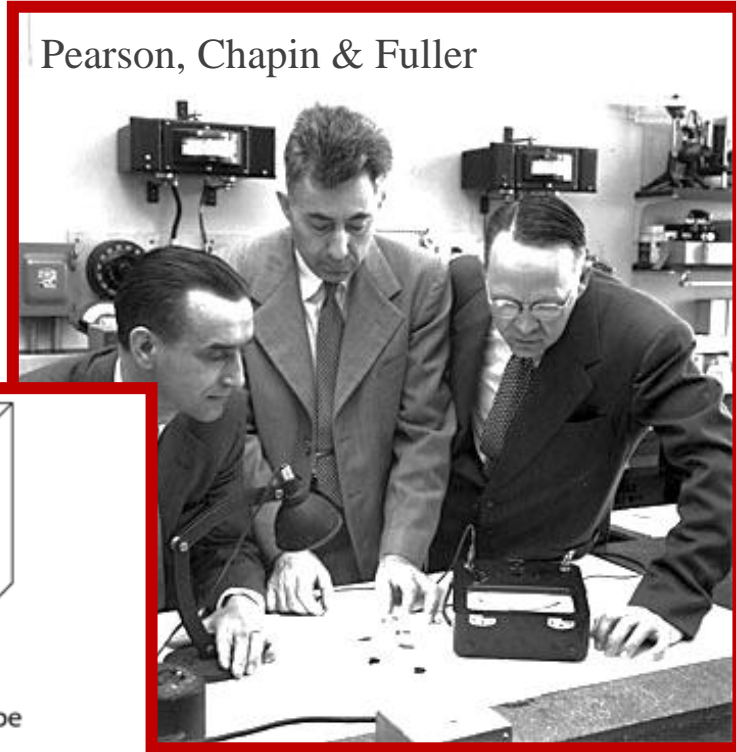
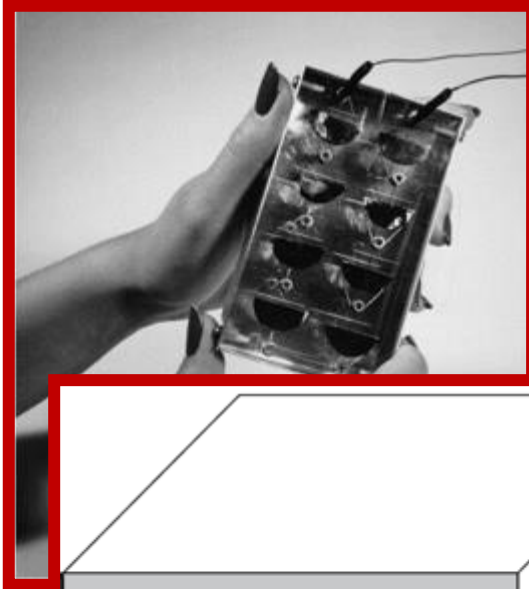


History and Future of the PV Industry

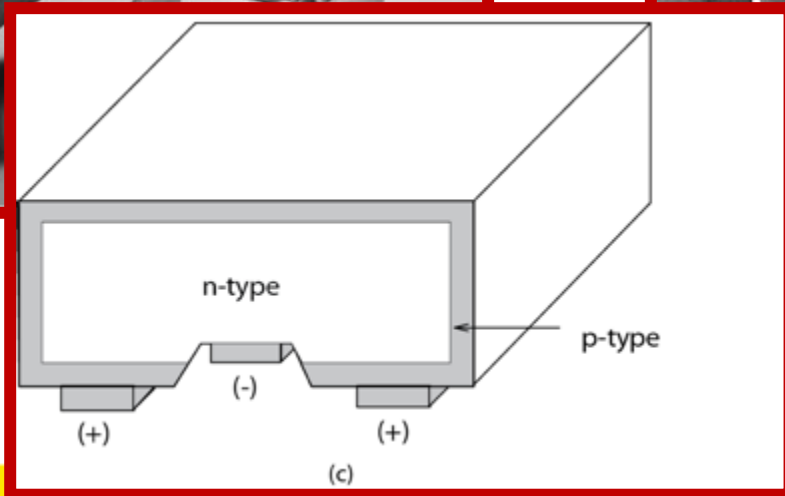
Martin Green, UNSW Sydney



The first efficient silicon cells (1954)



Credit: Bell Labs



HENSEL RECRUITAL ACCUSES MCARTHY OF MALACIOUS LIES
 HENSEL RECRUITAL ACCUSES MCARTHY OF MALACIOUS LIES
 HENSEL RECRUITAL ACCUSES MCARTHY OF MALACIOUS LIES

PERCECSON ASSERTS HOUSING INQUIRY MAY DELAY FUNDS
 PERCECSON ASSERTS HOUSING INQUIRY MAY DELAY FUNDS

U. S. and British Leaders on Two Active Diplomatic Fronts
 U. S. and British Leaders on Two Active Diplomatic Fronts

BRITAIN'S CABINET SEEKS WAY TO BAR AN ASIAN DISASTER
 BRITAIN'S CABINET SEEKS WAY TO BAR AN ASIAN DISASTER



WILL STILL HAVES AT THE TOP OF RACES
 WILL STILL HAVES AT THE TOP OF RACES

AUSTRALIA SPURS U. S. Backs Efforts by Paris FRENCH HANG MOSCOW'S DEMAND To End War in Indo-China
 AUSTRALIA SPURS U. S. Backs Efforts by Paris FRENCH HANG MOSCOW'S DEMAND To End War in Indo-China

IRAQ WILL HAVE U. S. MILITARY HELP
 IRAQ WILL HAVE U. S. MILITARY HELP

Vast Power of the Sun Is Tapped By Battery Using Sand Ingredient
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Vast Power of the Sun Is Tapped By Battery Using Sand Ingredient
 Special to The New York Times.

MURRAY HILL, N. J., April 25—A solar battery, the first of its kind, which converts useful amounts of the sun's radiation directly and efficiently into electricity, has been constructed here by the Bell Telephone Laboratories.

The new device is a simple-looking apparatus made of strips of silicon, a principal ingredient of common sand. It may mark the beginning of a new era, leading eventually to the realization of one of mankind's most cherished dreams—the harnessing of the almost limitless energy of the sun for the uses of civilization.

The sun pours out daily more than a quadrillion (1,000,000,000,000,000) kilowatt hours of energy, greater than the energy content of all the reserves of coal, oil, natural gas and uranium in the earth's crust.

With this modern version of Apollo's chariot, the Bell scientists have harnessed enough of the sun's rays to power the transmission of voices over telephone wires. Beams of sunlight have also provided electricity for a transistor in a radio transmitter, which carried both speech and music.

The Bell scientists reported they had achieved an efficiency of 6 per cent in converting sunlight directly into electricity. This, they asserted, compares favorably with the efficiency of steam and gasoline engines, in contrast with other photoelectric devices, which have a rating of no more than 1 per cent.

With improved techniques the efficiency may be expected to be increased substantially, they added. They observed that nothing is consumed or destroyed in the energy conversion process and there are no moving parts, so the solar battery "should theoretically last indefinitely."

The experimental solar battery uses strips of wafer-thin silicon about the size of common razor blades. These strips are extremely sensitive to light. They can be linked together electrically and can deliver power from the sun at the rate of 50 watts a square yard of surface.

The atomic battery recently announced by the Radio Corporation of America delivers one-millionth of a watt. The new Bell solar battery thus delivers 50,000,000 times the power of the R.C.A. atomic battery.

Silicon is a semiconductor.

Continued on Page 11, Column 4

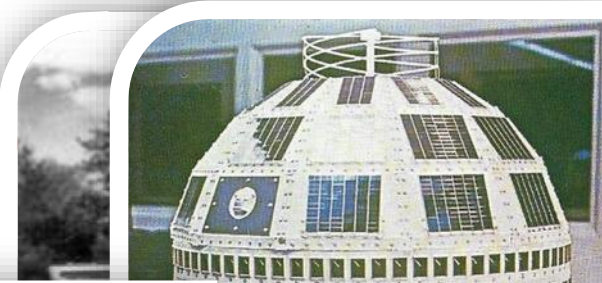
earso



Credit: Bell Labs

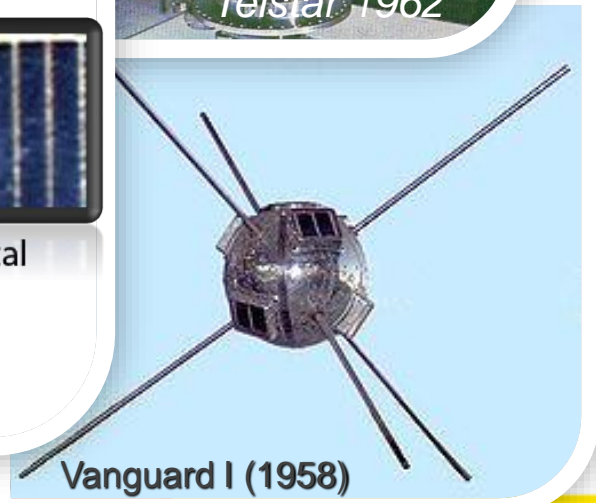
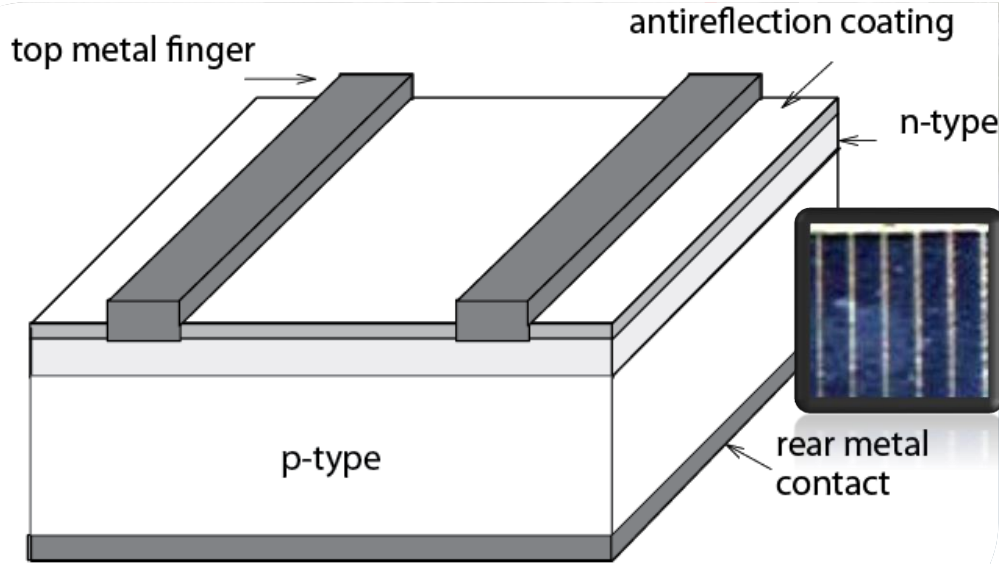


earso



Telstar 1962

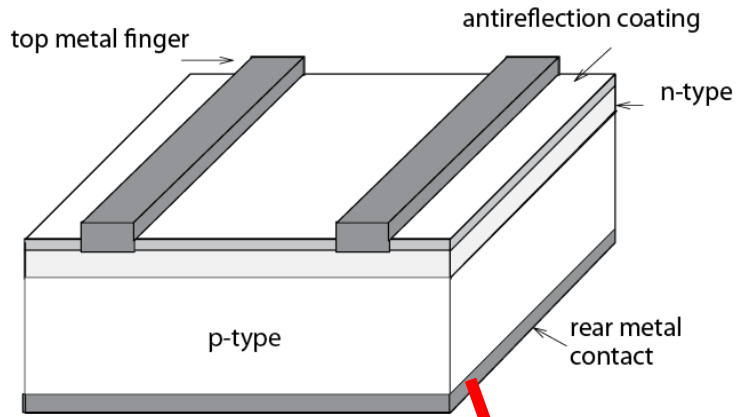
Credit: D. Darling



Vanguard I (1958)

