A novel concept based on thin film silicon triple-junction solar cells simultaneously generating solar electricity and hydrogen

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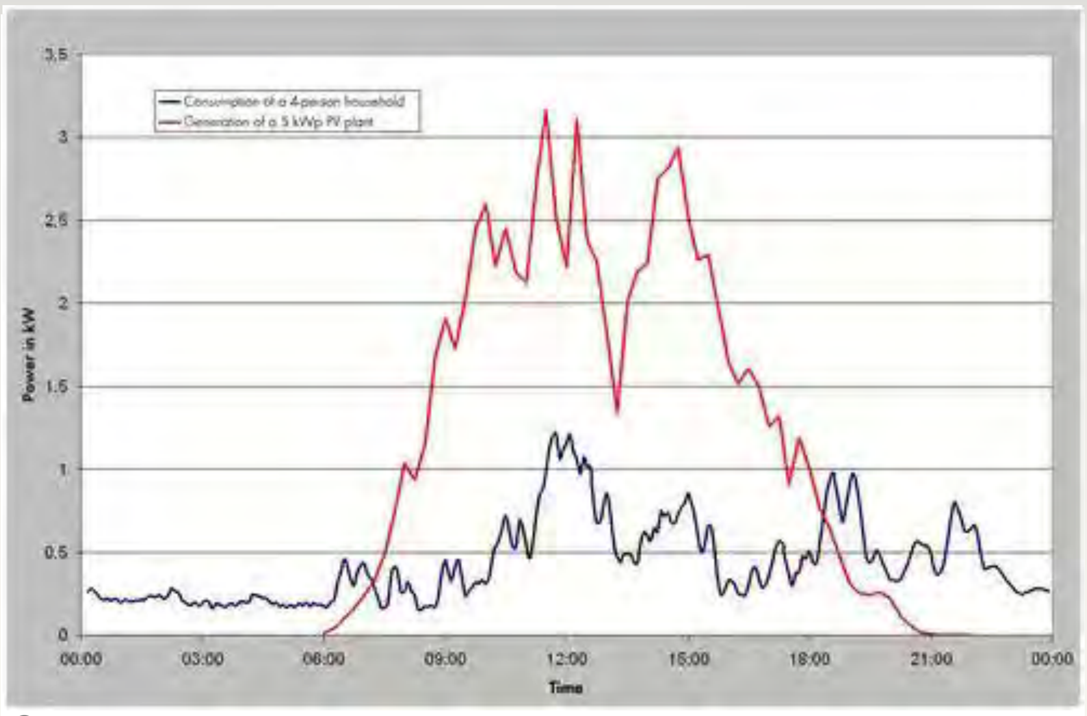
MOTIVATION

Daily rated power of a 5 kWp solar plant superimposed on the average power consumption of a 4-person household on a summer day:

