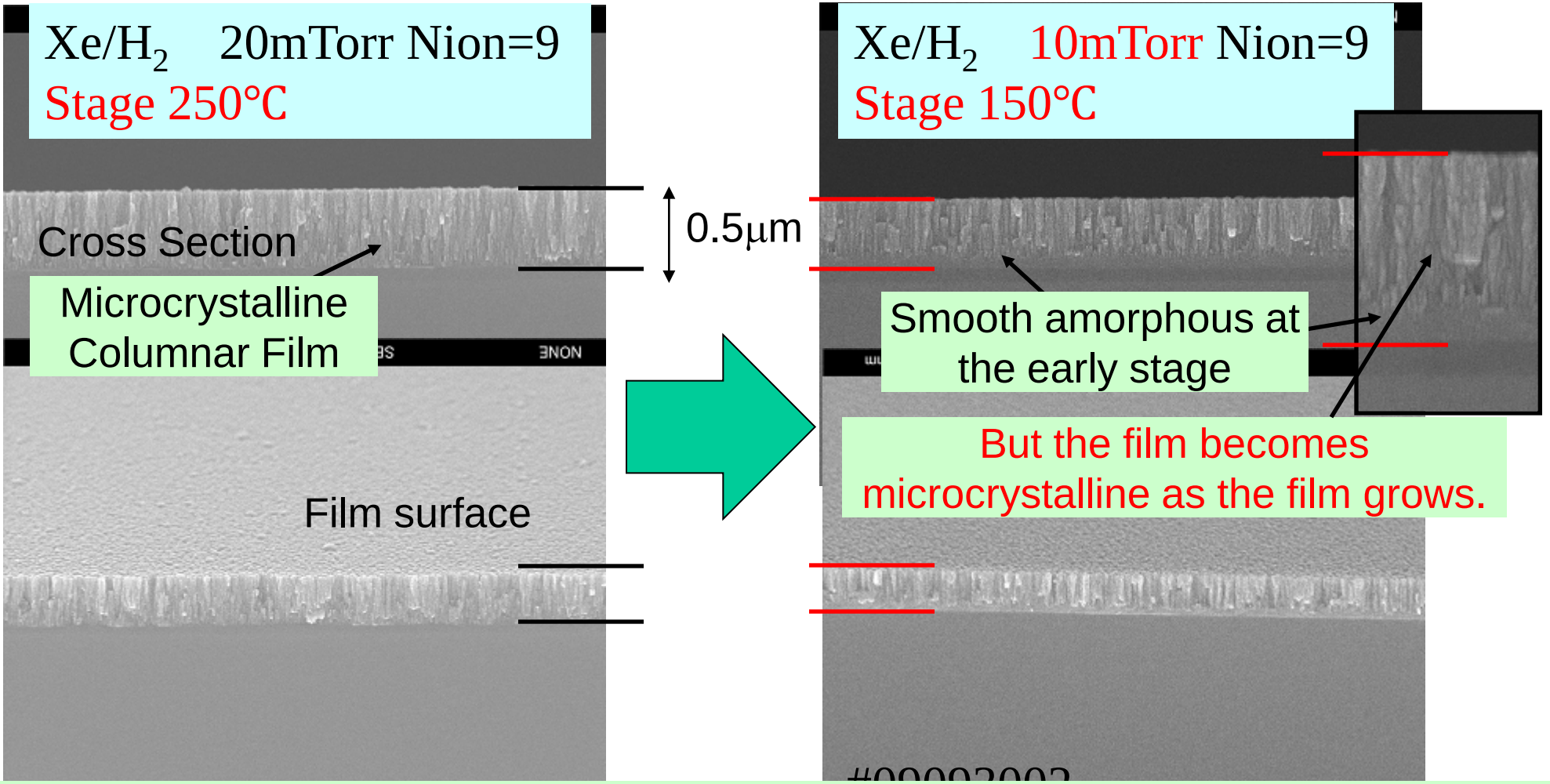
Efficiency of 2 junctions solar cell



When solar cell has 2 junctions , Efficiency becomes 30% or more .
The theoretical conversion efficiency of amorphous Si and microcrystalline Si tandem structure solar cell is 32%.