Credit: Wikimedia Commons

Violet cell (COMSAT 1972)

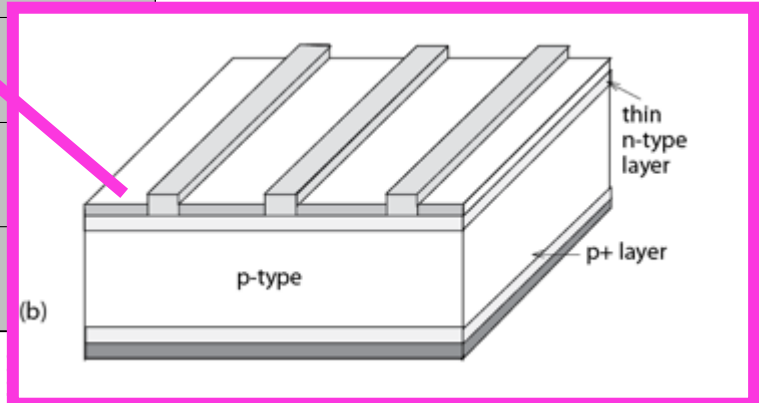
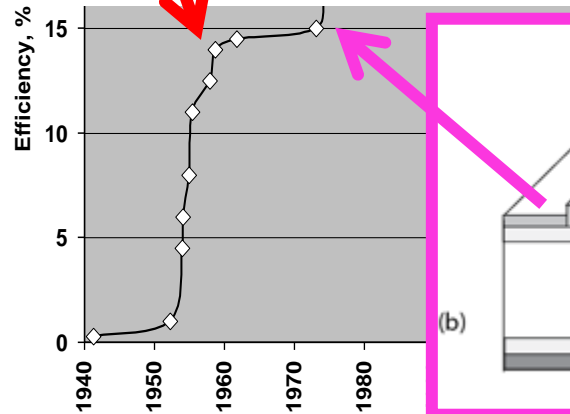


Credit: COMSAT Labs

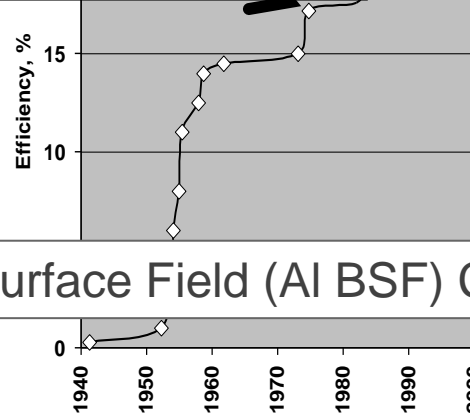
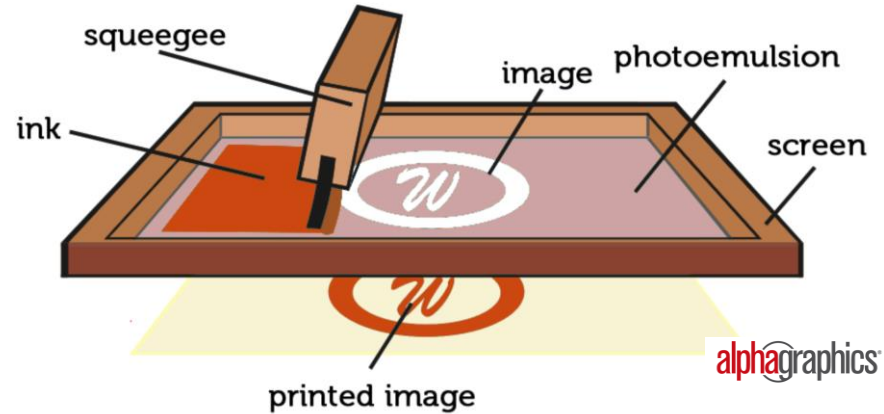
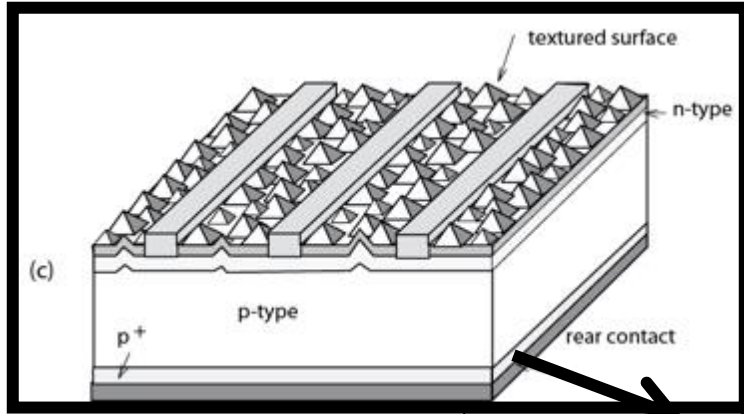


Joseph Lindmayer

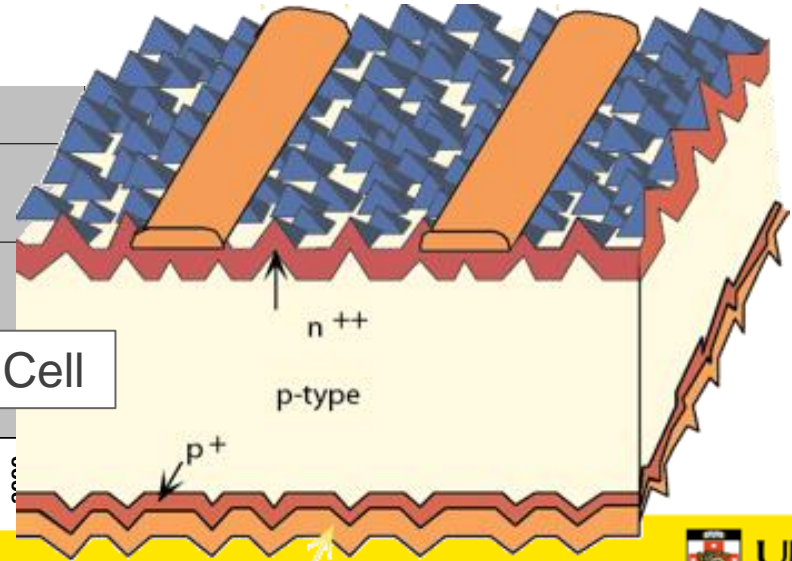
Credit: Electronics/Oct. 11, 1973



Black cell (COMSAT 1974)

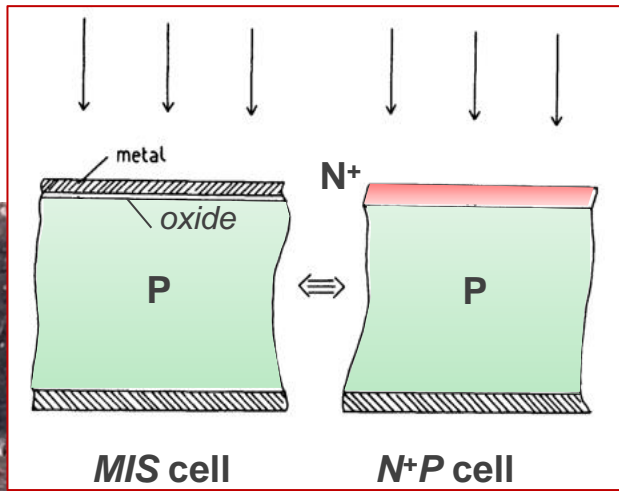


Al Back Surface Field (Al BSF) Cell



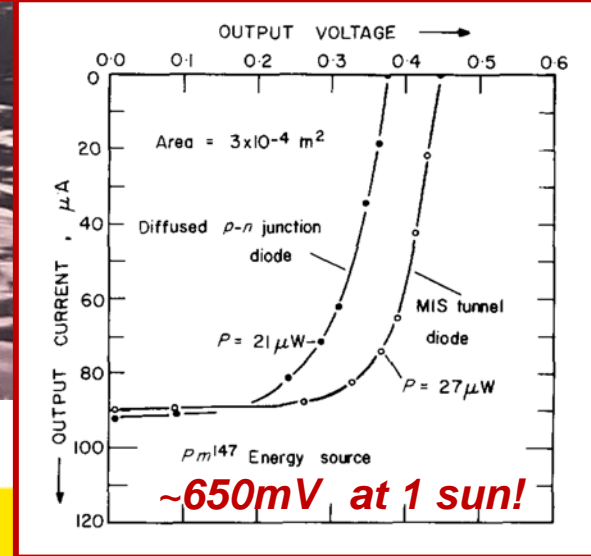
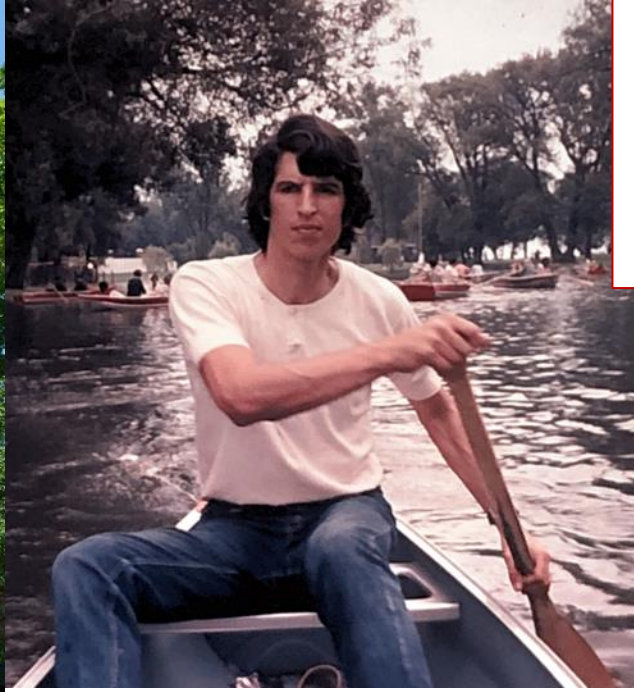
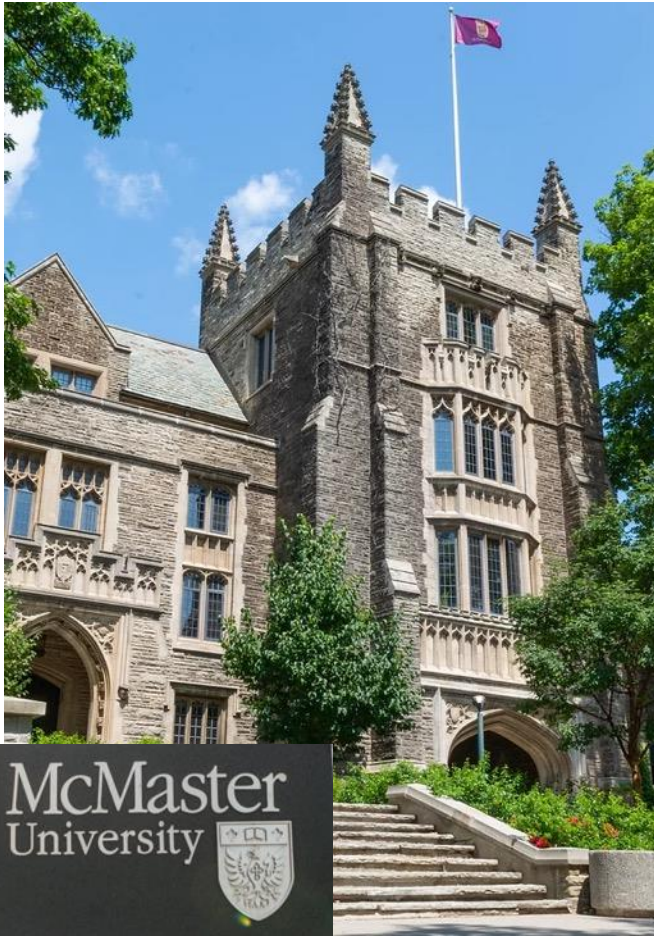
PhD McMaster Uni., Canada (1971-1974)

