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# Silicon Based Solar Cells for Hydrogen Production

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**Constraint: Photovoltaic made from non-toxic and earth abundant materials (Si absorber)**

**Challenge: Provide the right voltage to directly break water molecules w/o electronics**

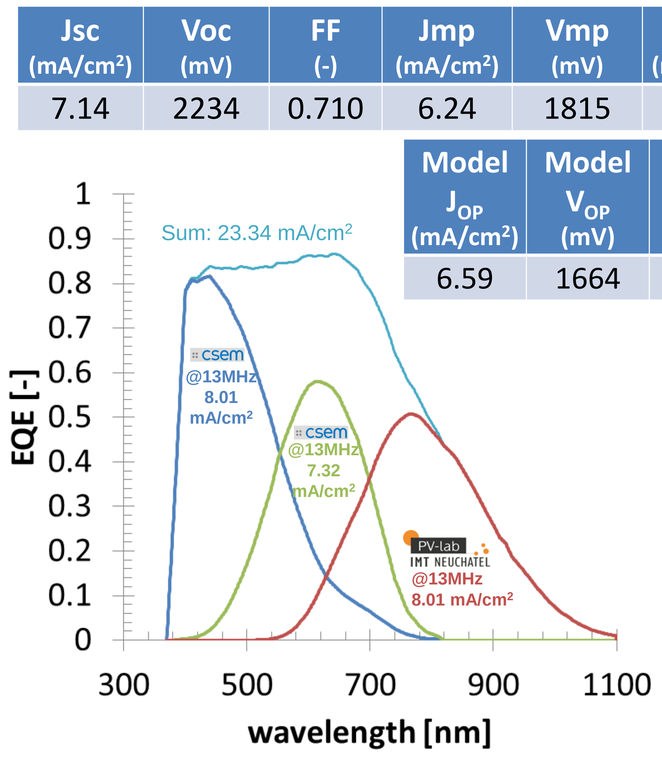
## Thin-film silicon triple-junction solar cell

- Control of surface morphology of LPCVD zinc oxide →light-trapping via diffuse scattering.
- aSi/aSi/µcSi p-i-n junctions by PECVD
- Electronic transport through SiOx reflectors by PECVD via dendritic silicon filaments.
- Back metallization by PVD
- All processes @ typ. <200°C
- Possibility of making integrated devices

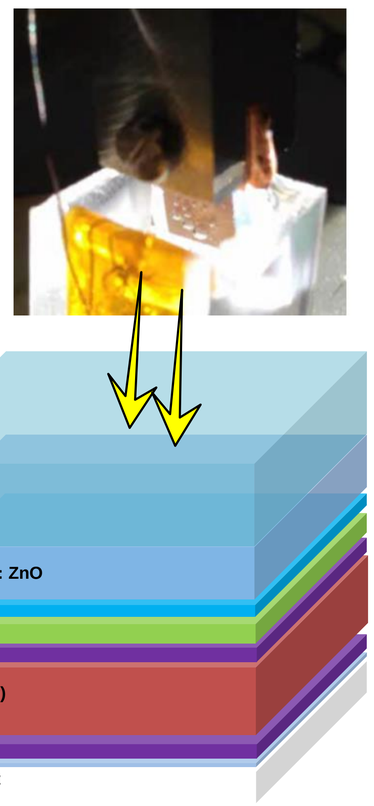
## Experimental results for Thin-film silicon

| Jsc (mA/cm²) | Voc (mV) | FF (-) | Jmp (mA/cm²) | Vmp (mV) | Pmp (mW/cm²) |
|---|---|---|---|---|---|
| 7.14 | 2234 | 0.710 | 6.24 | 1815 | 11.3 |

| Model $J_{OP}$ (mA/cm²) | Model $V_{OP}$ (mV) | Model SFE (%) |
|---|---|---|
| 6.59 | 1664 | 8.1 |

