Energy Harvesting for Wearables

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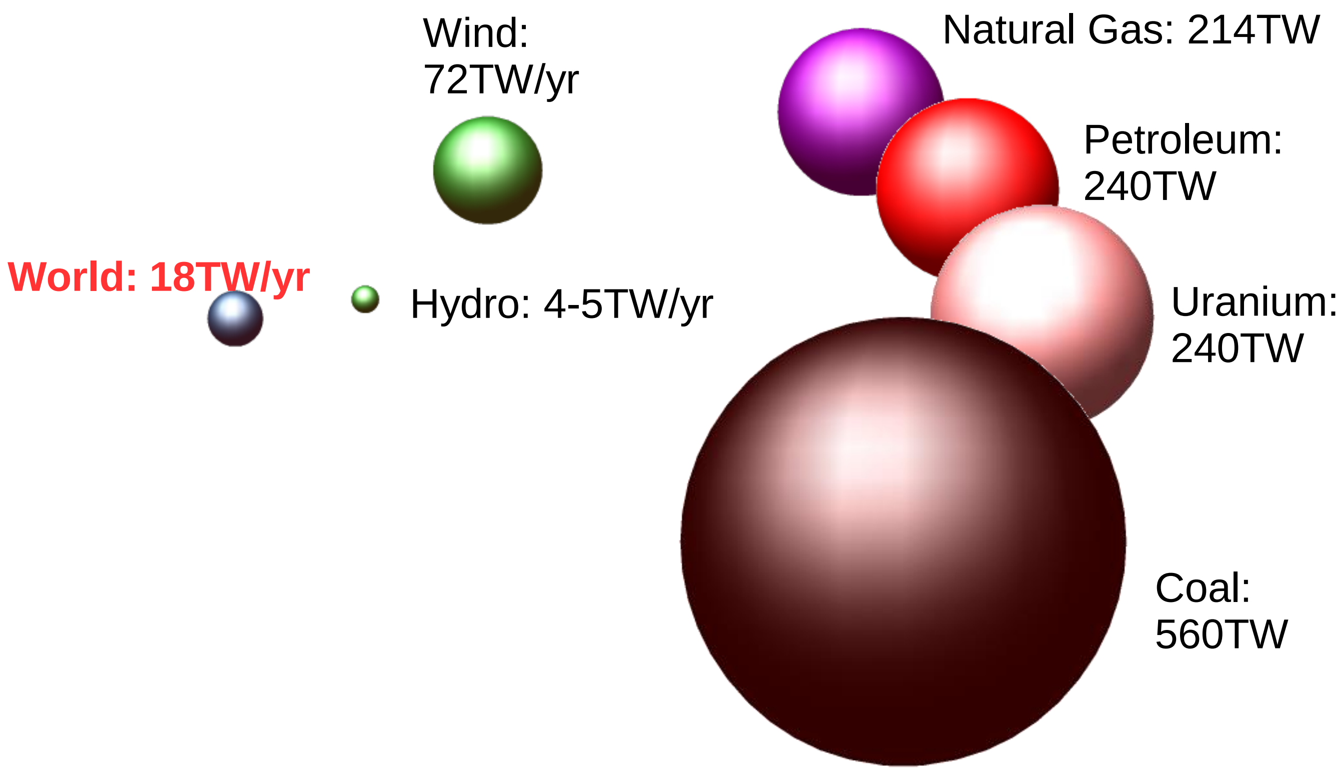
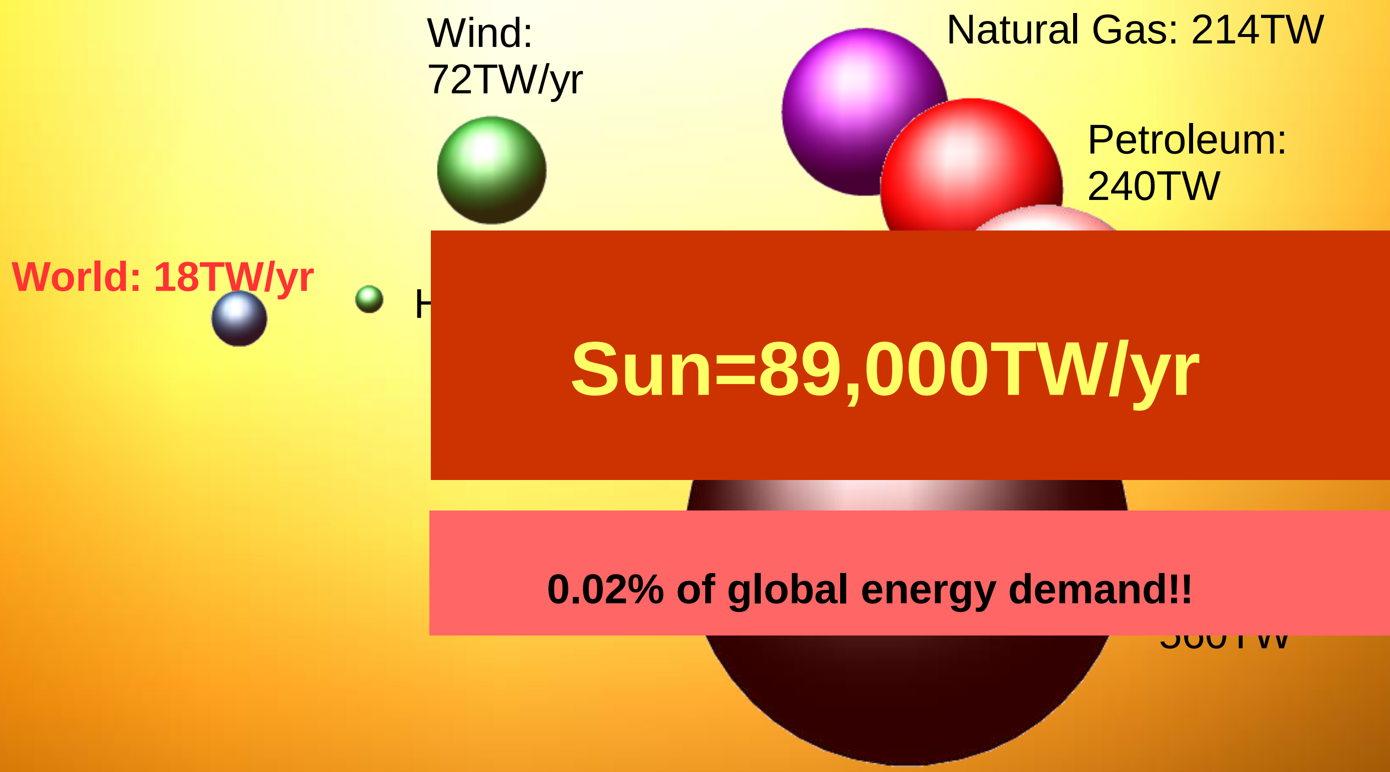
According to Richard Smalley, humanity's top 10 problems for the next 50 years are:

1. *Energy*
2. *Water*
3. *Food*
4. *Environment*
5. *Poverty*
6. *War*
7. *Disease*
8. *Education*
9. *Democracy*
10. *Population*

Energy Resources



Energy Resources



Sun=89,000TW/yr

0.02% of global energy demand!!

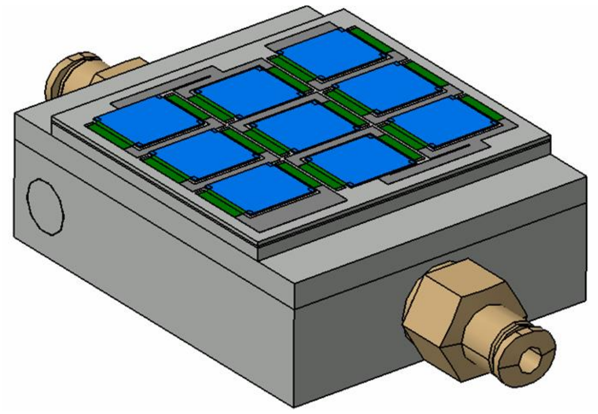
Why Solar?