First "TOPCon"

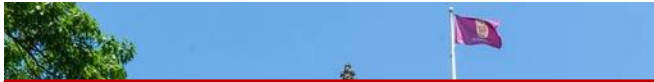


MIS cell

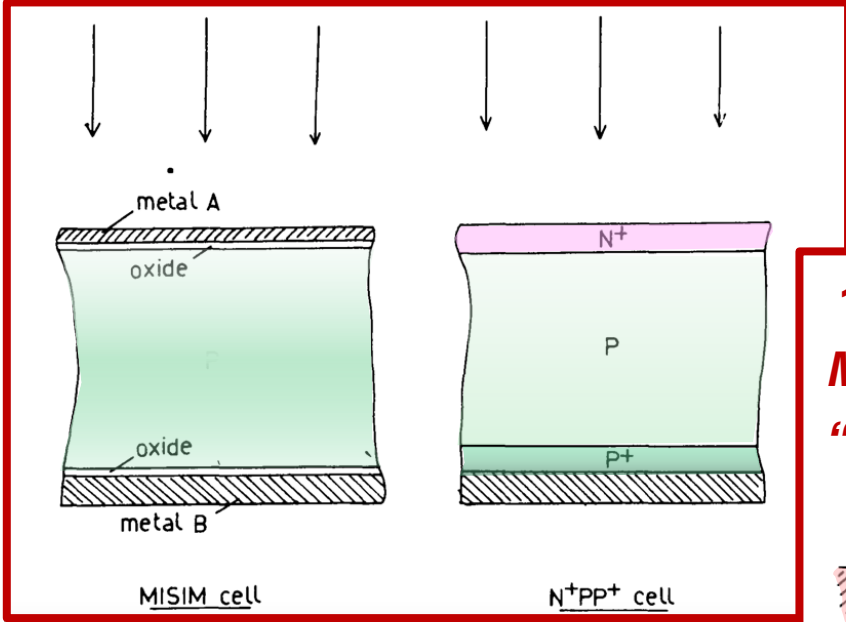
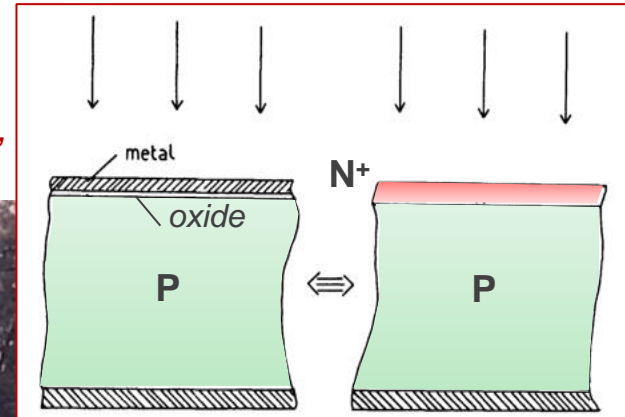
N+P cell



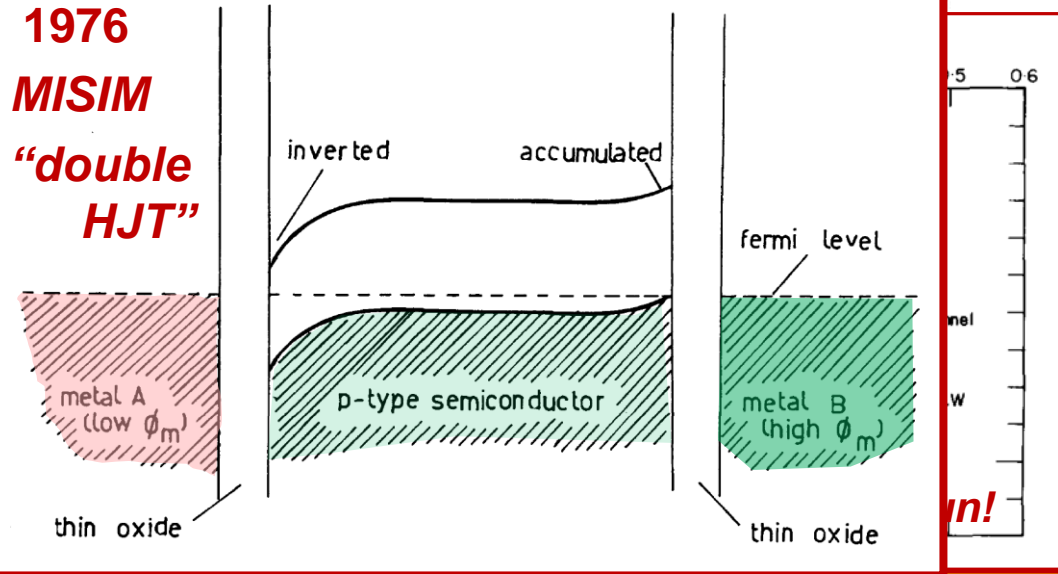
UNSW Sydney (1974 - present)



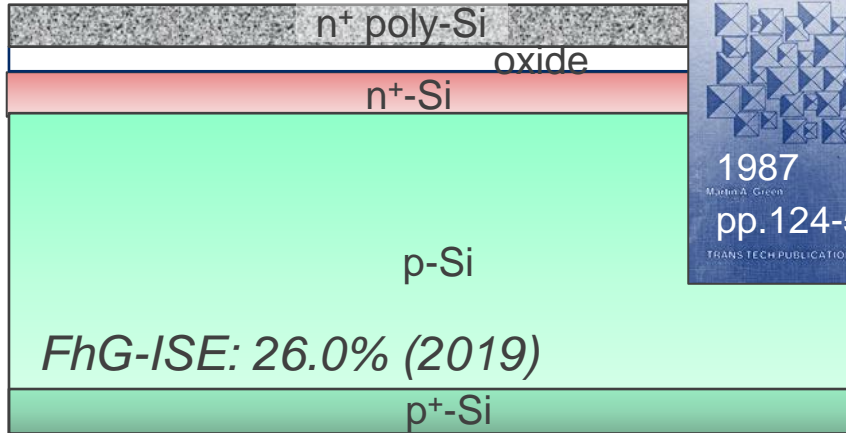
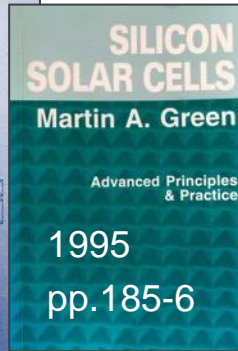
First "TOPCon"



1976
MISIM
"double
HJT"



First (poly-)‘TOPCon’ solar cell reported (1983)