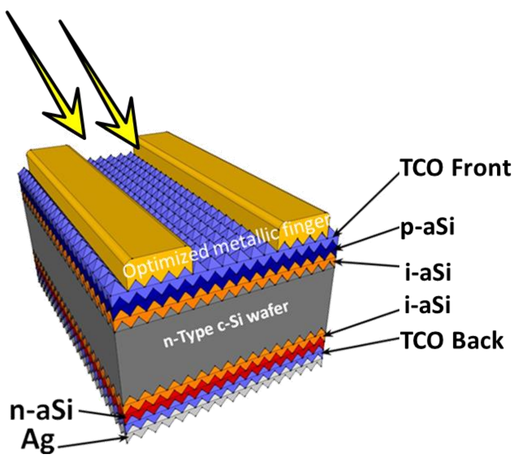


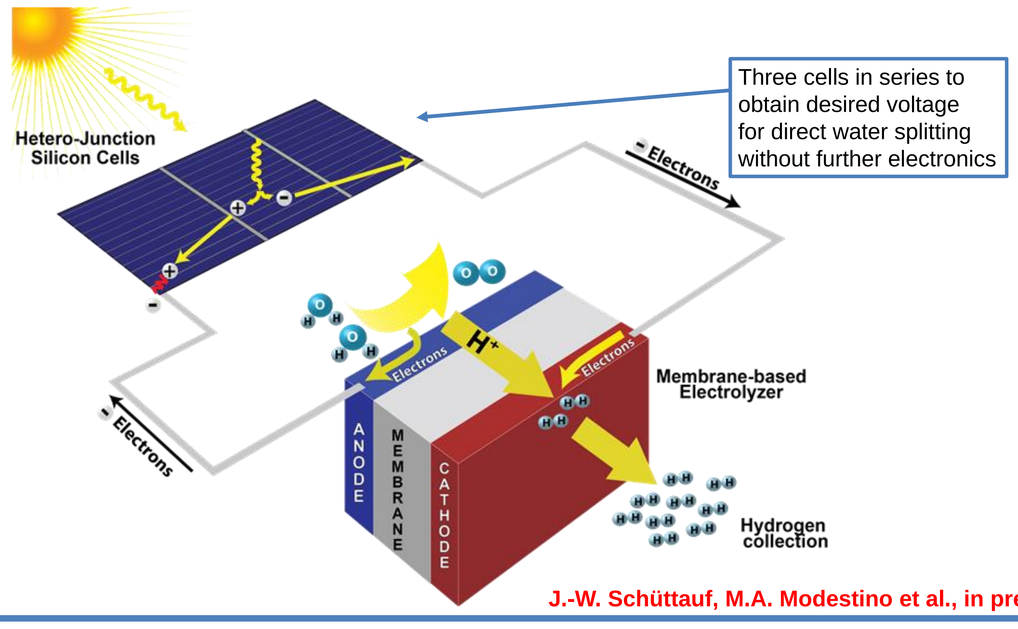

D. Dominé et al, Tech Digest 6th WCPEC (2014).




## c-Si hetero-junction technology

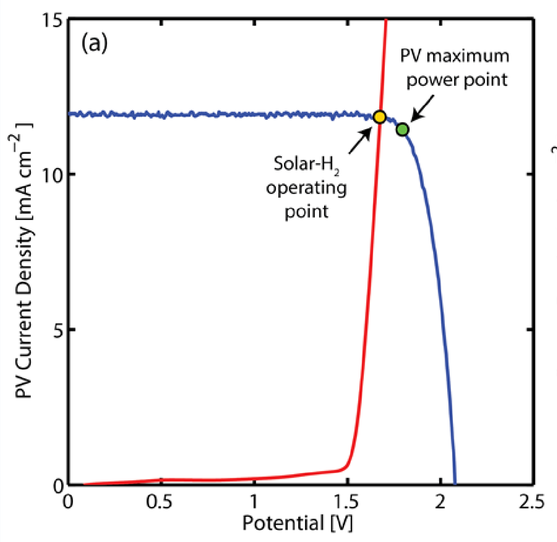
- High quality n-type crystalline silicon (float zone)
- Wafer texturing
- HF cleaning
- Surface passivation with a-Si deposited by PECVD
- TCO deposition by PVD
- Front and back metallization
- All processes @ typ. <200°C
- Record Si PV efficiency: 25.6%

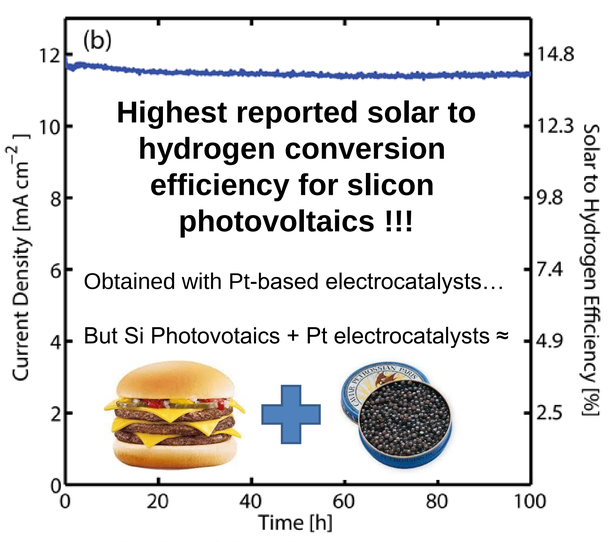



J.-W. Schüttauf, M.A. Modestino et al., in preparation.