"More solar energy hits the earth in one hour than all the energy the world consumes in a year"

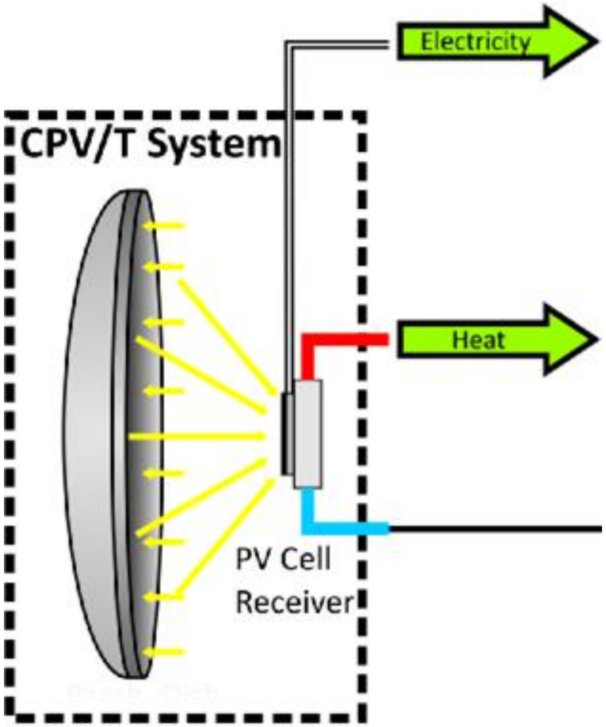
"Just 0.3% of solar energy from the Sahara* Desert *is enough to power the whole of Europe"

Why CPV/T?

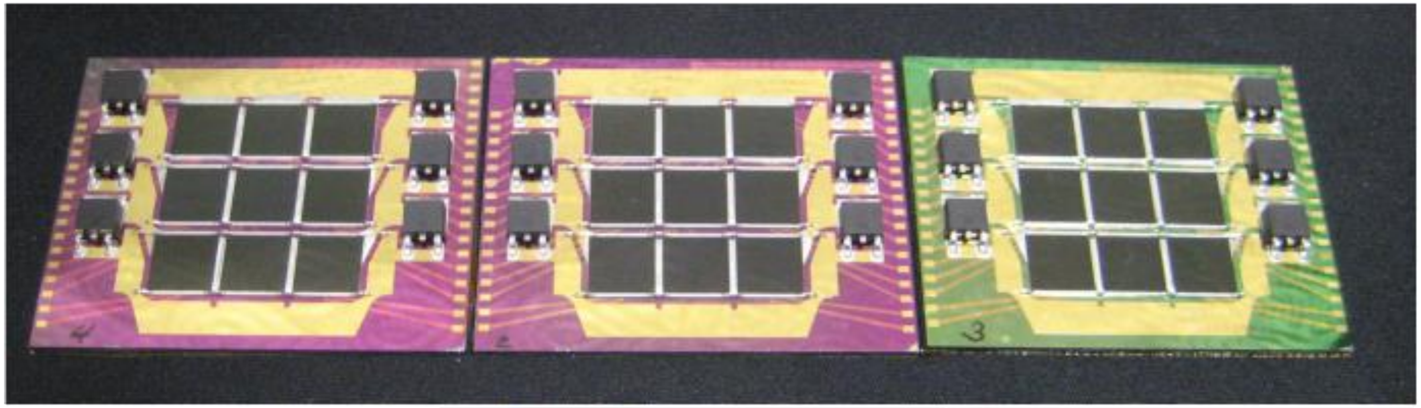
- Among the obstacles to widespread use of solar electricity is the cost.
  - In tackling the cost problem, we can:
    - Use less photovoltaic material
    - Introduce a multi-chip module design
    - Use less expensive optics
    - Use fewer coolers

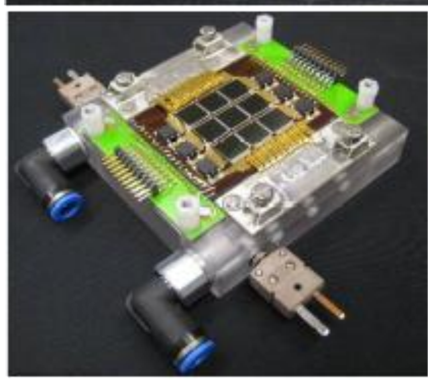


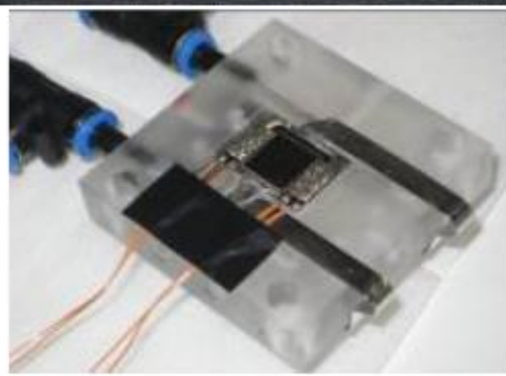
- Make use of excess heat generated from Concentrated PV (CPV) systems to drive an auxiliary system.
    - Overall CPV system acts as a Combined Heat and Power system.
    - Excess heat can be used for water desalination, space heating, cooling, storage, … etc.