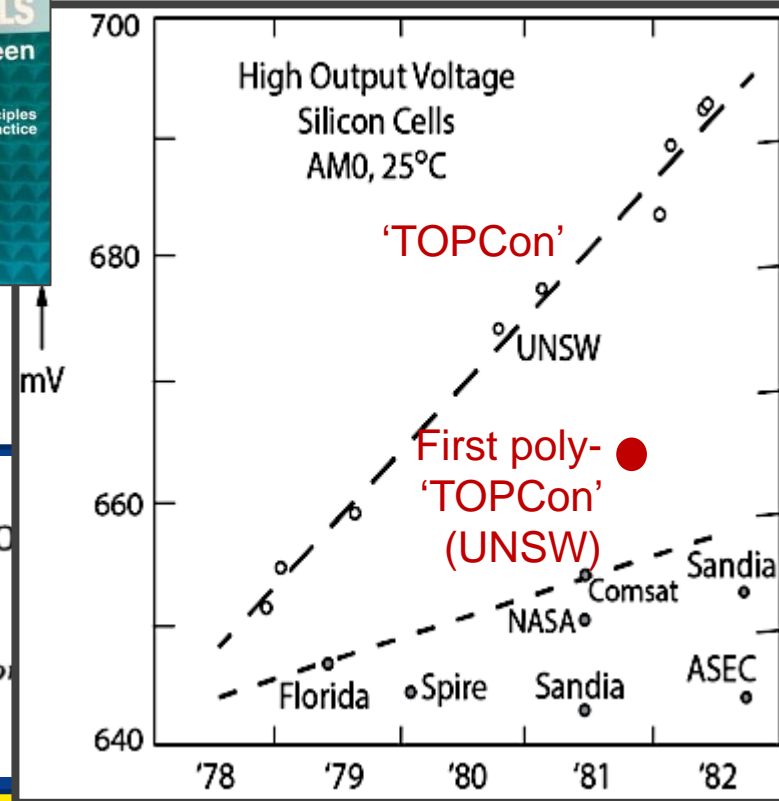
Solar Cells, 8 (1983) 3 - 16

ADVANTAGES OF METAL-INSULATOR-SEMICONDUCTOR STRUCTURES FOR SILICON SOLAR CELLS

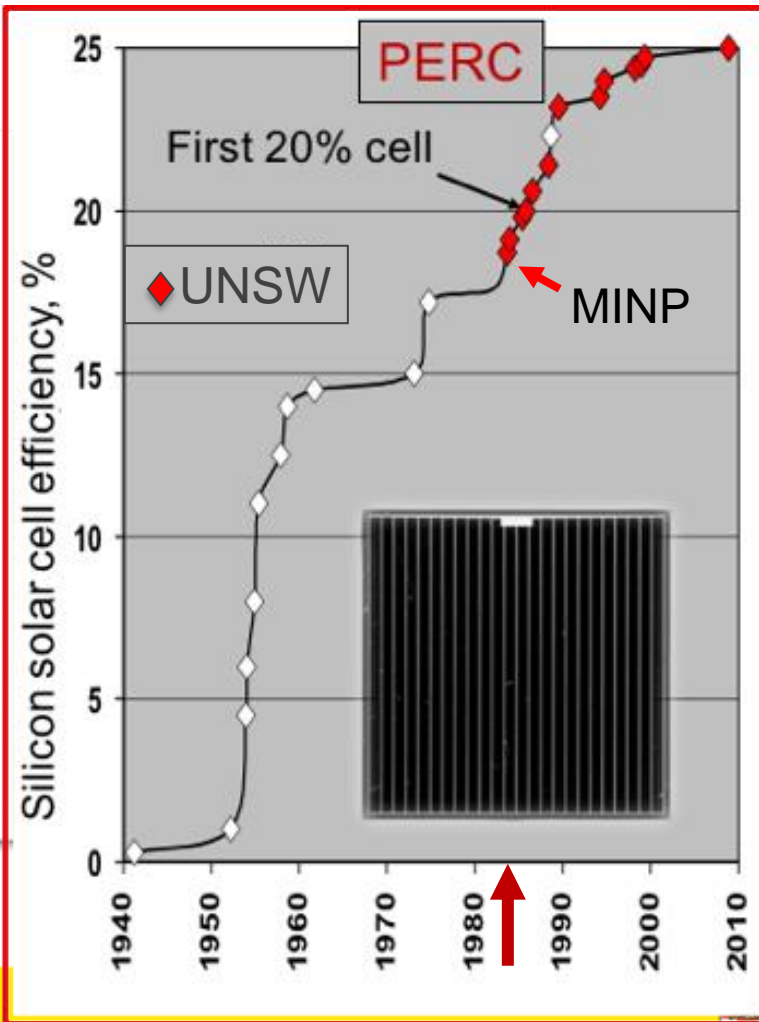
M. A. GREEN and A. W. BLAKERS

Solar Photovoltaic Laboratory, University of New South Wales, Kensington (Australia)

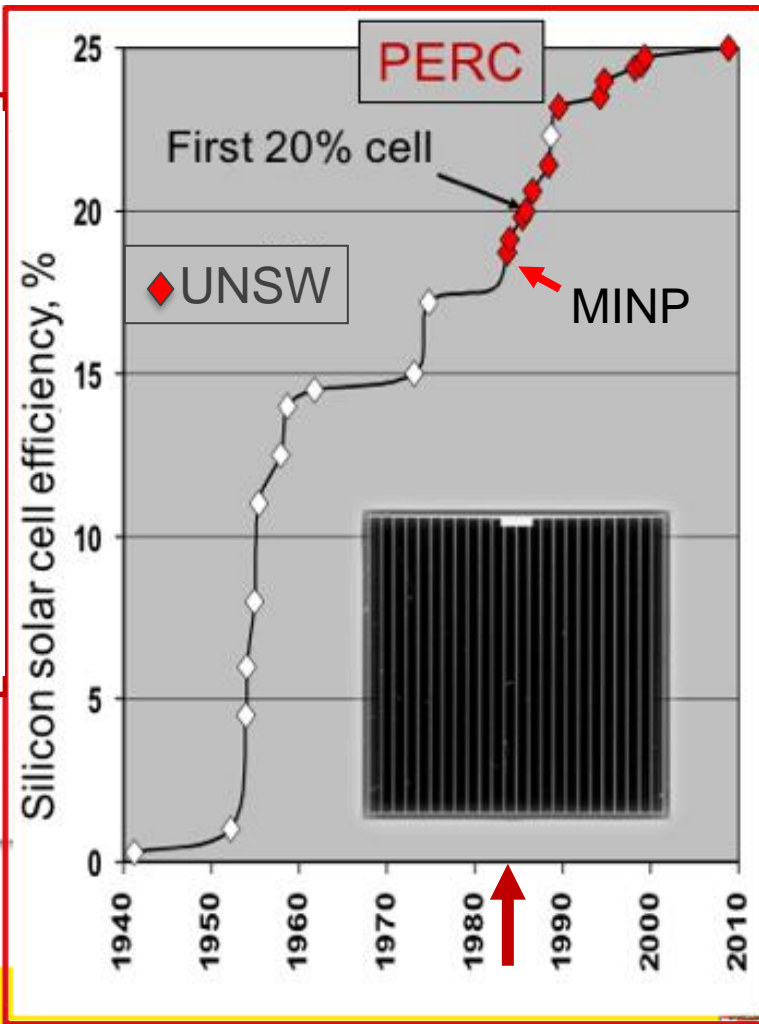
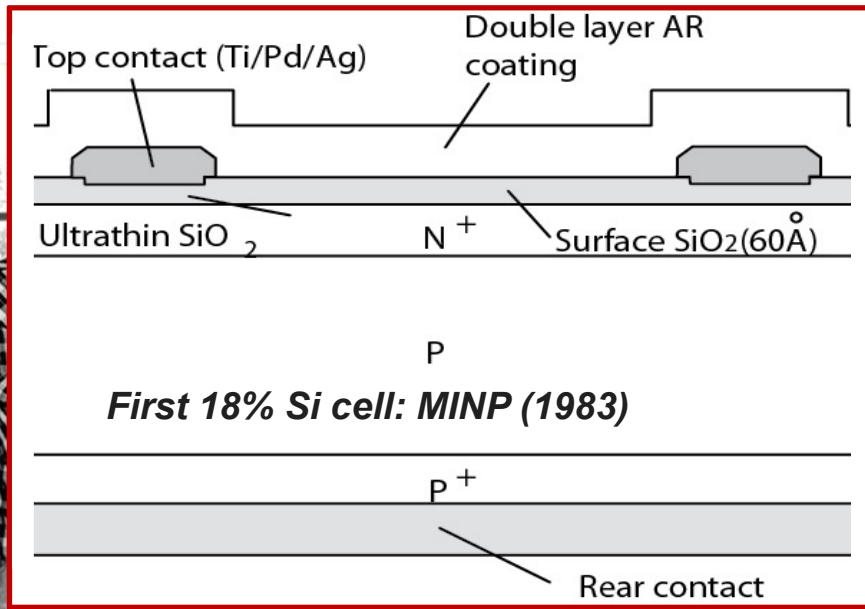
(Received January 26, 1982; accepted April 5, 1982)



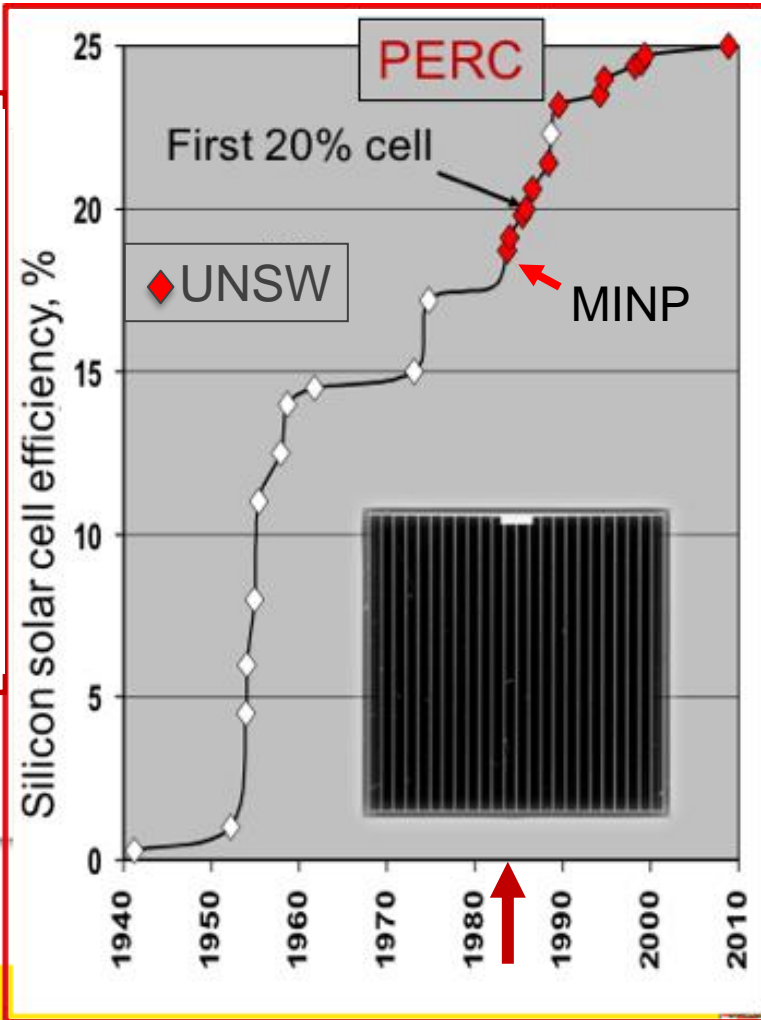
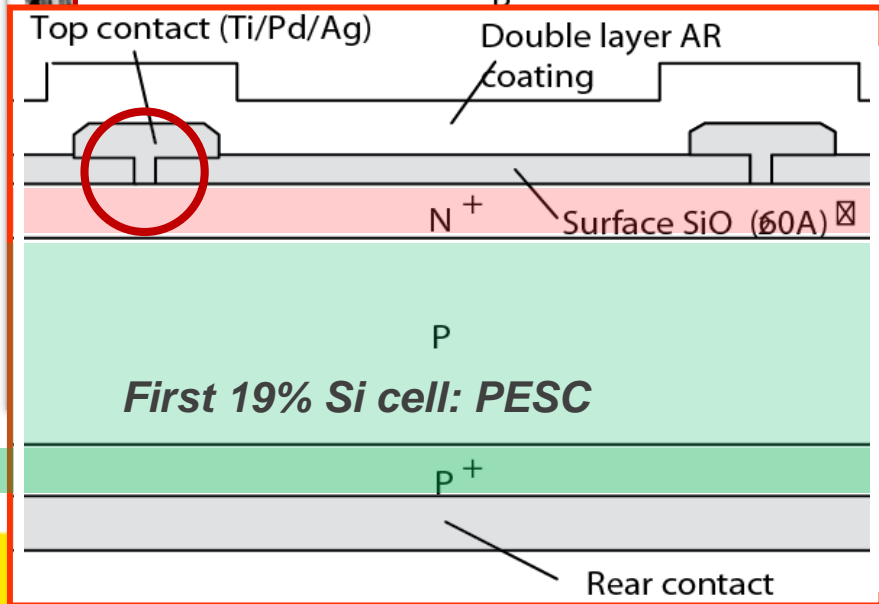
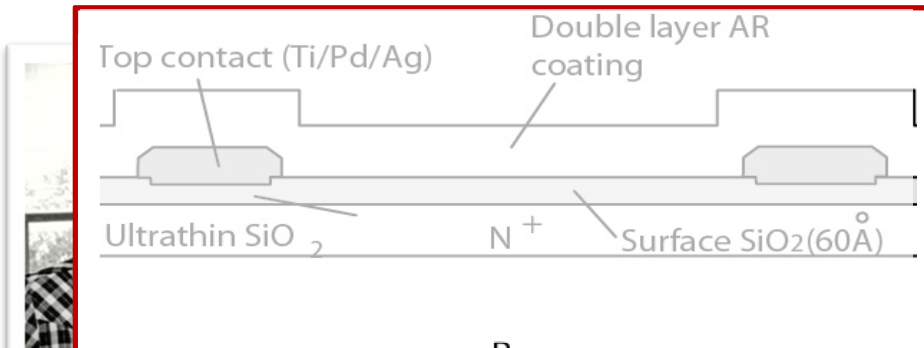
1983: First 18% Si cell