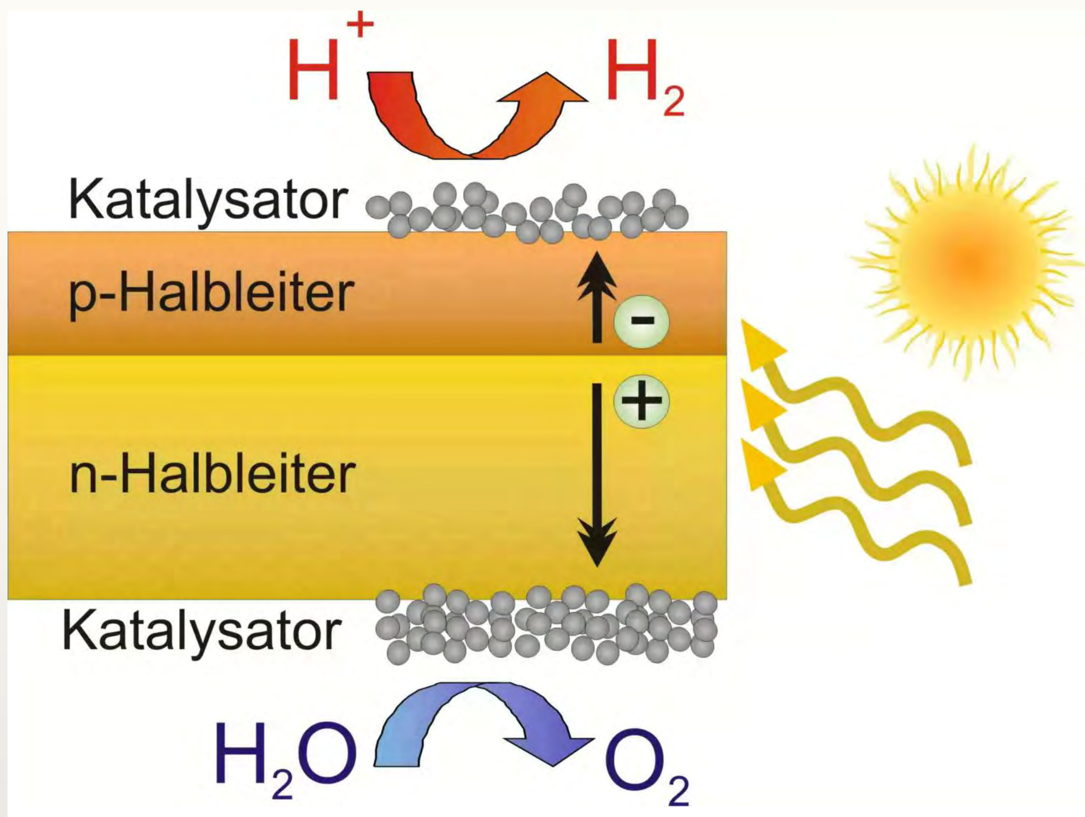


Source:
SMA Solar Technology
http://www.sma.de/en/products/knowledge-base/requirements-for-the-pv-system-technology-of-the-future-and-solutions-by-sma.html

INTRODUCTION

The 'Achilles' heel' of photovoltaic (PV) energy generation is the non-uniform electricity generation. Accordingly, the direct combination of a PV system with an energy storage component appears desirable.

Hydrogen can be stored, shipped and combusted without harmful reactants. Moreover, it can be produced by renewable energy sources, such as light-induced water splitting.



Source:
Helmholtz Zentrum Berlin: Solar Fuels and Energy Storage Materials
http://www.helmholtz-berlin.de/forschung/enma/solare-brennstoffe/index_en.html