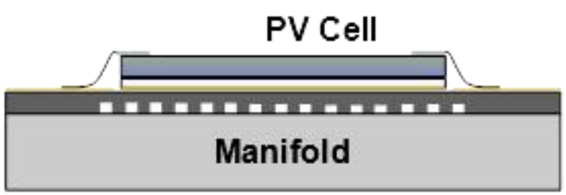


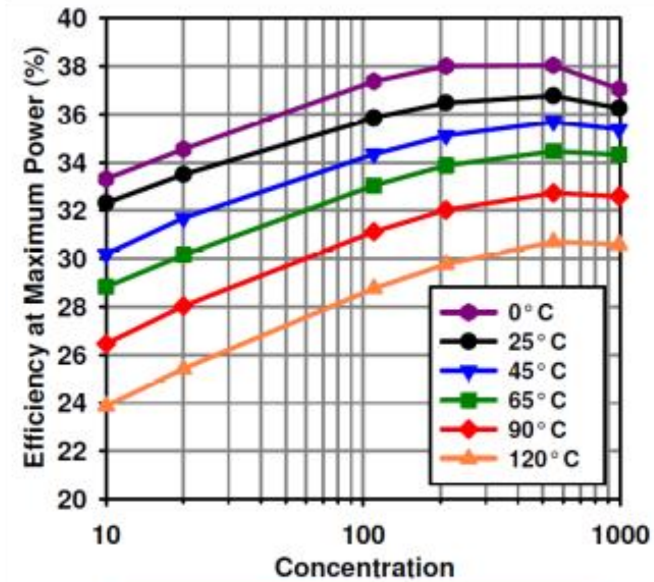
MCM Product





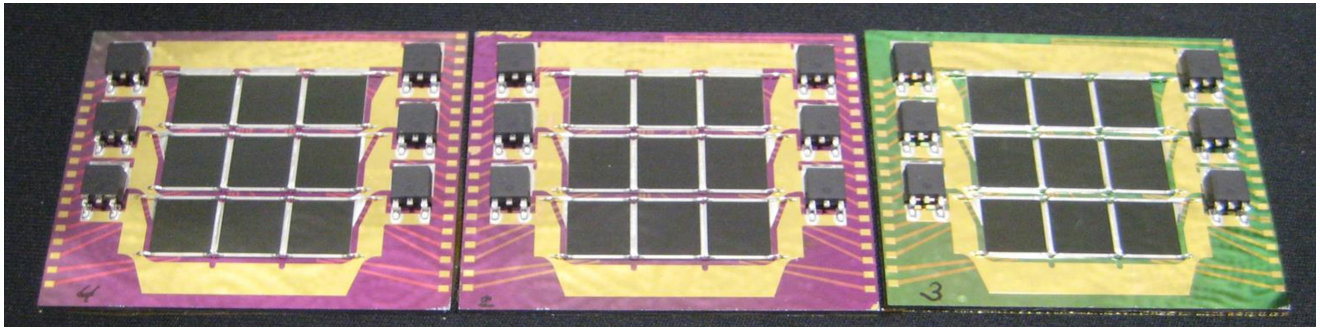


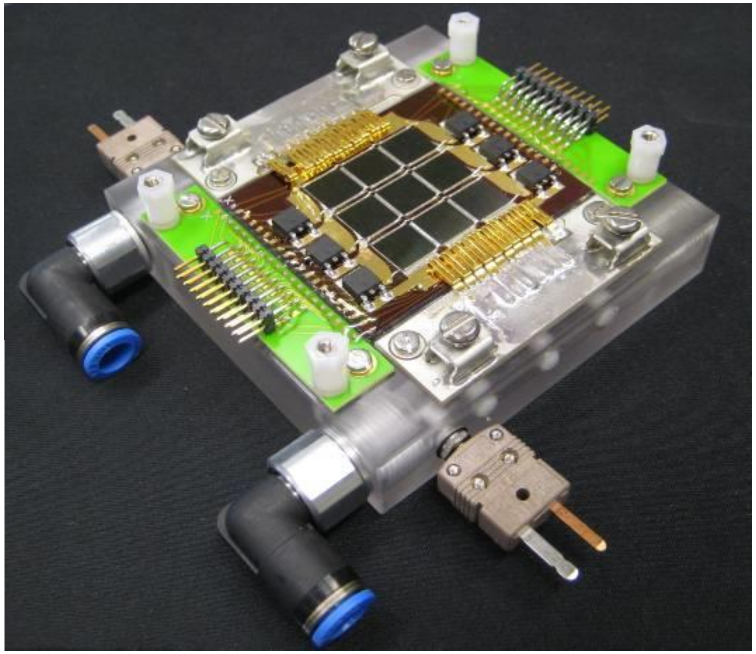

PV Cell
Manifold

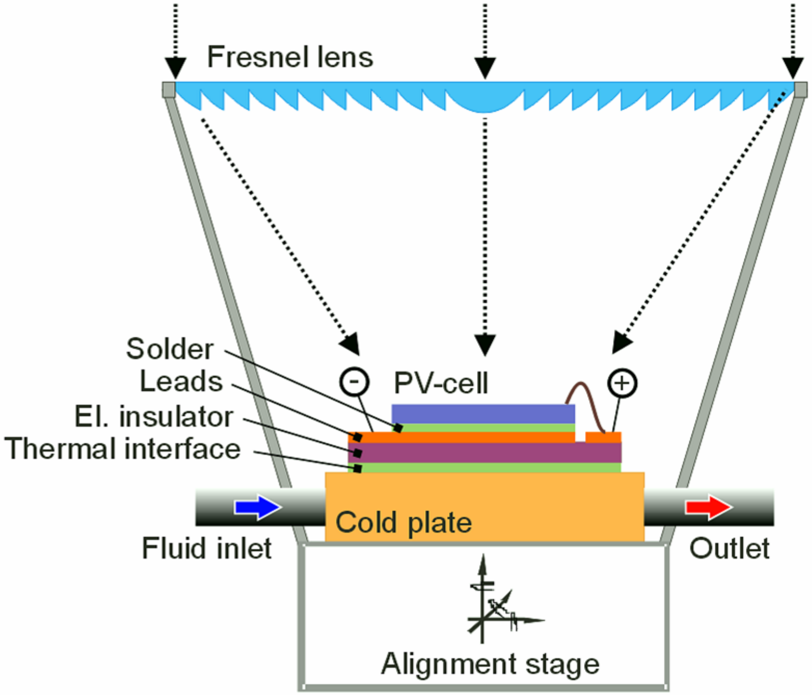

Efficiency at Maximum Power (%)
Concentration
0° C
25° C
45° C
65° C
90° C
120° C

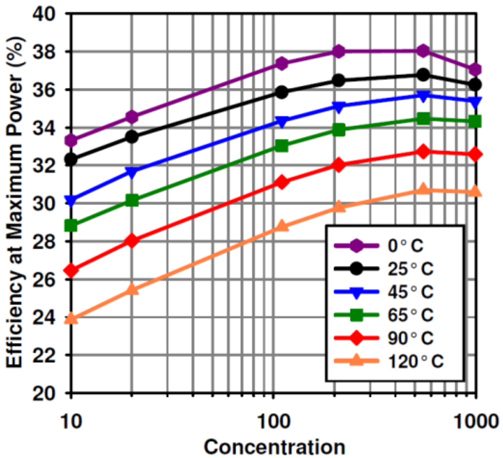
MCM Product

Multichip Module (MCM) with 9 PV Cells









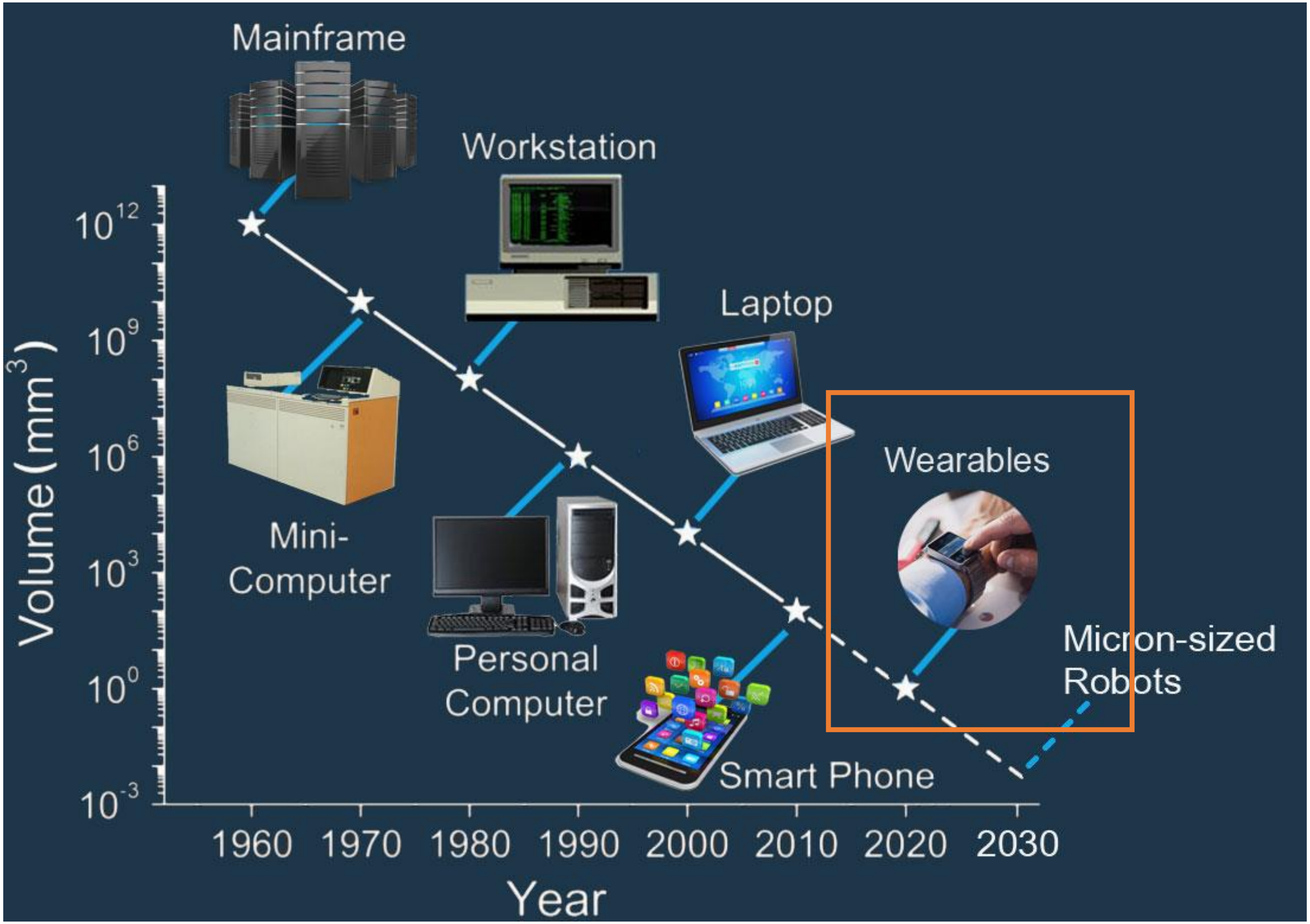
MCM Performance @ different concentrations and temperatures