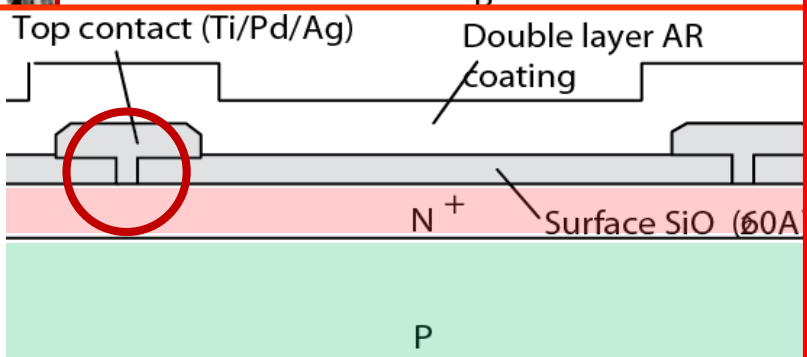
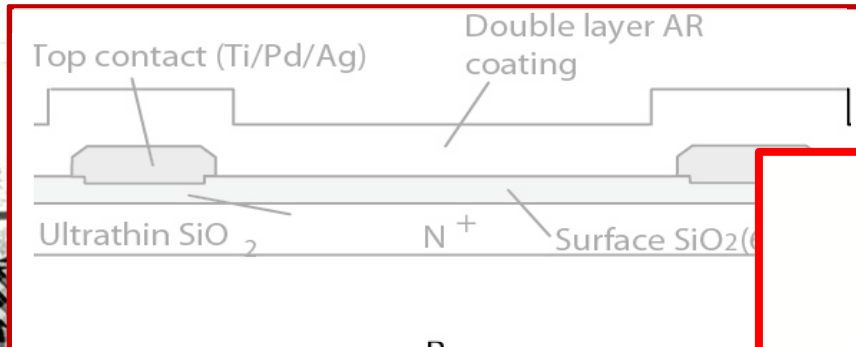
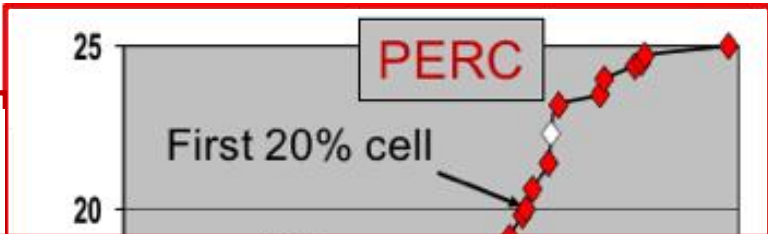
1983: First 18% Si cell



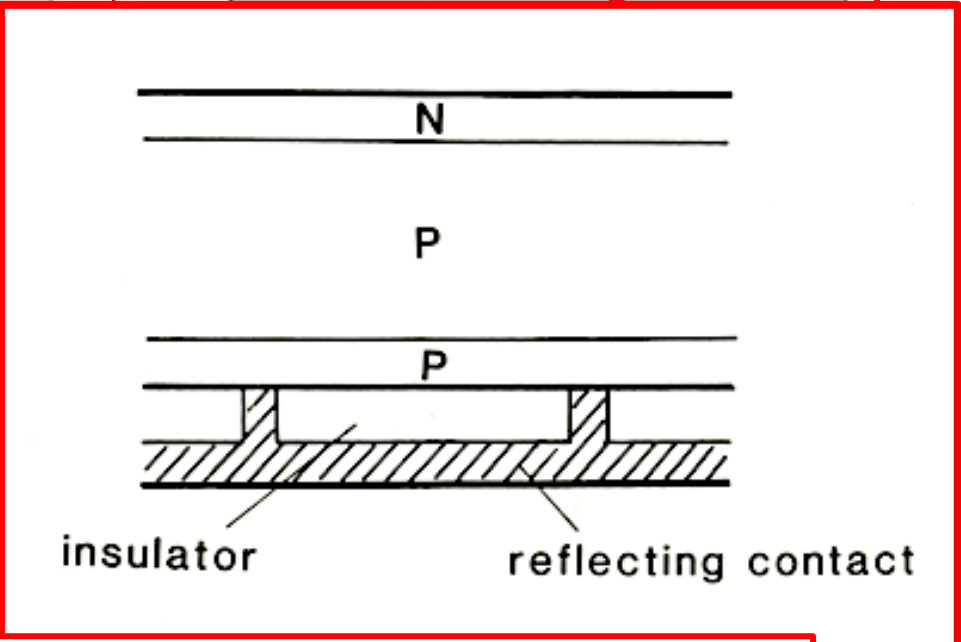
1983: Also first 19% cell



1983: Also PERC conceived



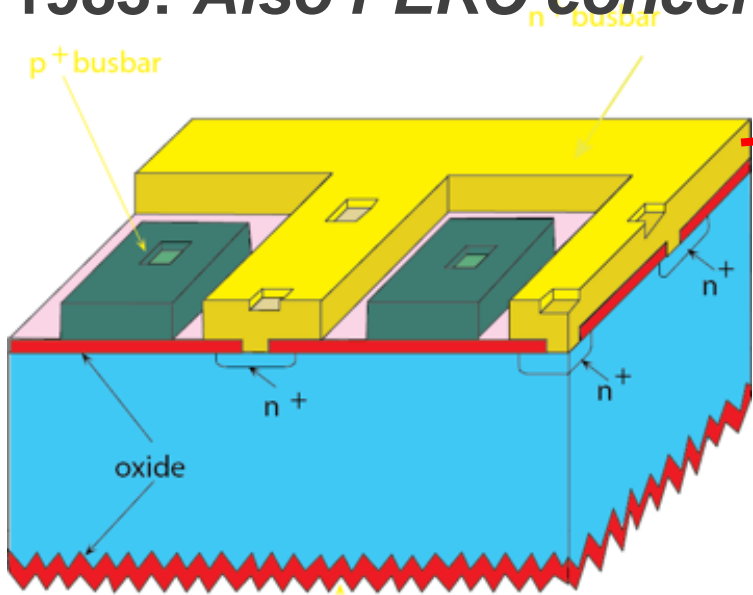
First 19% Si cell: PESC (also 20%, 21%)



M.A. Green et al., "Ultimate Performance Silicon Solar Cells", Final Report, NERDDP Project 81/1264, Jan. 82 - Dec. 83 (dated Feb. 1984).
 M.A. Green, "High Efficiency Silicon Solar Cells", Proposal in response to RFP RB-4-04033, SERI (now NREL), March 1984.

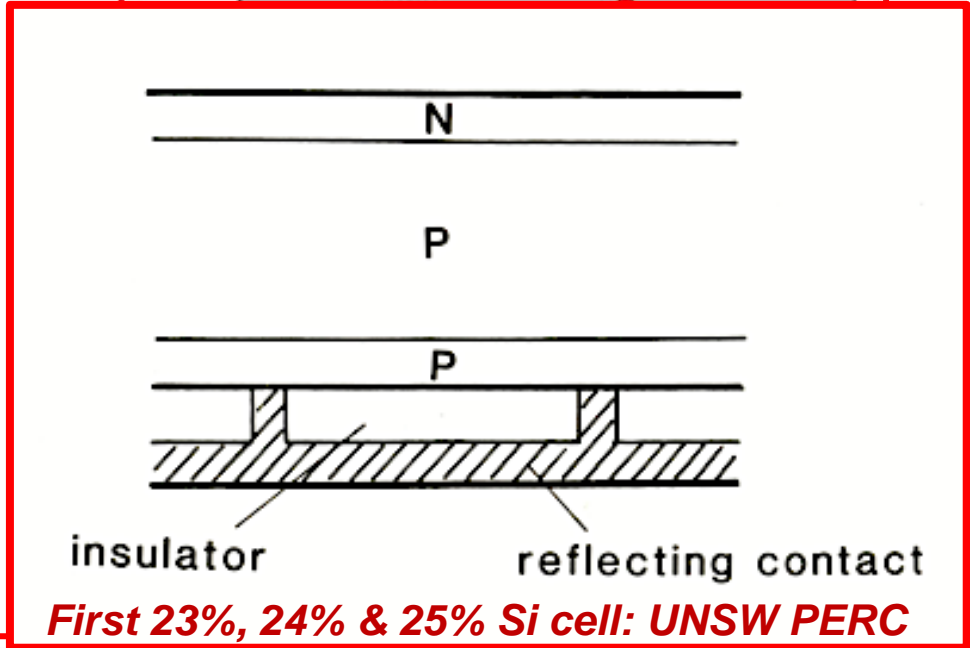
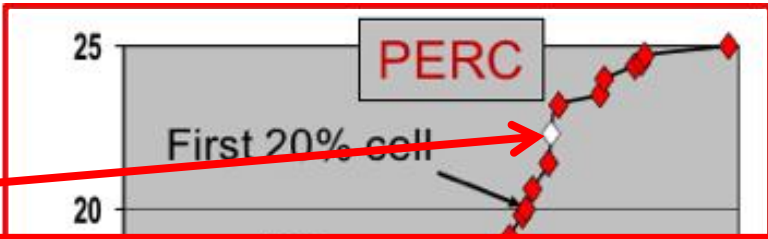


1983: Also PERC conceived



First 22% Si cell: Stanford IBC (1988)