* Yamaguchi (Toyota Technological Institute)

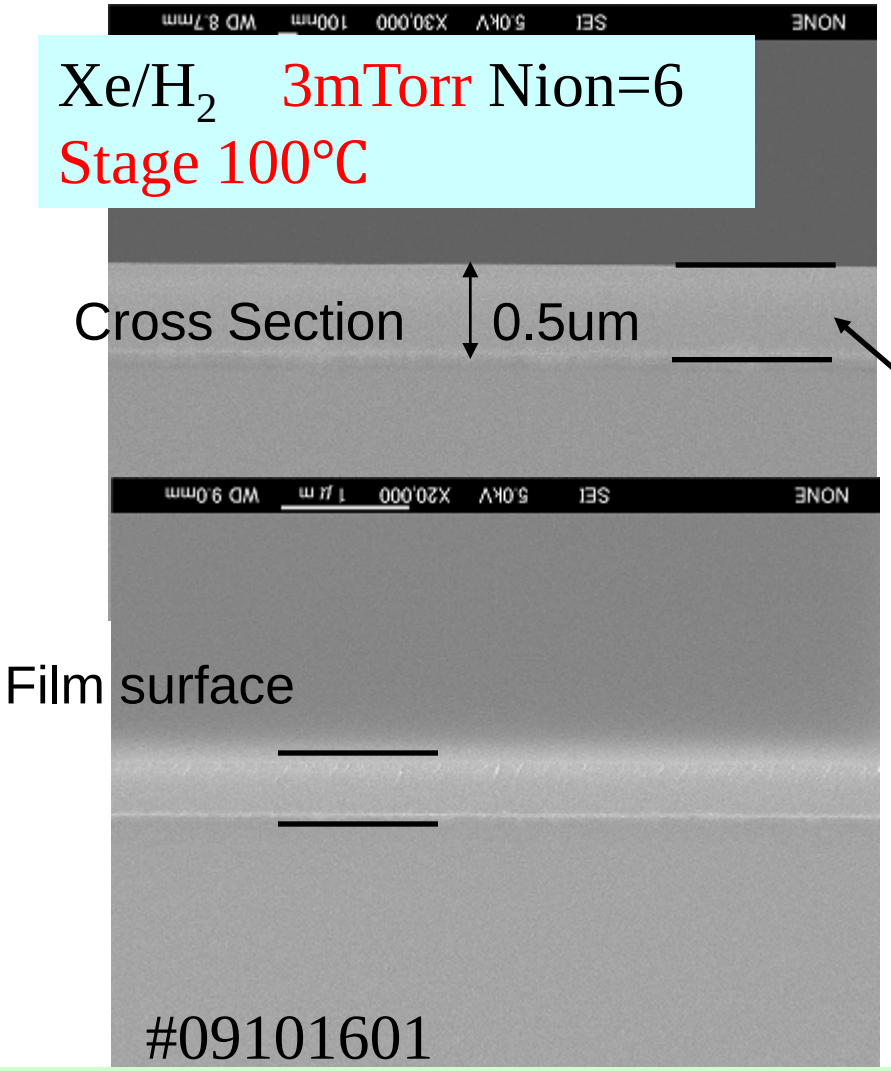
SEM Photograph of Deposited Si 1



Even at 150ºC、Film becomes microcrystalline as the film grows.