Assembled Multichip Module (MCM) with 9 PV Cells

Assembled CPV/T System

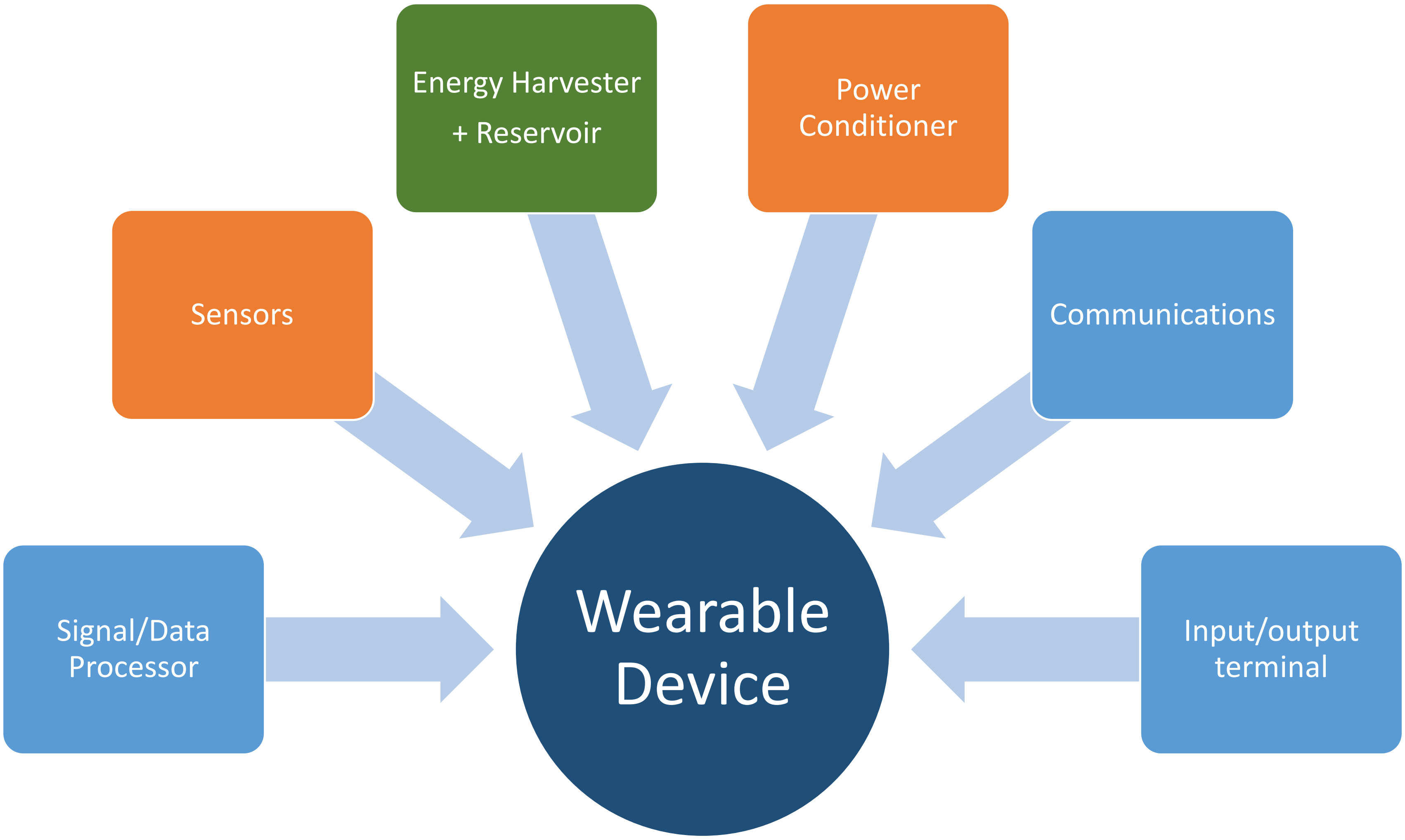
Escher, W., Michel, B., Paredes, S. and Ghannam, R., *Photovoltaic thermal hybrid systems and method of operation thereof*. U.S. Patent 9,437,766.

Trends in Computation



[Image from: https://www.zurich.ibm.com/st/smartsystem/](https://www.zurich.ibm.com/st/smartsystem/)

Wearables - Building Blocks



Energy Harvesting Methods

Energy Source	Type	Harvesting Method	Power Density
Radiant	Solar	Solar Cells	$15000\ \mu W/cm^2$
	RF	EM Conversion (GSM)	$0.1\ \mu W/cm^2$
		EM Conversion (WIFI)	$0.01\ \mu W/cm^2$
Mechanical	Acoustic Noise	Piezoelectric	$0.96\ \mu W/cm^2$
	Motion	Piezoelectric	$330\ \mu W/cm^2$
Thermal	Body Heat	Thermoelectric	$40\ \mu W/cm^2$

Avoiding Batteries

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Health

Button batteries pose 'deadly' risk to toddlers

Fergus Walsh
Medical correspondent

22 September 2016

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00:33:22

See what a battery can do to a child's throat

Top Stories

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The death toll jumps by 133 in one day, as cases increase elsewhere in Europe and in the US.
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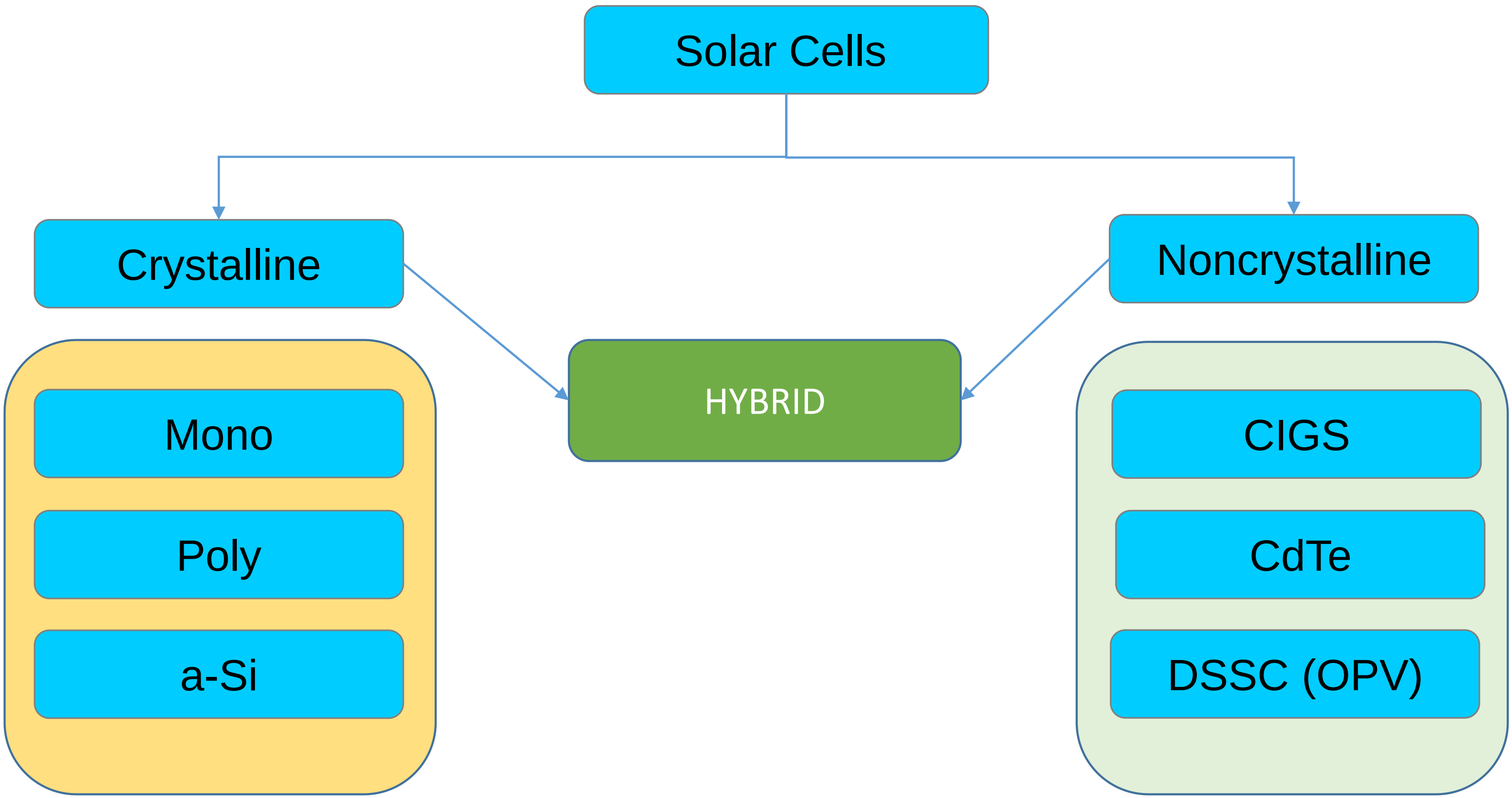
Features