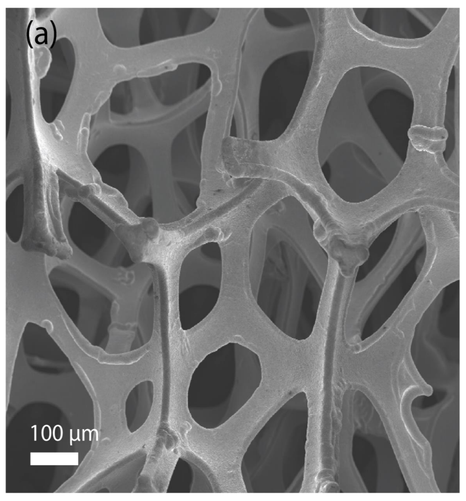
## c-Si: Solar-to-$H_2$ Efficiency of 14.2% for > 100 h



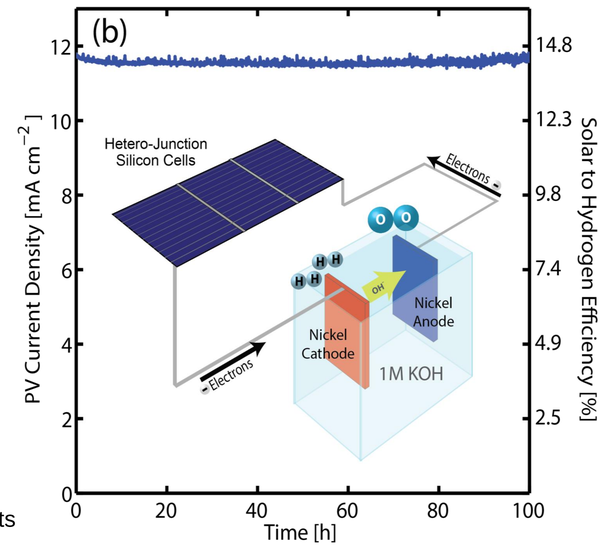




J.-W. Schüttauf, M.A. Modestino et al., in preparation.

## With fully earth-abundant electrocatalysts…..




SEM micrograph of Ni-based electrocatalysts




**Same efficiency and stability obtained as with Pt electrocatalysts !!!!! ☺**
**Highest reported efficiency for solar water splitting fully based on earth-abundant components ☺**

J.-W. Schüttauf, M.A. Modestino et al., in preparation.

## Highest solar-hydrogen efficiencies

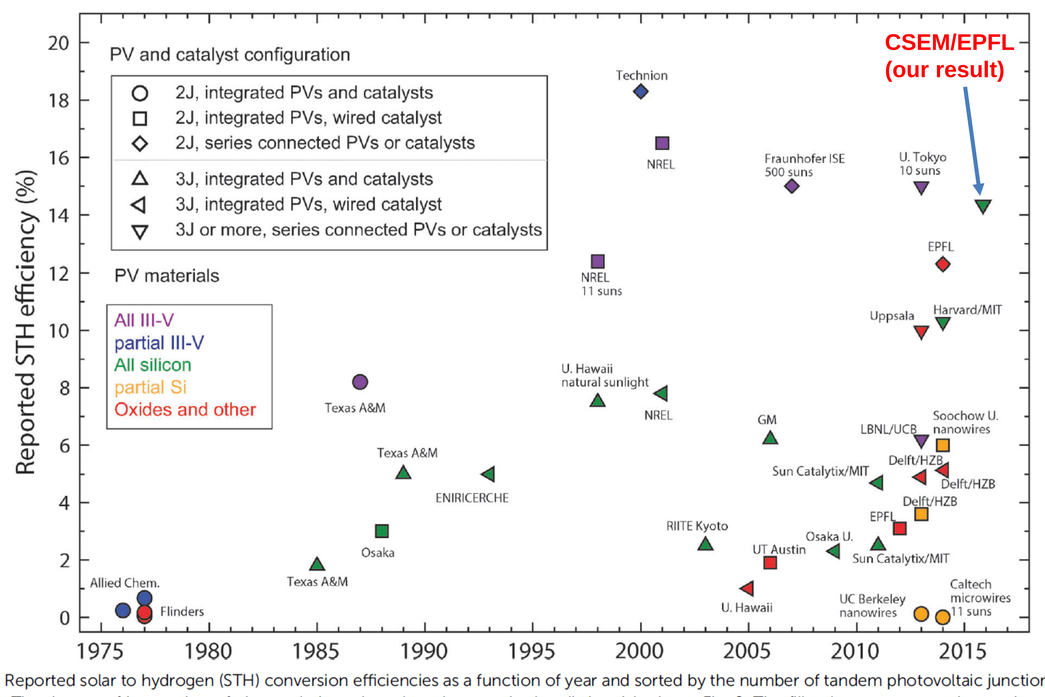



Fig. 3 Reported solar to hydrogen (STH) conversion efficiencies as a function of year and sorted by the number of tandem photovoltaic junctions used (2 or 3). The degree of integration of photovoltaic and catalyst elements is also distinguished, see Fig. 2. The fill colour represents the semiconductor materials used in the photovoltaic portion of the device. All STH conversion efficiencies are as reported in the original publications (see Tables 2–5).

Adapted from: J.W. Ager *et al.*, Energy Environ. Sci. 8, 2811-2824 (2015).

## Conclusions

- Hydrogen production by splitting water molecules using power from solar energy
- Silicon solar cells and earth-abundant electrocatalysts used
- Voltage of solar module adapted for direct water splitting without further electronics
- Two different approaches: Thin-Film Si and Si Heterojunctions
- Highest reported solar to hydrogen efficiency obtained for Silicon photovoltaics
- Highest reported solar to hydrogen efficiency obtained for system fully based on earth-abundant conponents