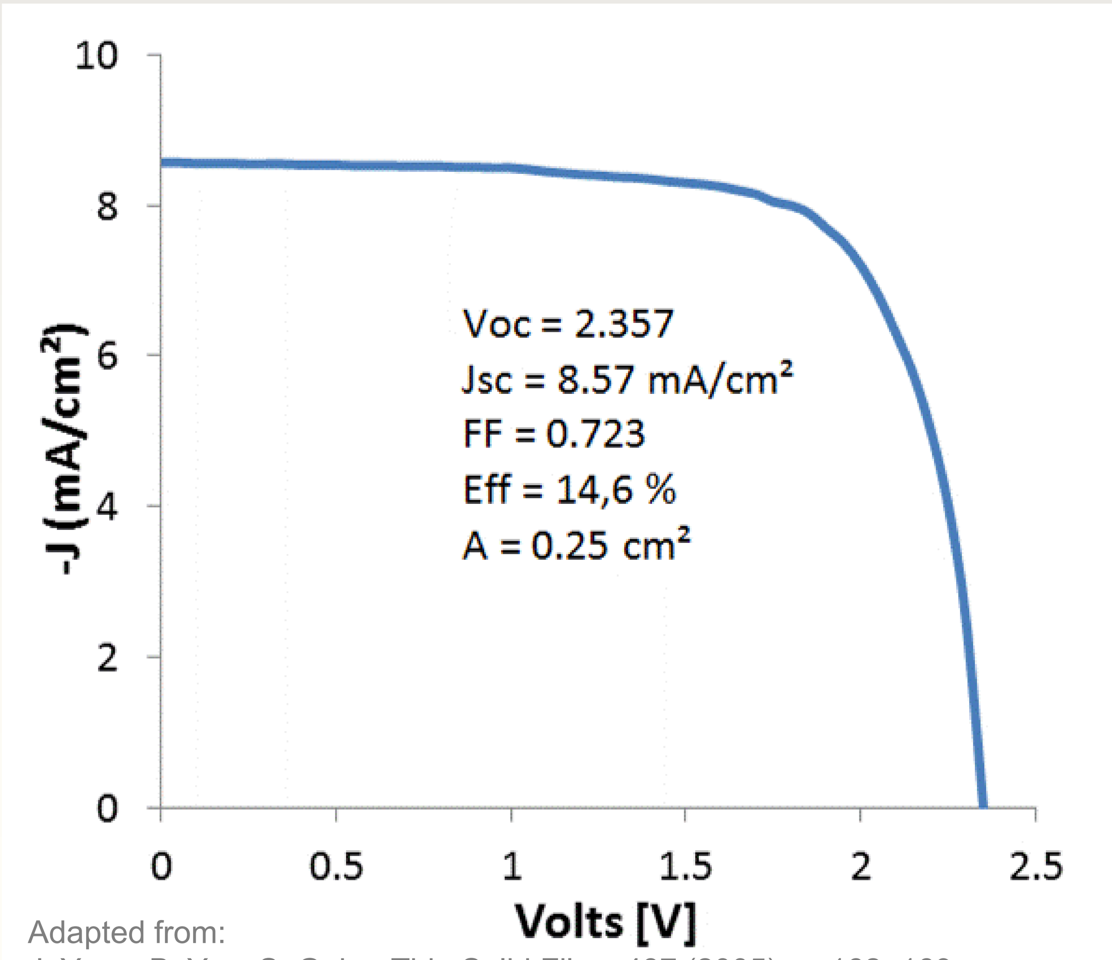
The solar splitting of water to hydrogen and oxygen driven by photon energy is schematically shown above.

A solar cell has to generate a voltage of at least ~1.5 V to effectively split water and it has to be stable in the aqueous environment under illumination.