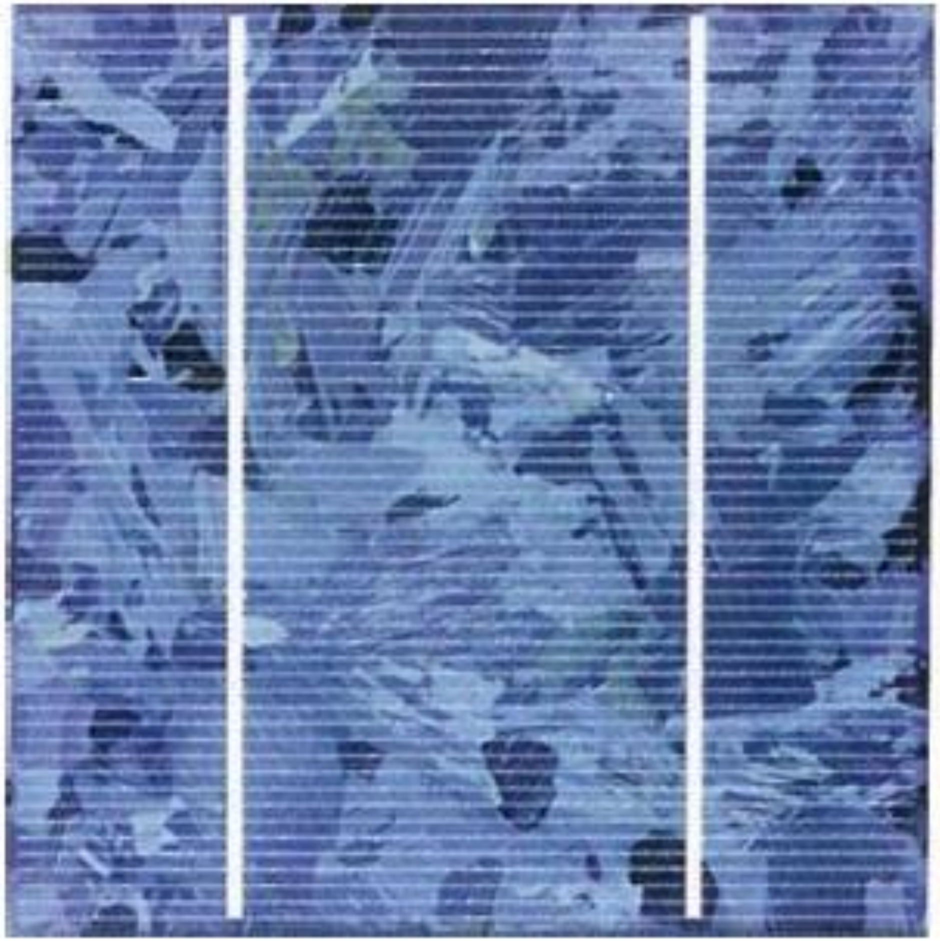
LGBT and homeless: 'I was told to contact my abusive dad'

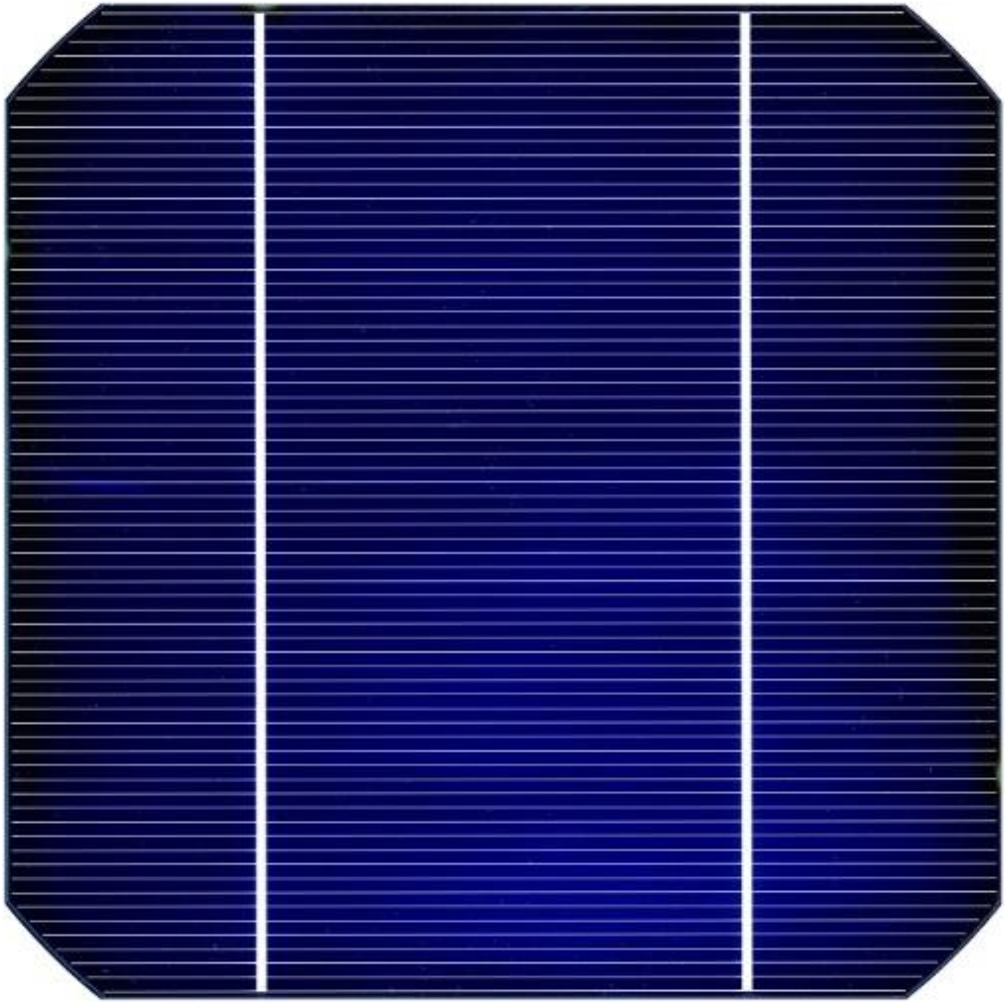
https://www.bbc.co.uk/news/health-37410343