⇒It is very difficult to obtain high quality amorphous Si film

SEM Photograph of Deposited Si 2



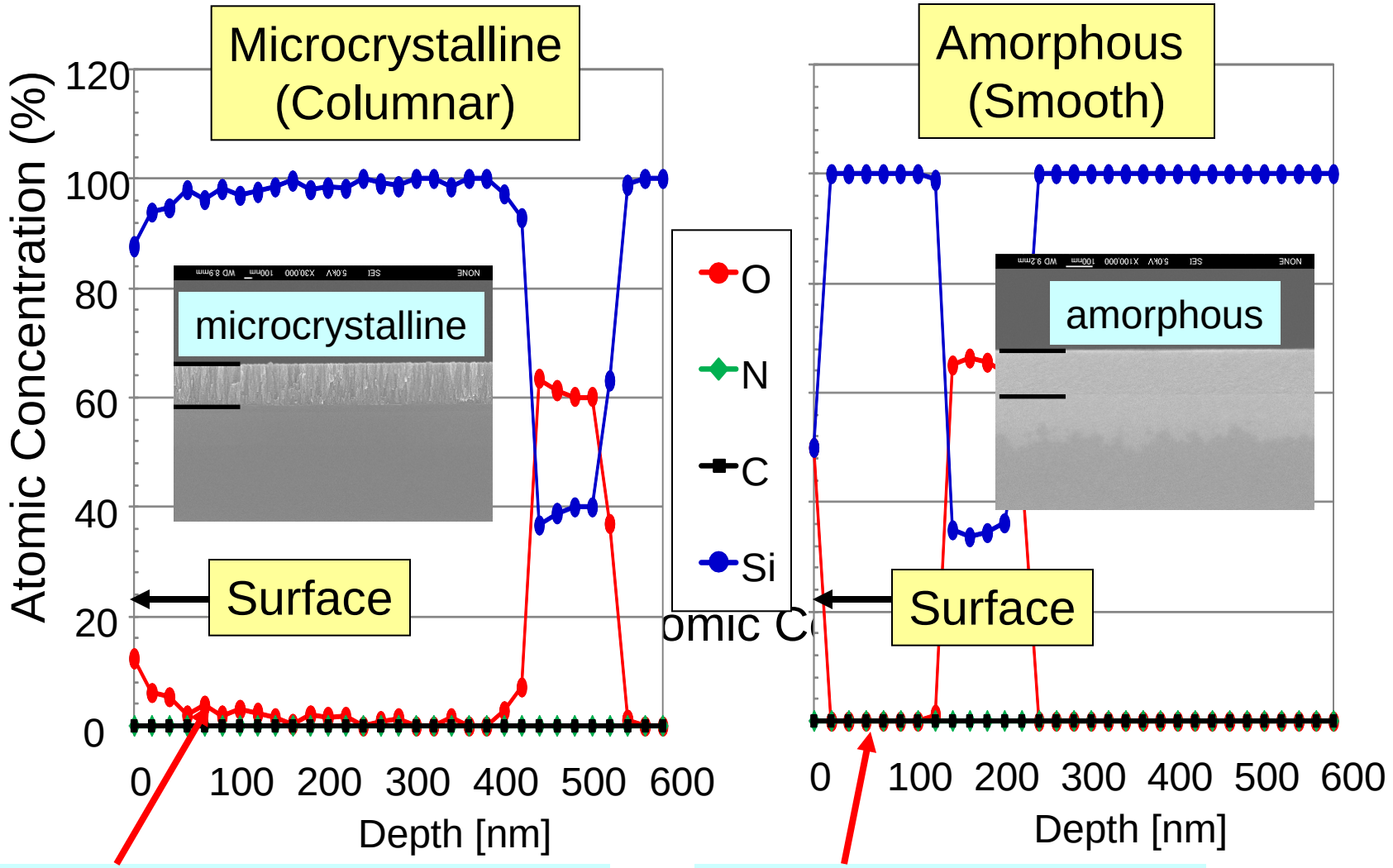
Smooth amorphous at the entire region of the film with a thickness of 0.5 μm

Very smooth amorphous Si film with a thickness of 0.5 μm can be realized at 100℃ and 3 mTorr Xe/H_2 deposition !!