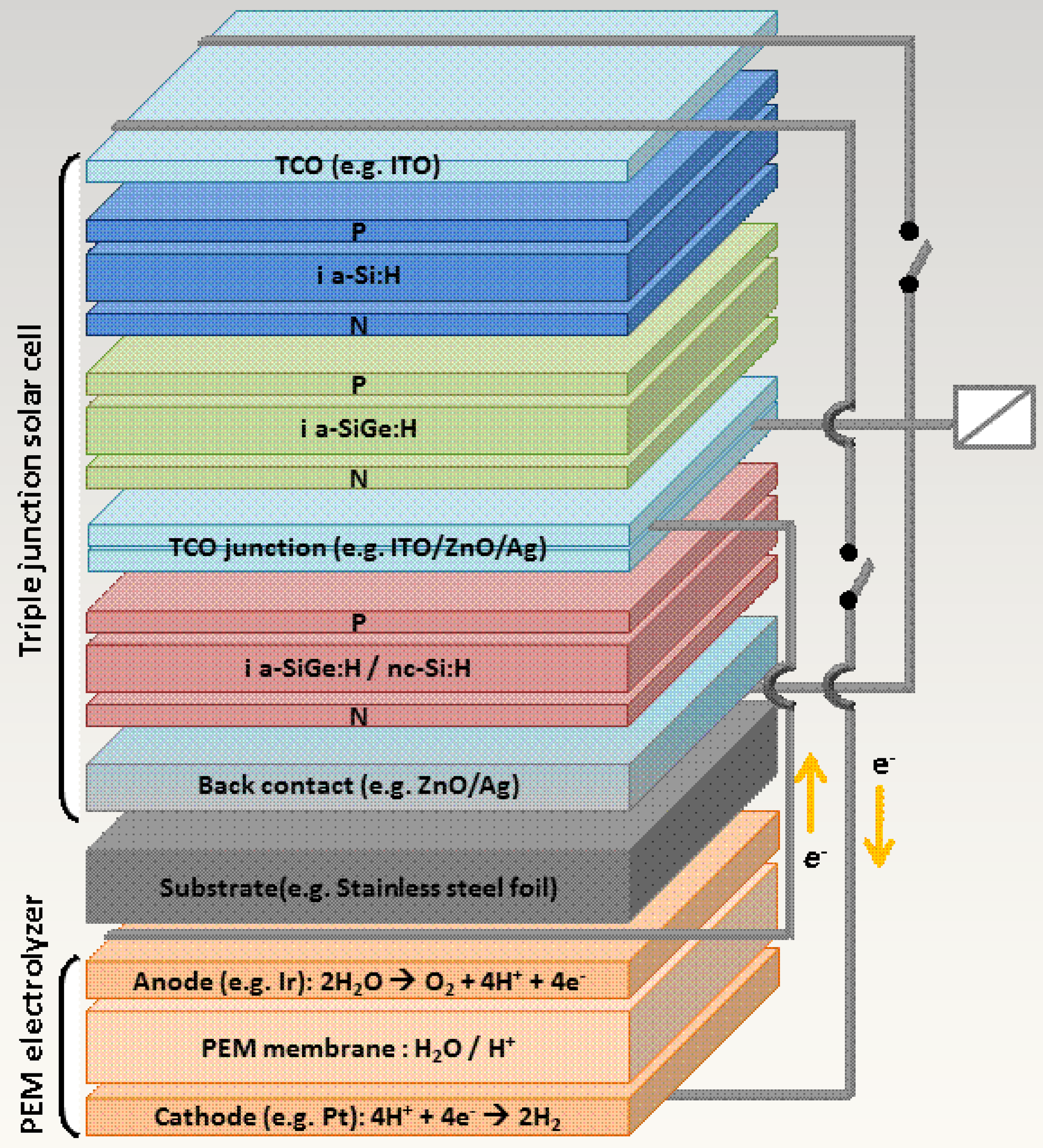
Separating the electrolyte from the solar cell material appears beneficial, especially regarding stability issues. In this case the electrodes of the electro-chemical cell are either directly connected or form a part of the back contact.