Solar Cell Basics

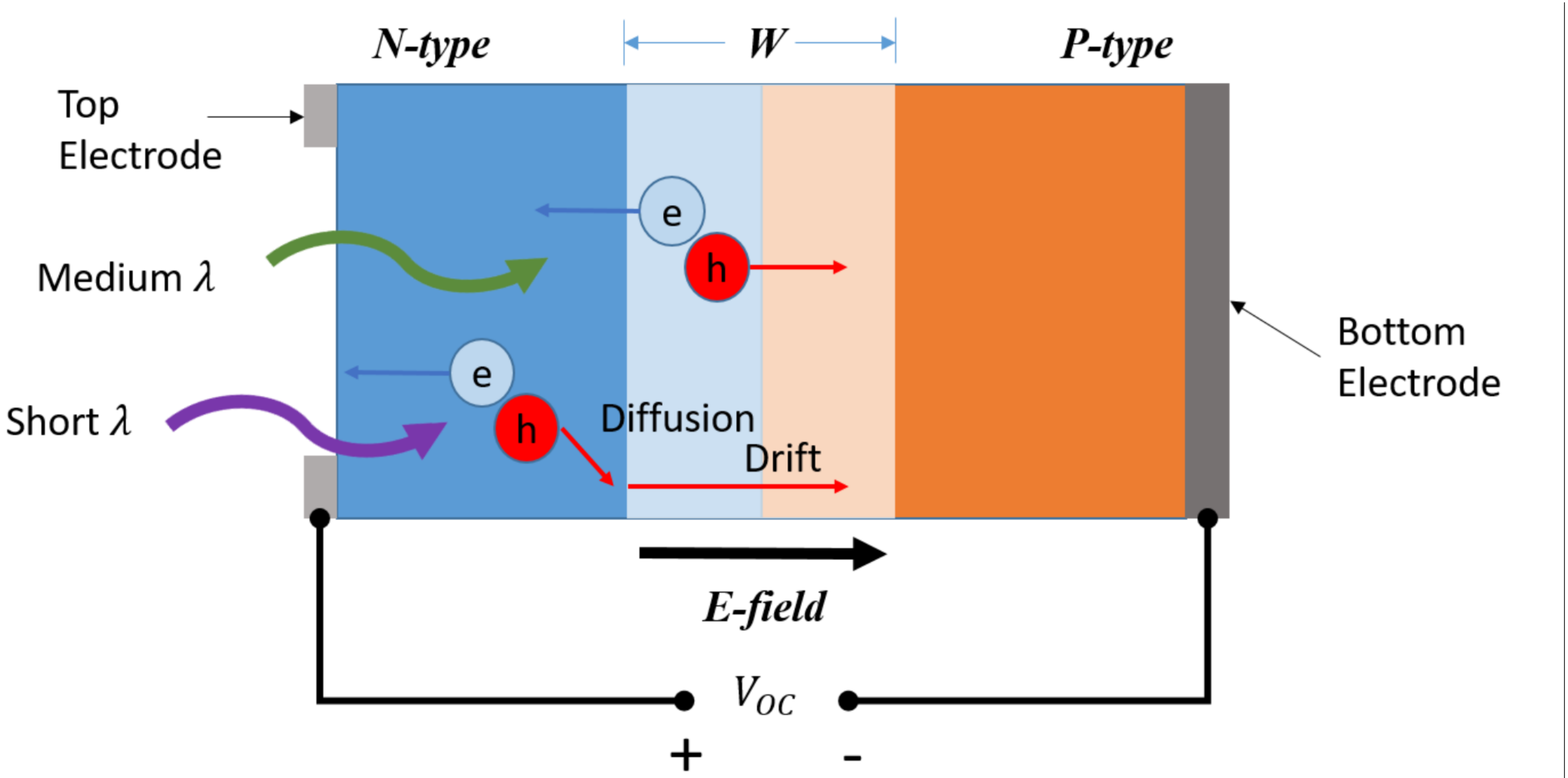


Solar Cells

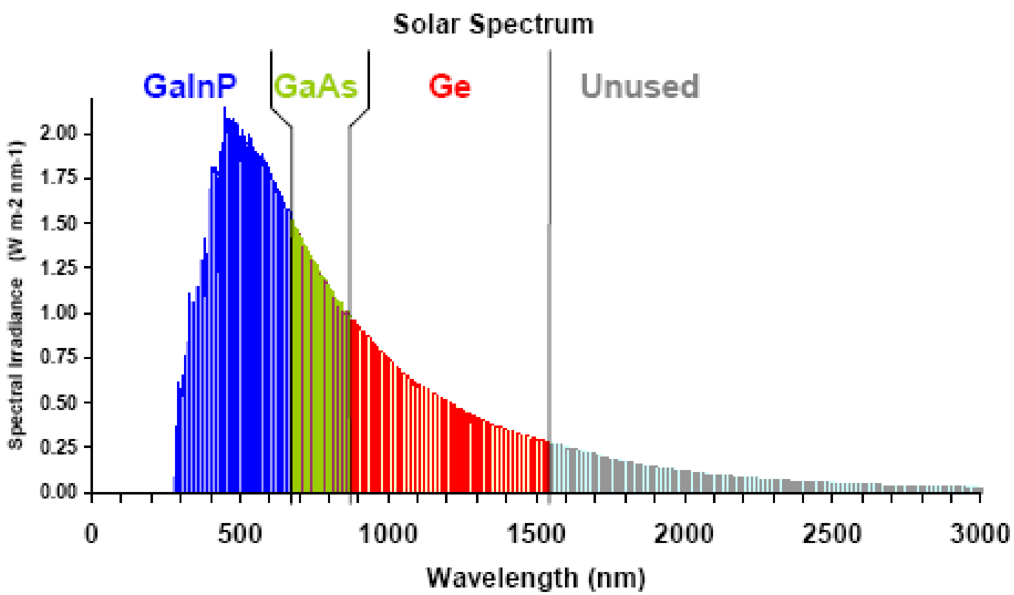




Basic Solar Cell



Engineering Better Solar Cells



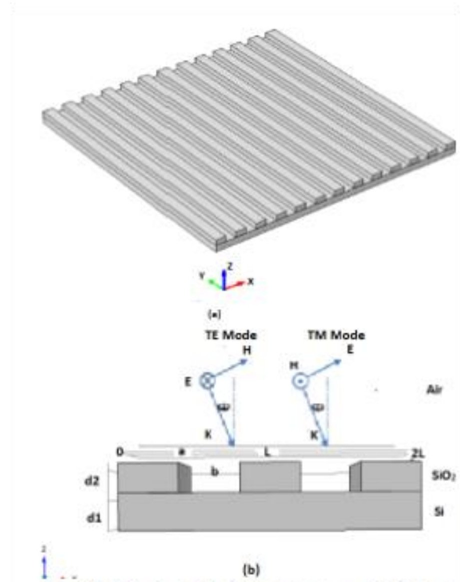
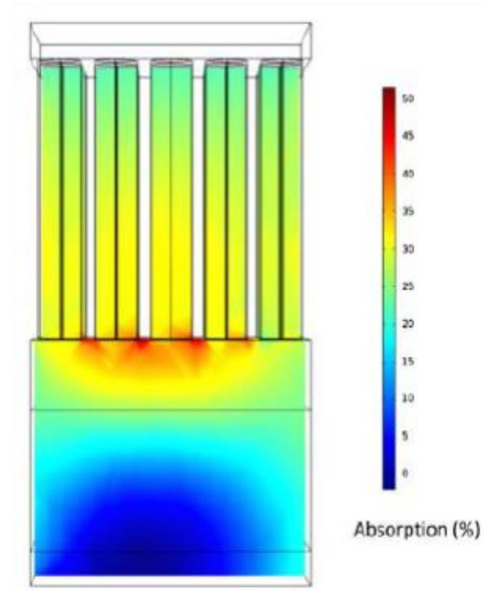
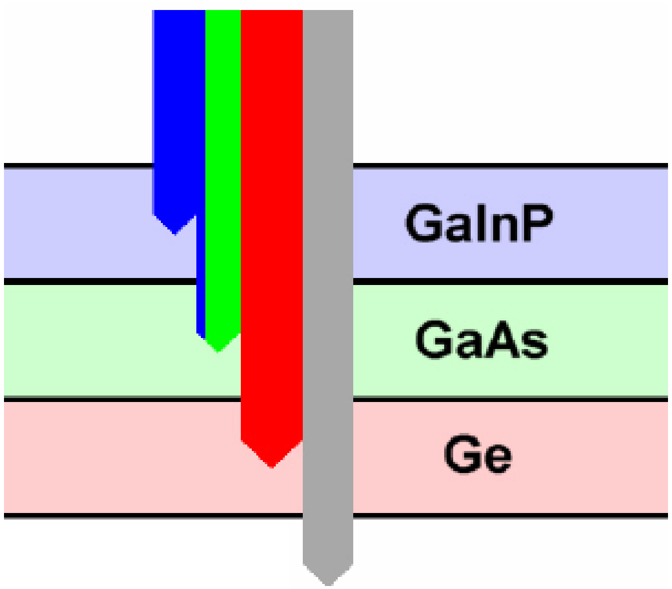
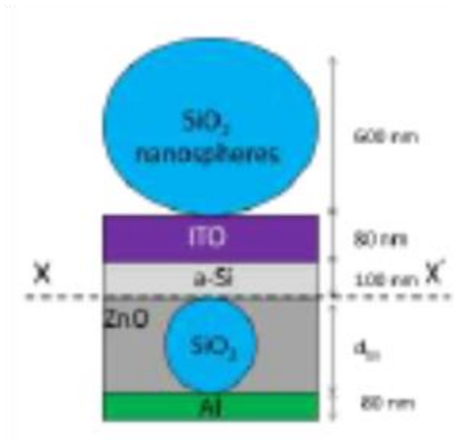
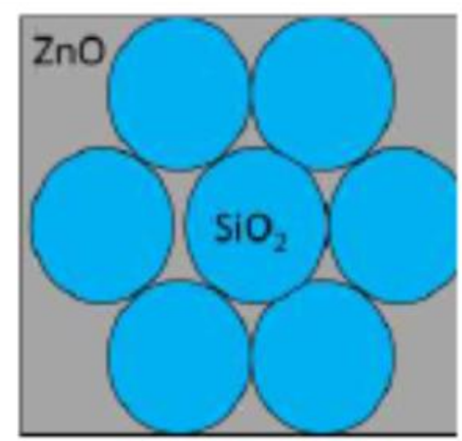


Figure 17. a) 3D schematic for the 1D grating strucures. (b) X-Z cross section for 1D grating structure