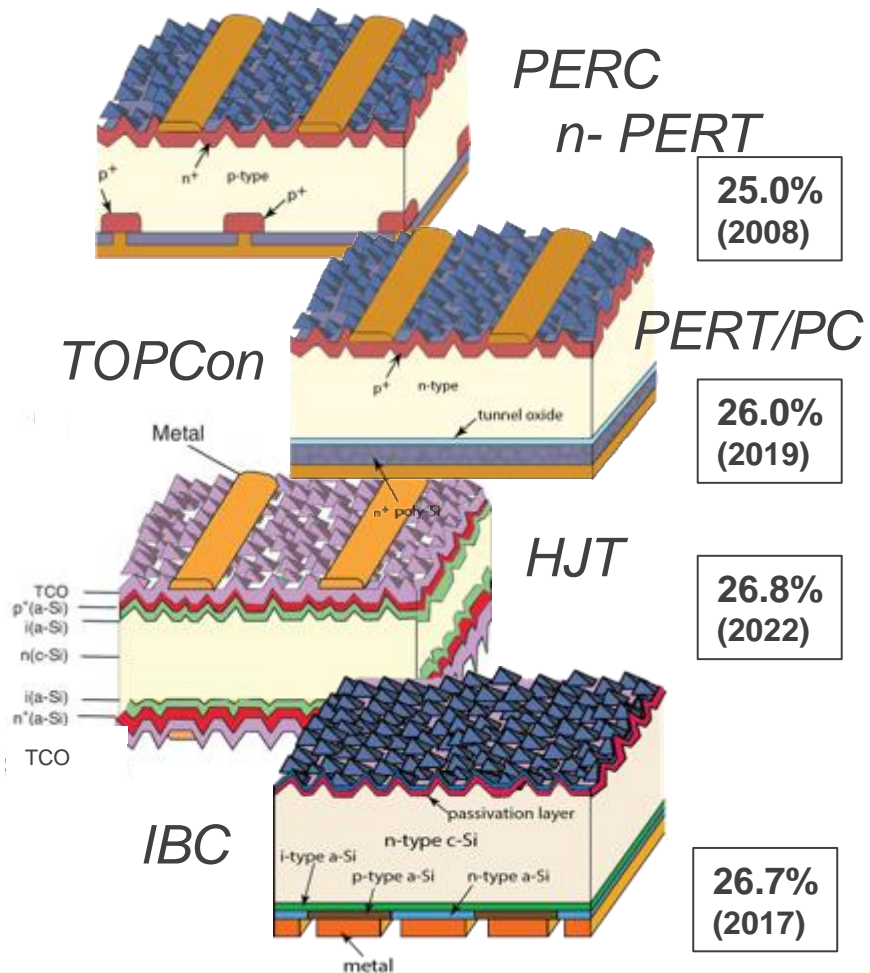
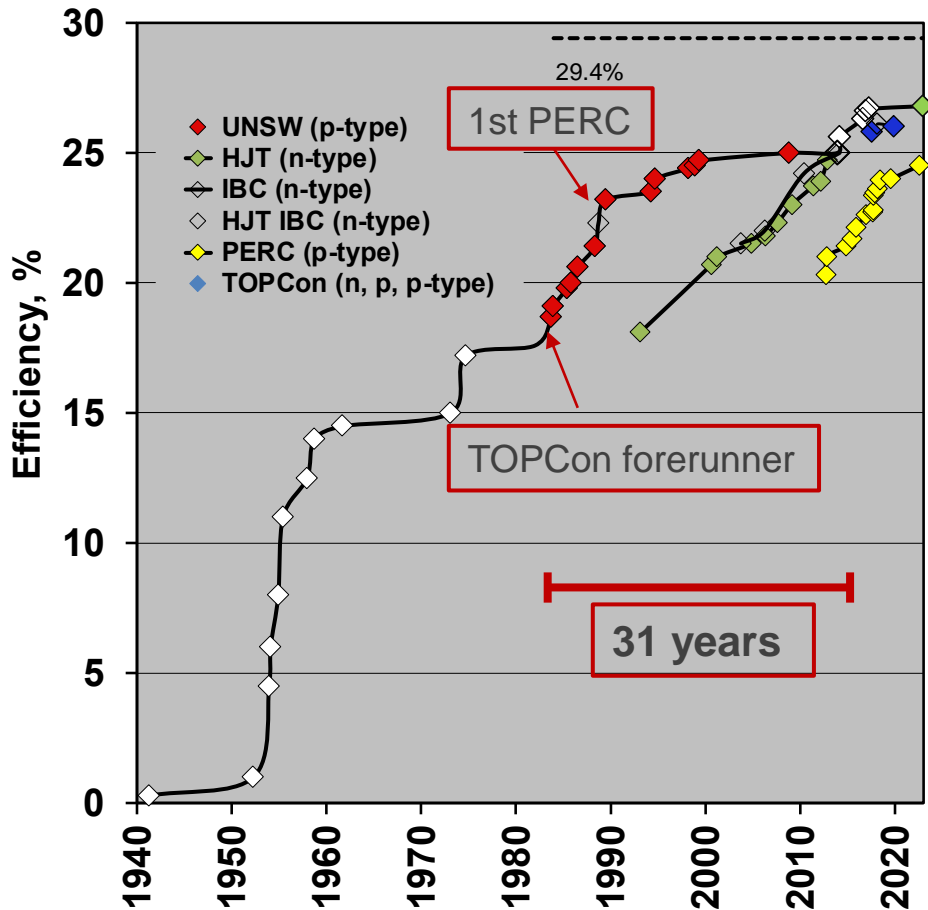
sunlight



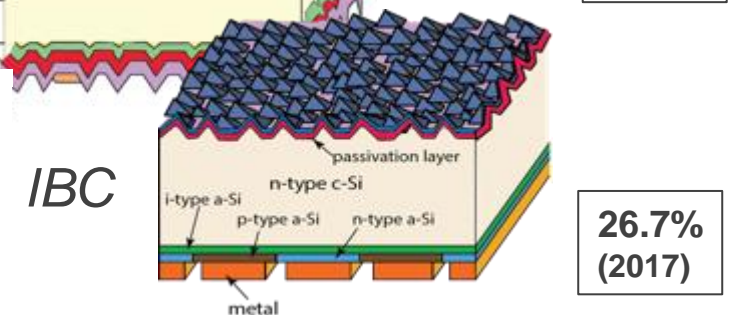
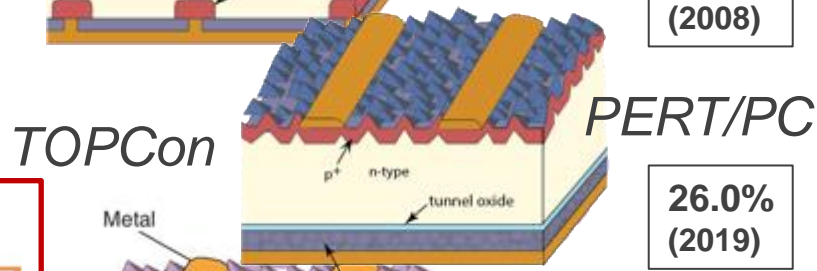
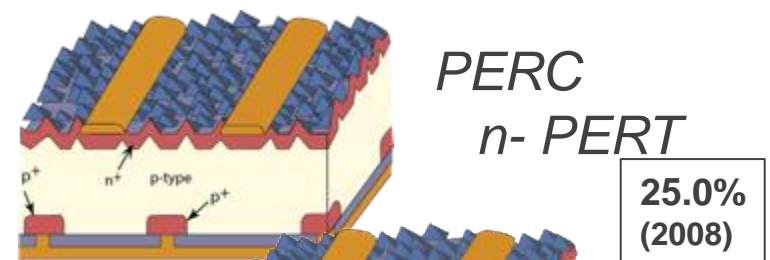
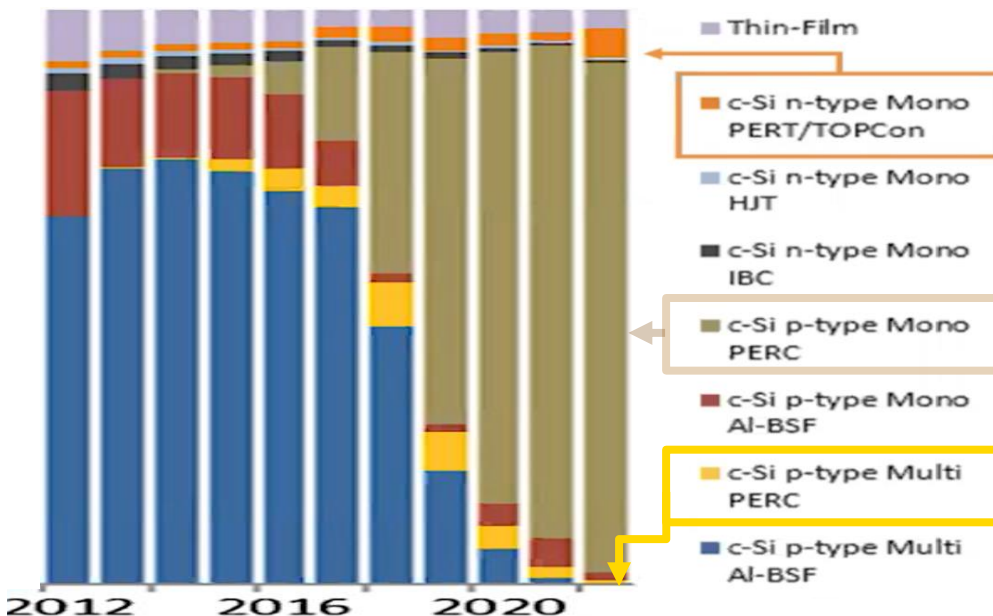
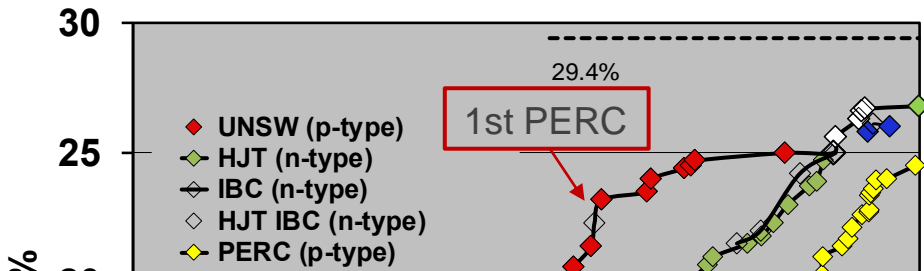
First 23%, 24% & 25% Si cell: UNSW PERC

M.A. Green et al., "Ultimate Performance Silicon Solar Cells", Final Report, NERDDP Project 81/1264, Jan. 82 - Dec. 83 (dated Feb. 1984).
M.A. Green, "High Efficiency Silicon Solar Cells", Proposal in response to RFP RB-4-04033, SERI (now NREL), March 1984.