Oxygen concentration after Air Exposure

Depth Profile of Atomic Concentration obtained by ESCA

(Electron Spectroscopy for Chemical Analysis)

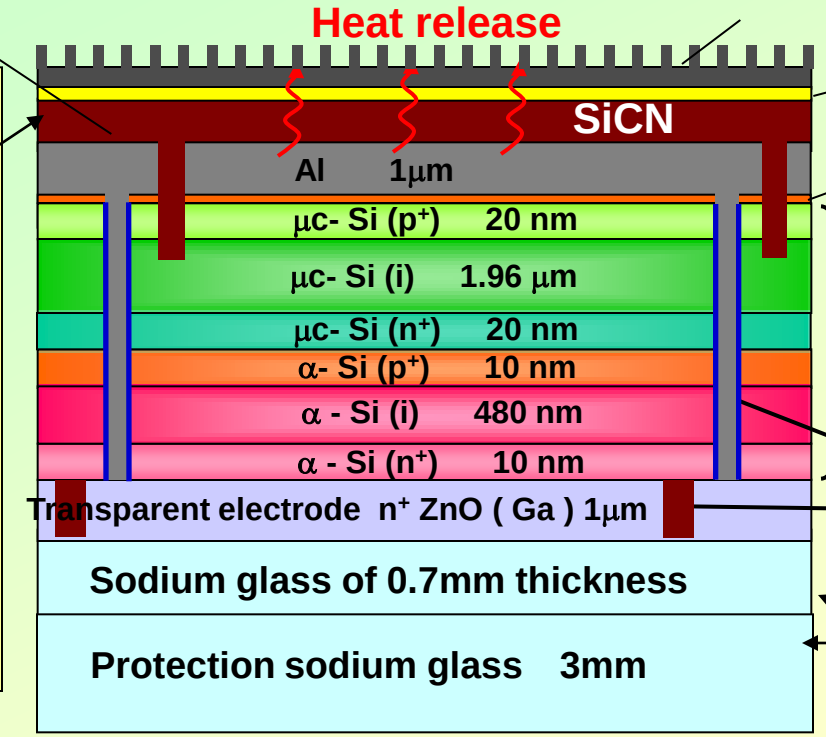


Amorphous/Microcrystalline Si Solar Cell Structure

6 stacked layer (α-Si/μc-Si pin diodes) Total thickness of 2,500nm

Passivation Film
:SiCN
- High Thermal Conductivity (70W/mK)
- No Stress (No cracks!!)
- No H_2 gas penetration

Highly Reliable Solar Cell without Degrading Conversion Efficiency



Very low price sodium glass (500yen/m^2)

[Simulation value] Output : 570W (350.4V, 1.628A)
Cell conversion Efficiency : 30.0%
Module Conversion Efficiency : 29.3%
Glass size 1.20m×1.64m (Edge protection area : 1cm)
Transparent electrode resistivity : 1E-4

Balance of payment of Solar cell :Japan Case

In Japan

★ **Amorphous/Microcrystalline Si Solar Cell : 570W**

3 hours/day x 365 days → 624.15 kWh/year

10 years → 6,241.5 kWh/10year

10 yen (10 cent) → 62,415 yen/10year

→ 33,000 yen to solar cell (330 dollars to solar cell)

624.1 dollars/10year

30,251 yen to battery power device system and etc.
(302.5 dollars to battery power device system and etc.)

Production cost of solar cell : 23,000 yen
(230 dollars)

Balance of payment of Solar cell : Riverside Case

In Riverside

☆**Amorphous/Microcrystalline Si Solar Cell : 684W**

6 hours/day x 365 days → 1,497.96 kWh/year

10 years → 14,979.6 kWh/10year

10 yen (10 cent) → 149,796 yen/10year

Production cost of solar cell : 23,000 yen (230 dollars)

1,497.9 dollars/10year

→ Highly profitable business!!