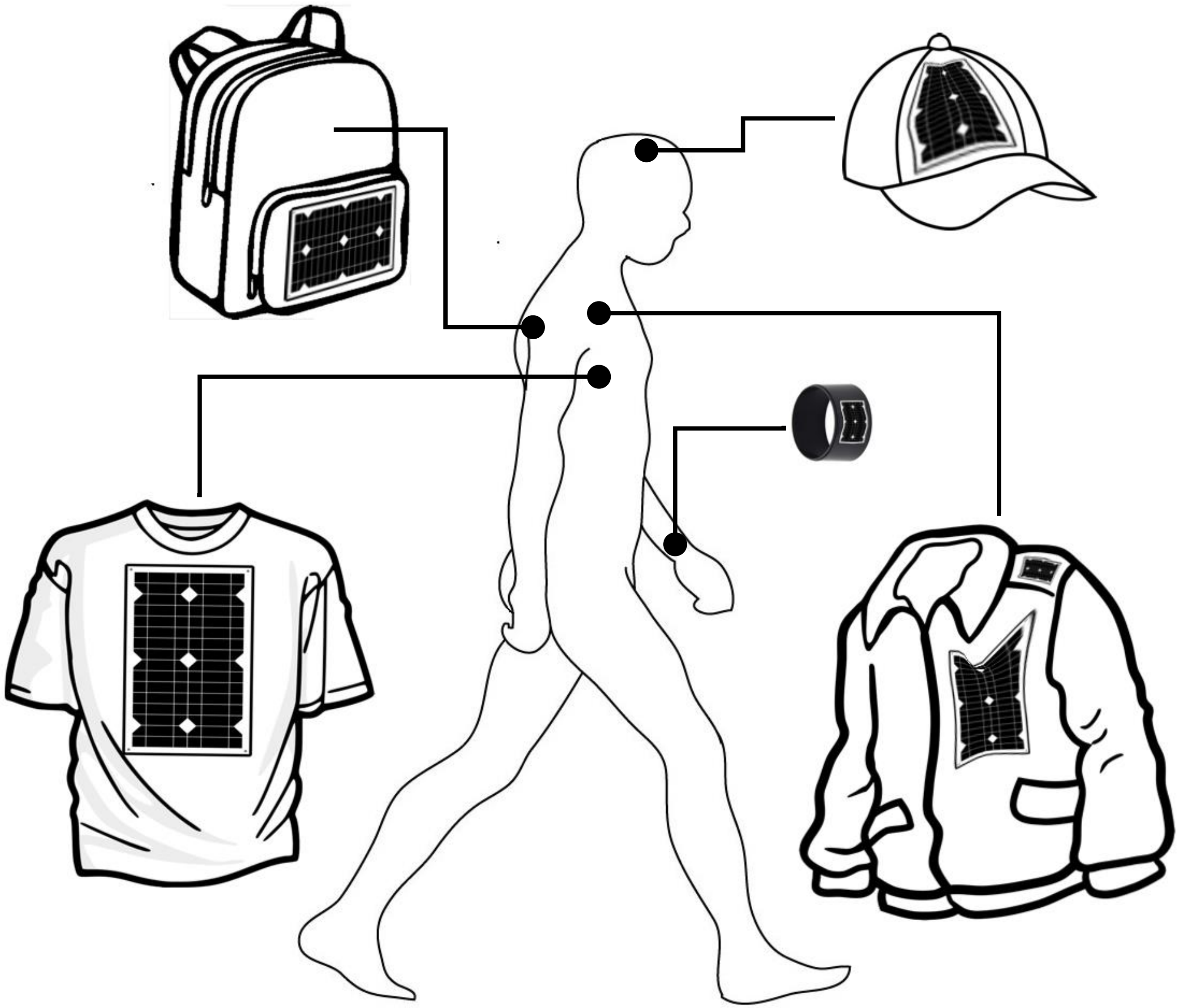




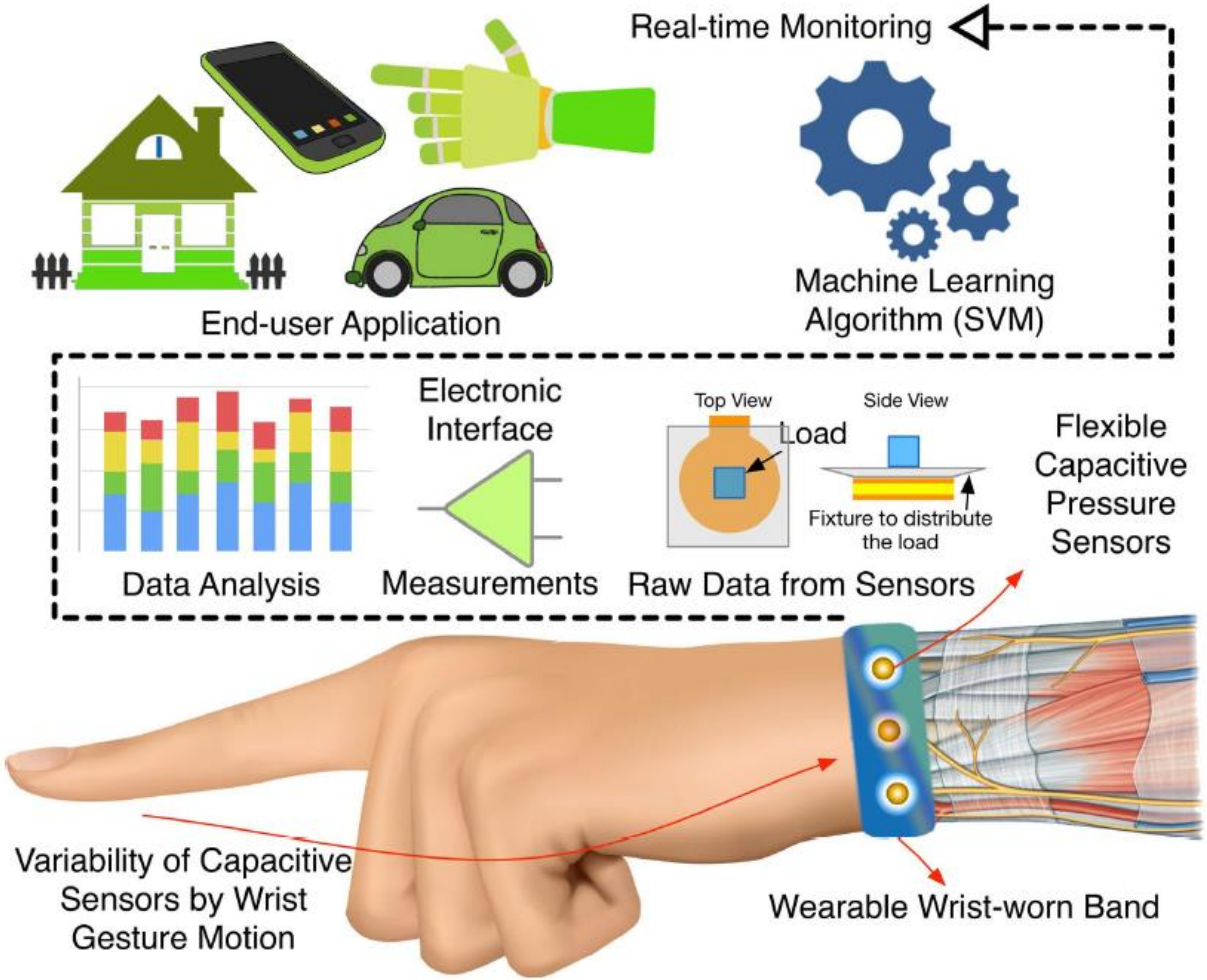
Innovative Solar Cell Products

https://www.youtube.com/watch?v=UYy1GmJgFXA

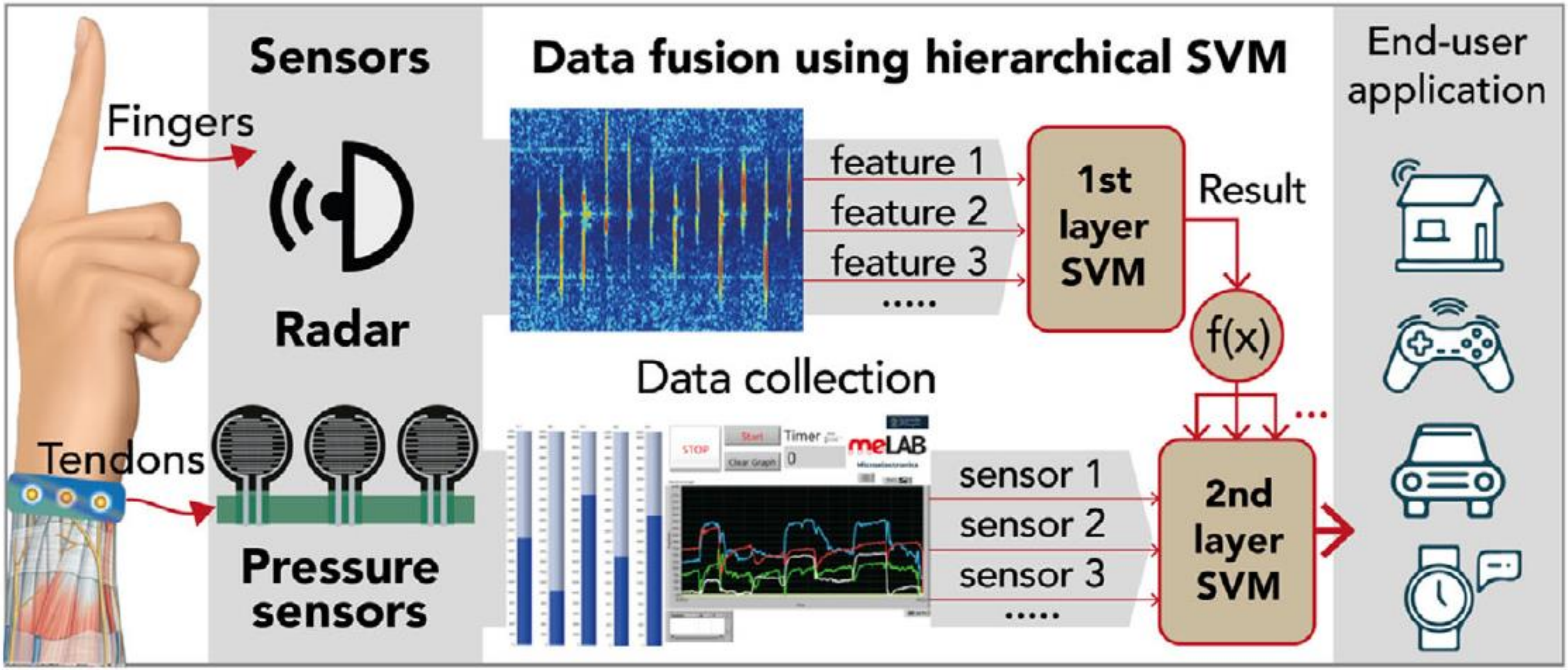
Solar Cells in Wearables