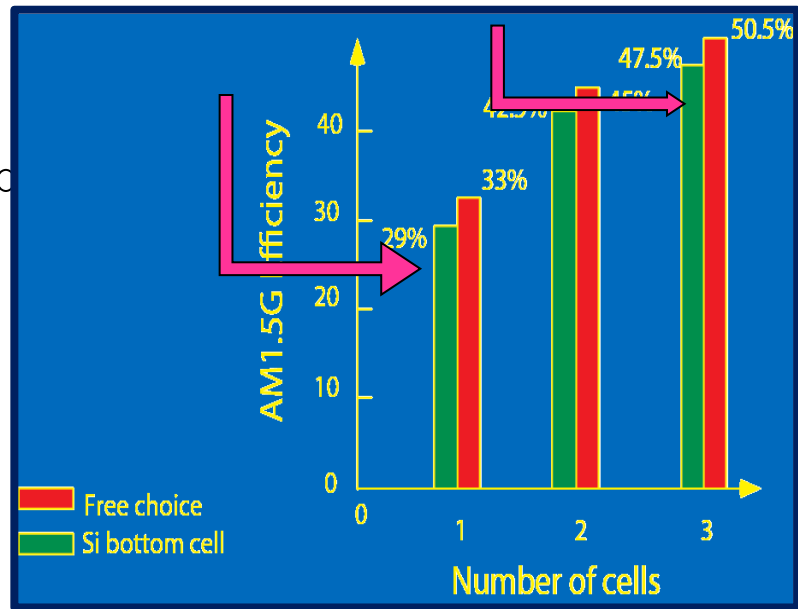
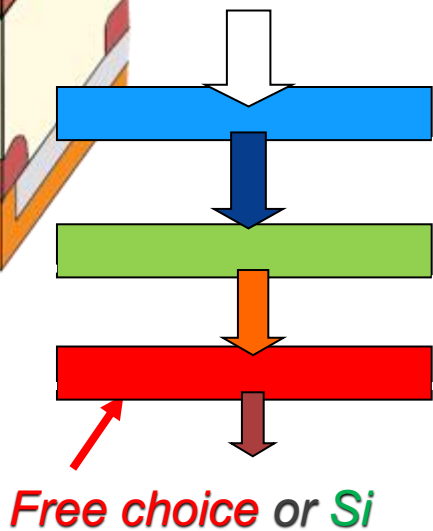
Subsequent progress



Subsequent progress



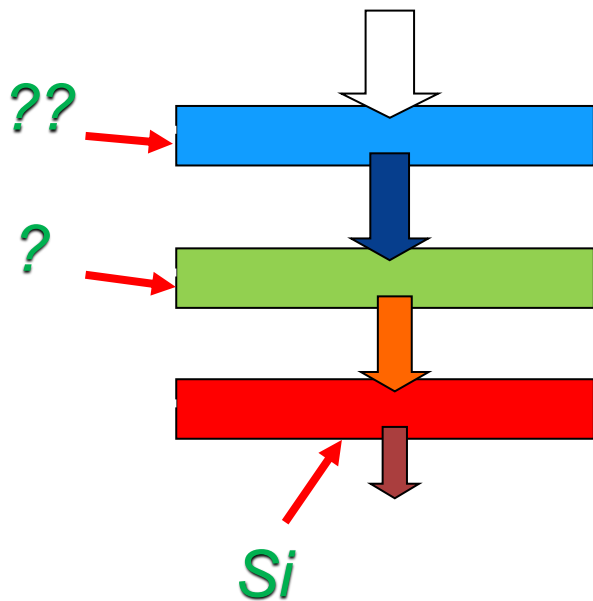
What comes after PERC? – longer term



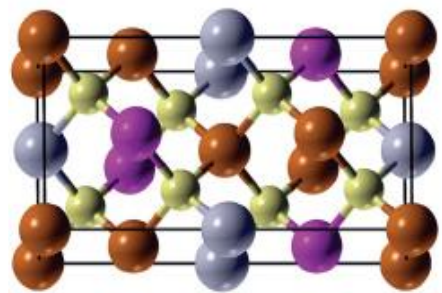
Supercharged tandem PERC, TOPCon, HJT?

What comes after PERC? – longer term

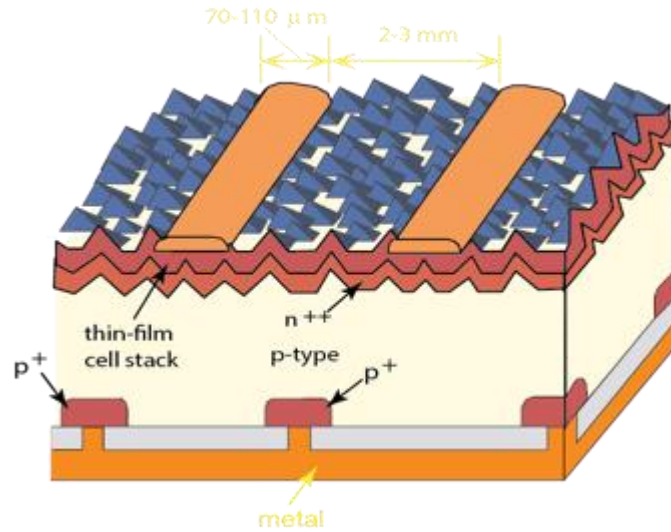
Like silicon, ? needs to be abundant, non-toxic, stable, efficient (>20%)



	<i>Perovskite</i>	✓	✗	✗	✓
	<i>Organics (OPV)</i>	✓	✓	✗	✗
II-VI	<i>Cu₂Zn(Sn:Si)S₄</i>	✓	✓	✓	✗
	<i>Cu(In:Ga)(S:Se)₂</i>	✗	?	✓	✗
	<i>(Cd:Zn:Mg)(Se:Te)</i>	✗	✗	✓	?
III-V	<i>(Al:Ga:In)(As:P)</i>	✗	?	✓	?