NOVEL CONCEPT BASED ON THIN FILM SILICON TRIPLE-JUNCTION SOLAR CELLS

- Solar cells based on stacks of hydrogenated amorphous silicon (a-Si:H), silicon germanium (a-SiGe:H), and nanocrystalline/ microcrystalline silicon (nc-Si:H/(μc-Si:H)
- Amorphous silicon triple-junction solar cells, as for example a-Si:H/a-SiGe:H/nc-Si:H or a-Si:H/a-SiGe:H/a-SiGe:H can supply open circuit voltages of up to 2.3 to 2.5 V as given below.



Adapted from:
J. Yang, B. Yan, S. Guha, Thin Solid Films 487 (2005), p. 162–169.

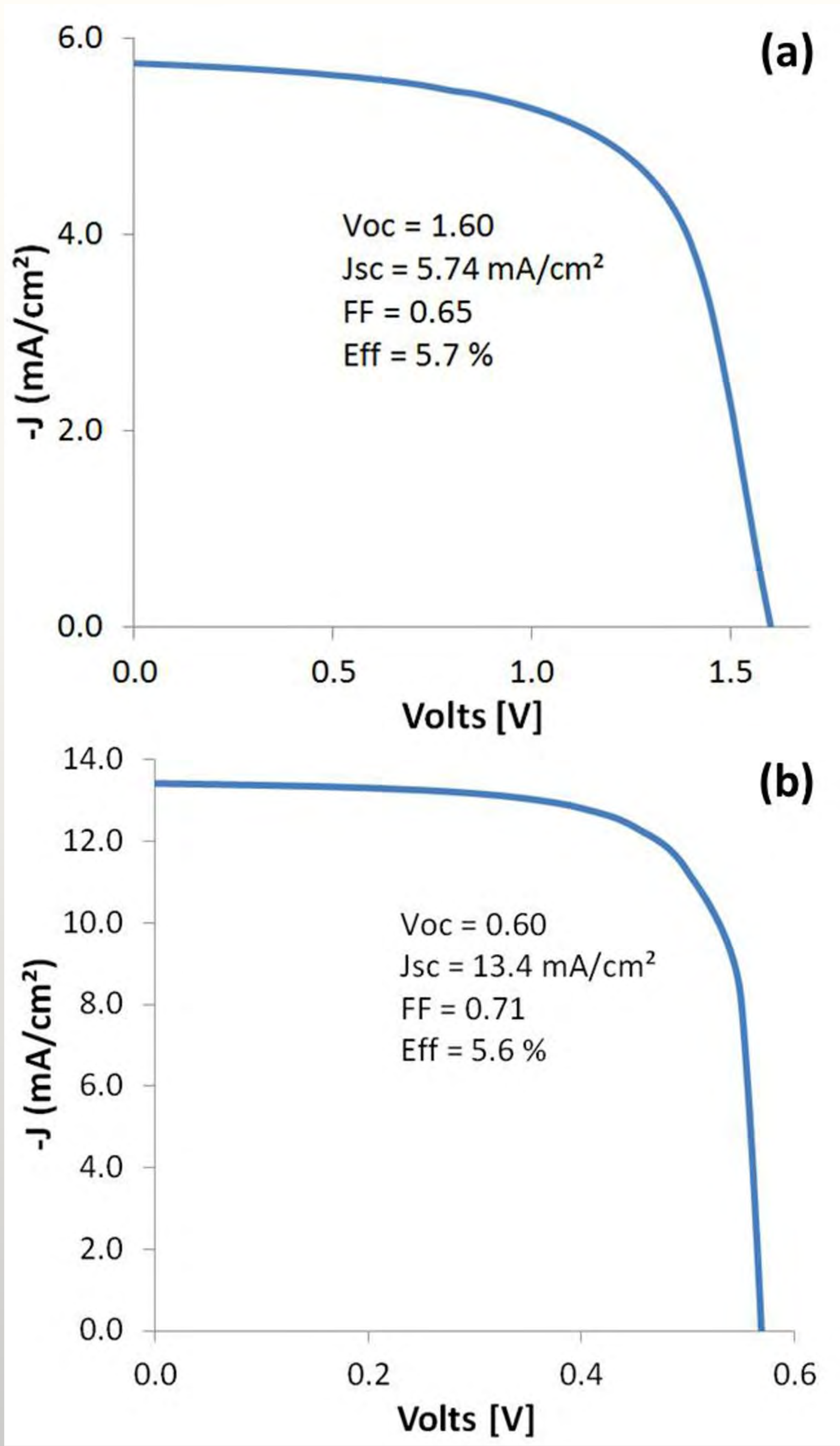


Schematic of the novel concept: The current of the upper dual junction enables the water splitting reaction in the PEM electrolyser. Contacts, possible wiring, currents, and water dissociation reaction are shown schematically.

MODELING AND SIMULATION

- Different combinations of a-Si/a-Si/a-S device configurations were evaluated by using wxAMPS (https://wiki.engr.illinois.edu/display/solarcellsim/Simulation+Software).
- Idealized a-Si p-i-n and p-i-n/p-i-n – structures were used as device structures, and the general 'default' physics parameters from the software were chosen.
- **Modeling parameters:**

p-i-n junction:	Top	Middle	Bottom
Energy gap [eV]	1.8	1.6	1.4
i-layer thickness [nm]	90	380	380
p/n-lay. thickness [nm]	10/10	10/10	10/10



(a) Simulated AM1.5G J-V plot of an a-Si p-i-n(Eg=1.8eV)/p-i-n(Eg=1.6eV) device; **(b)** sim. AM1.5G J-V plot of a-Si p-i-n(Eg=1.4eV) device.

RESULTS & CONCLUSION

- A novel concept based on a-Si:H triple-junction solar cells and a solar water splitting system integrating a PEM electrolyser is presented.
- It is possible to achieve a sufficient voltage of greater than 1.5 V with the top dual junction (E_{G1}=1.8 eV and E_{G2}=1.6 eV) of a triple junction a-Si based solar cell (figure a).
- The corresponding J-V characteristics of a-Si p-i-n single junction (E_G=1.4 eV) usable for PV electricity generation is given in figure b.
- Additional modeling has to be done to clarify the applicability of an a-Si based cell regarding simultaneous generation of electricity & hydrogen.

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