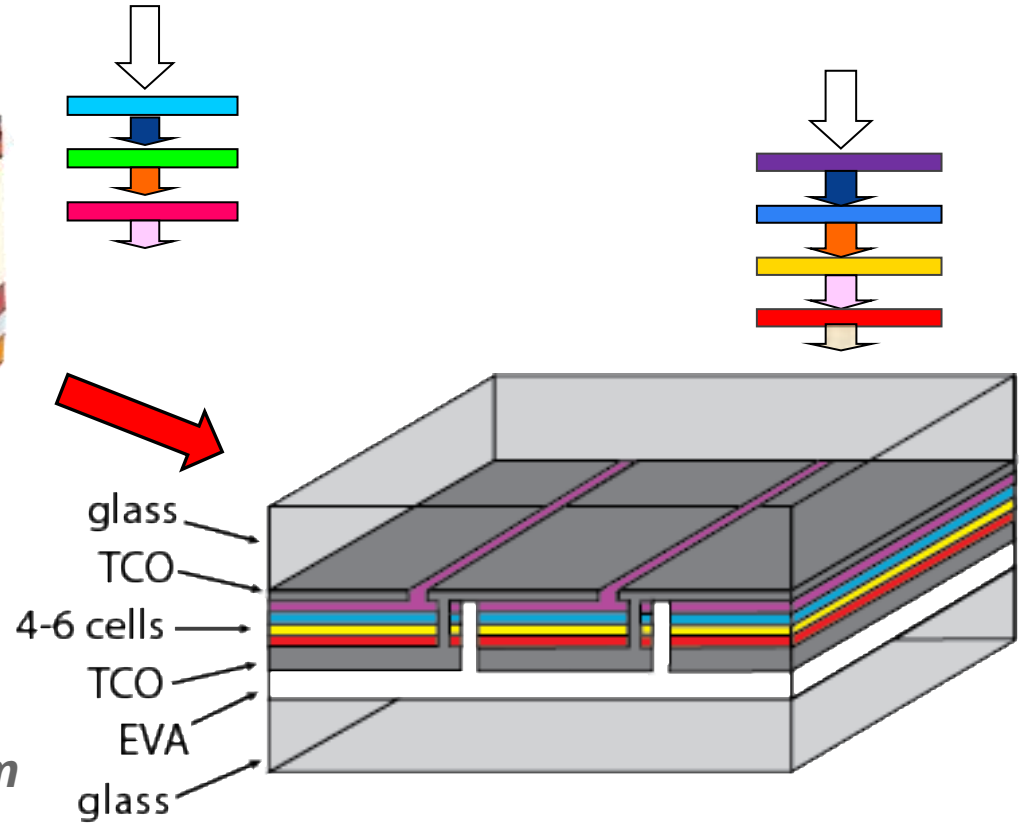


When found – *the end for silicon?*

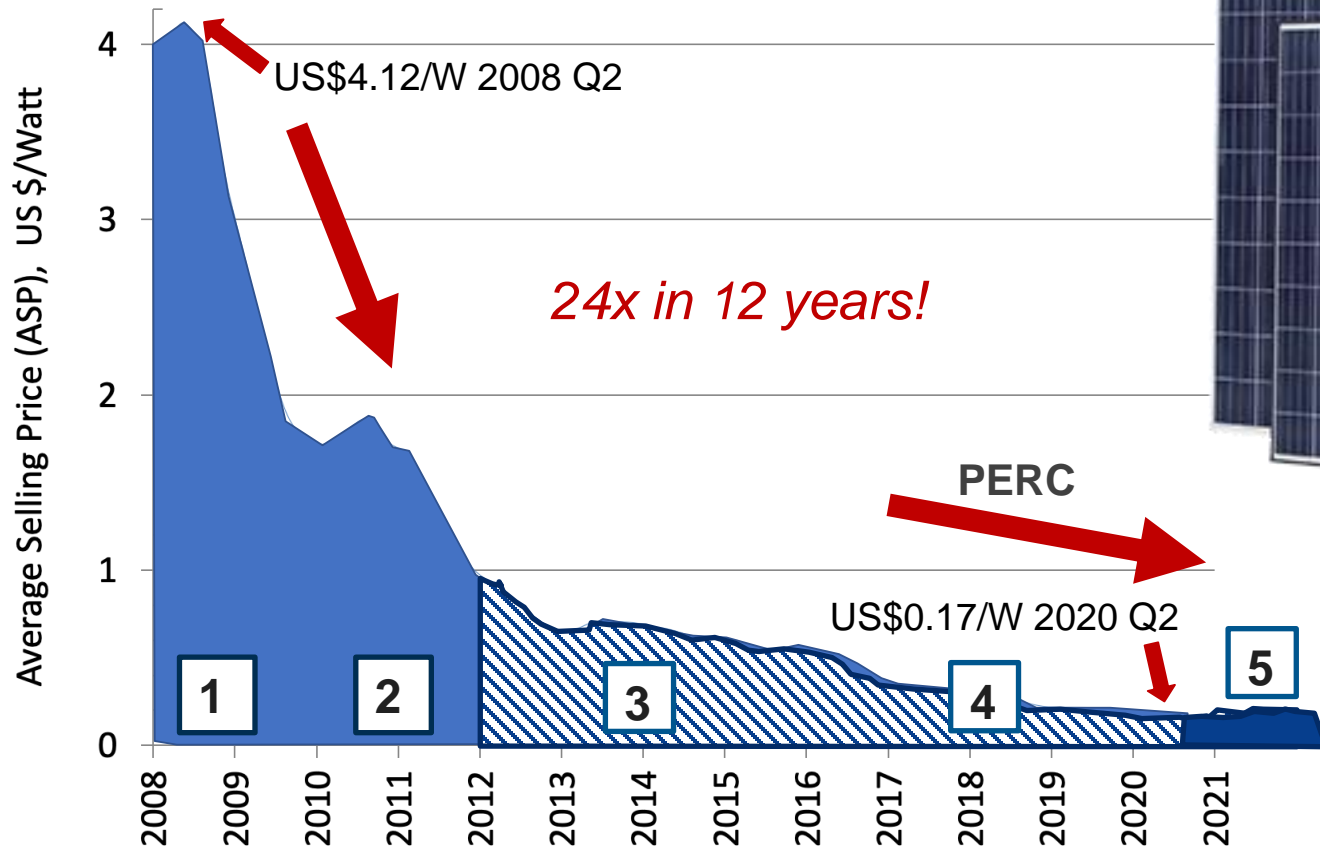


Si - 3 cell tandem

4-6 cell thin-film tandem

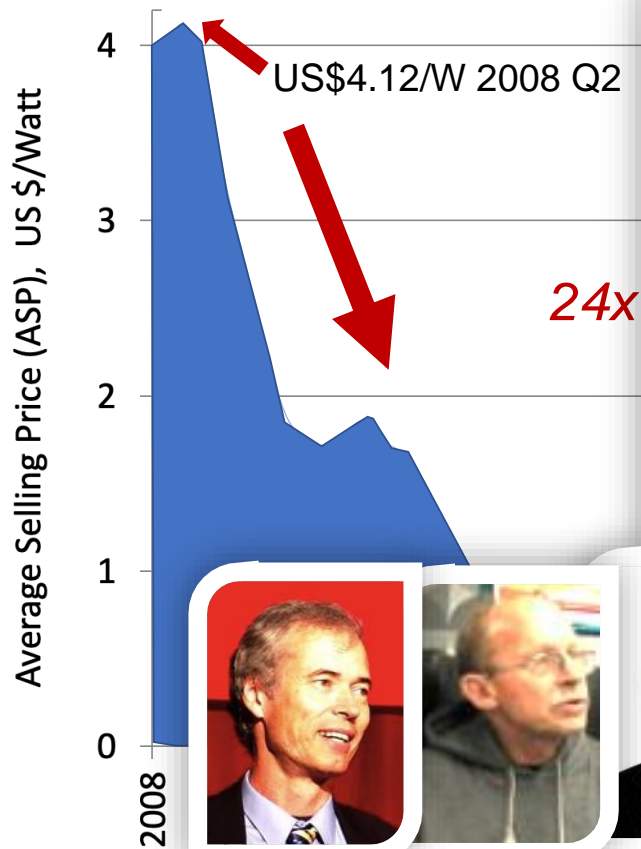


Modern industry



Dr Zhengrong Shi (12th PhD student)

Modern industry



CEO



CTO



Co-Founders

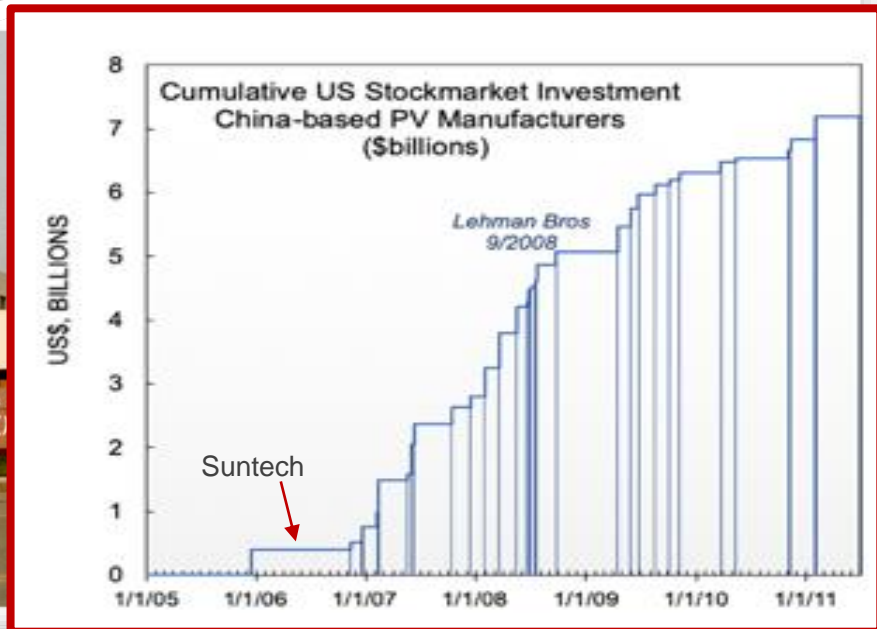




\$4.12/W 2008 Q2

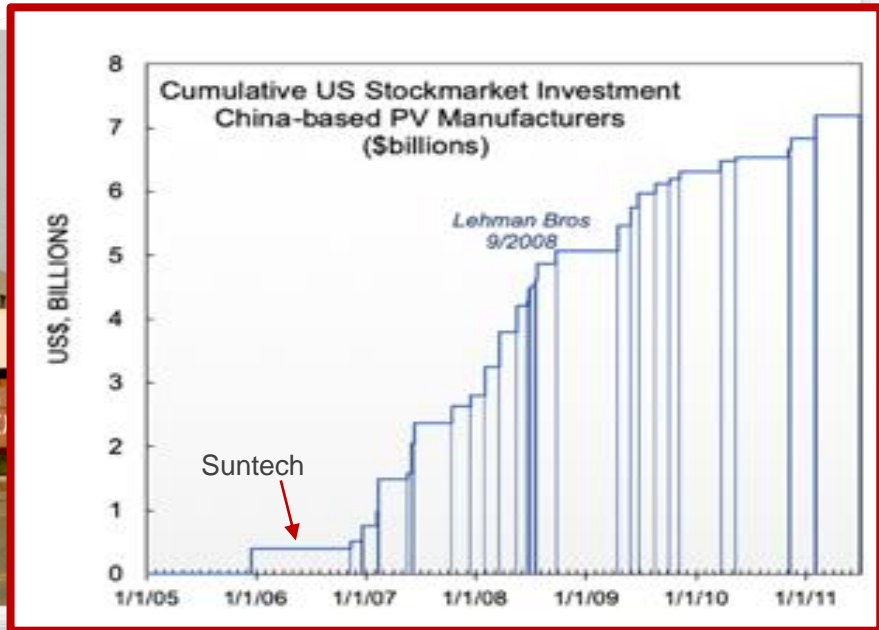


CO-FOUNDERS





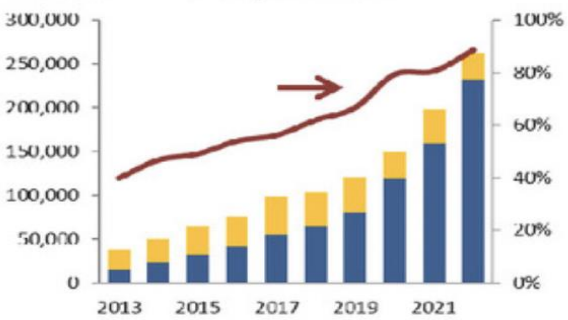
\$4.12/W 2008 Q2



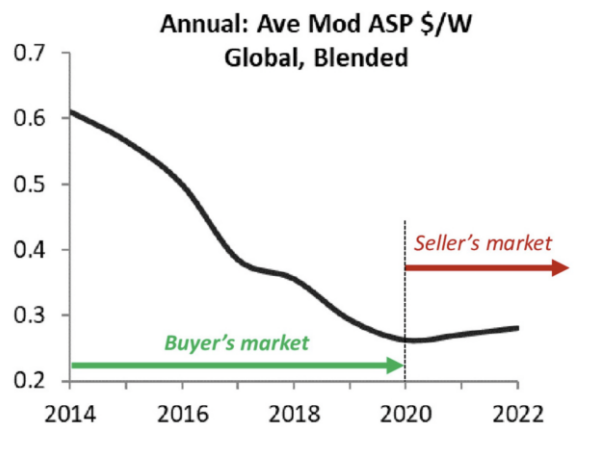
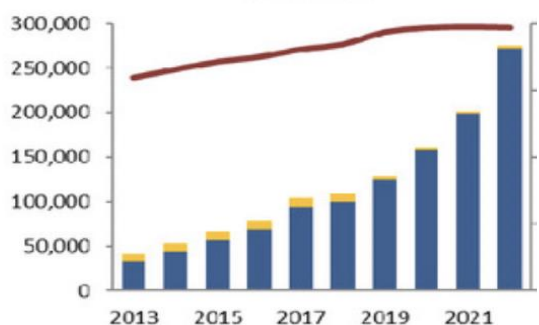
Companies listing 2005-2010 (2021 world rank): *Suntech^f (9th)*, *CSI^a (5th)*, *Trina^c (2nd)*, *Solarfun^c (now Hanwha) (7th)*, *JA Solar^f (3rd)*, *CSUN^f*, *LDK^a*, *Yingli^c*, *Renesolar*, *Jinko^c (4th)*.

Where is everything made in 2022?

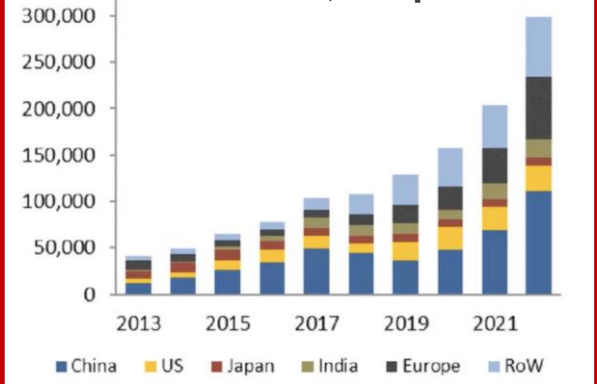
MWp-dc Polysilicon



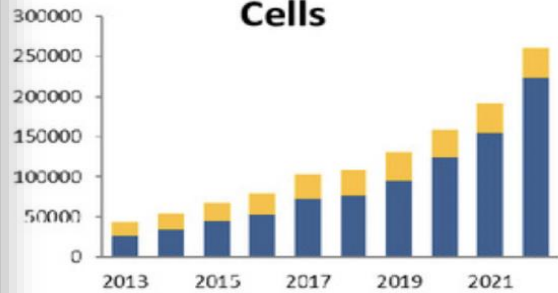
Wafers



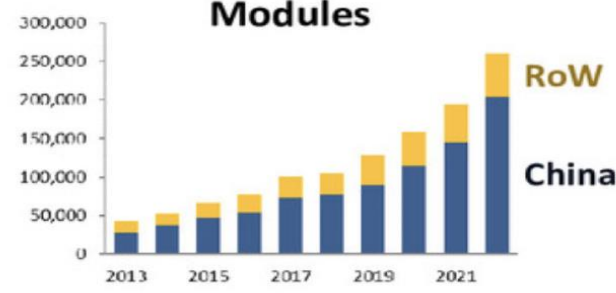
Installation, MWp-dc



Cells



Modules



Thank you!