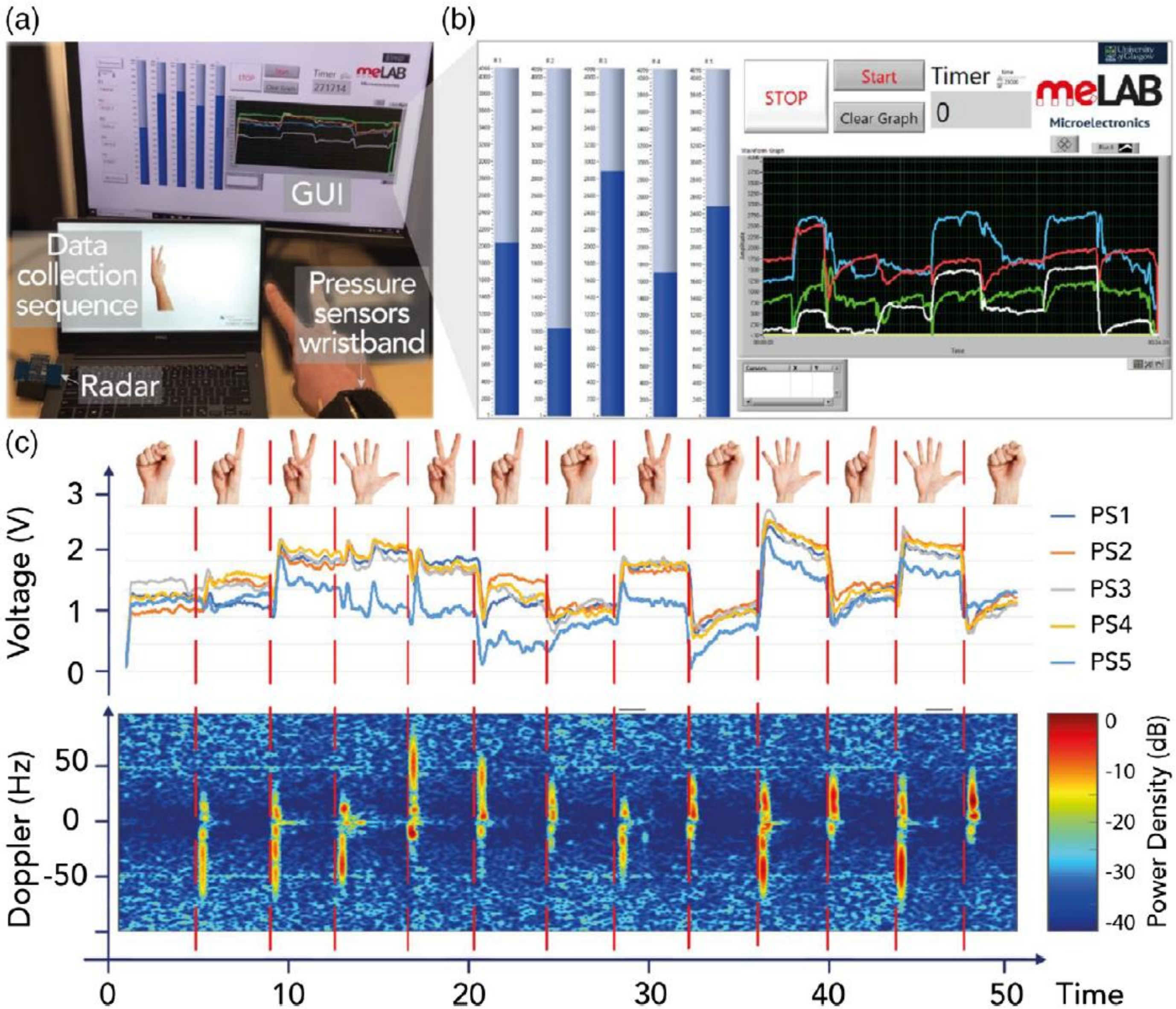
Gesture Recognition Device

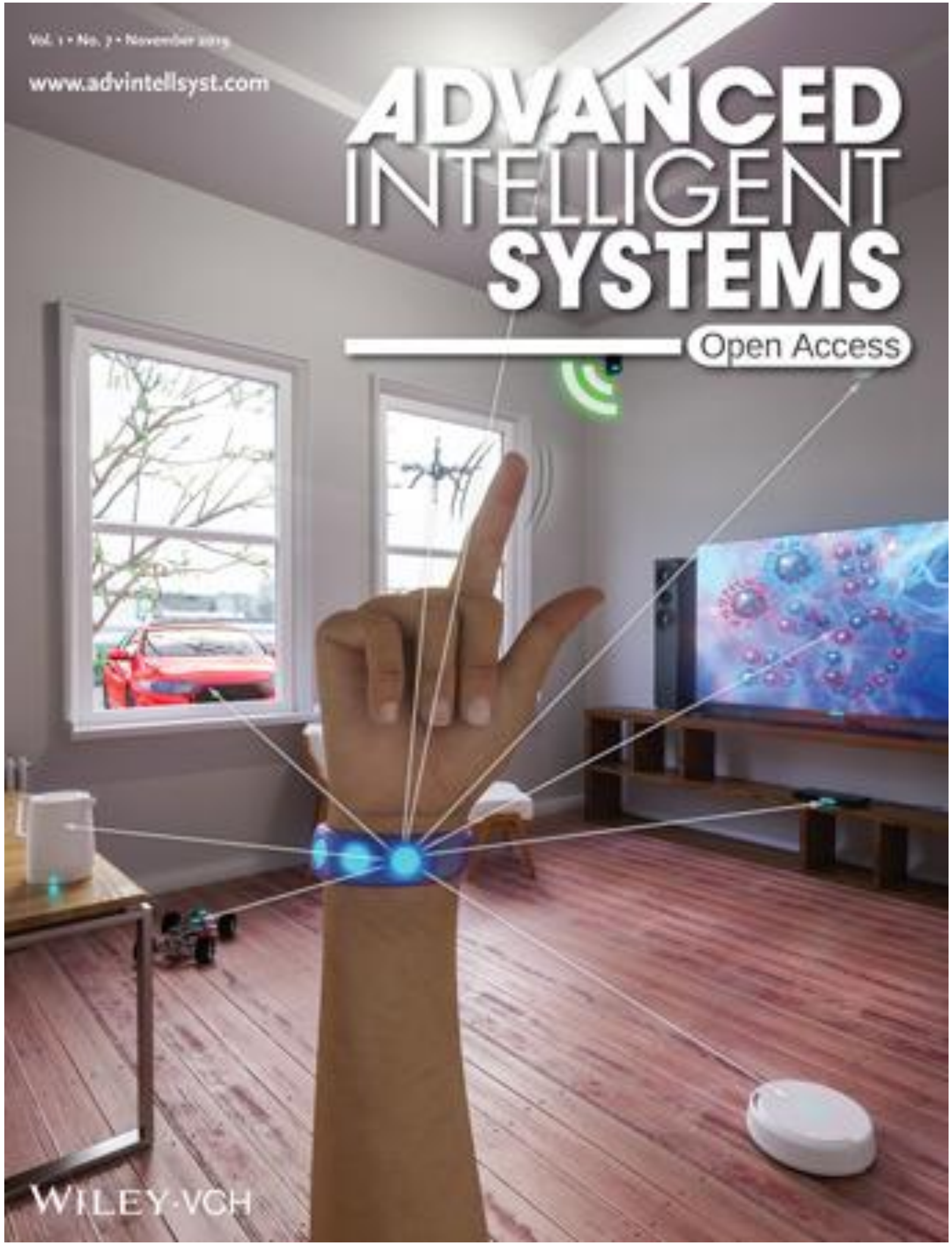


Gesture Recognition Device



Gesture Recognition Device

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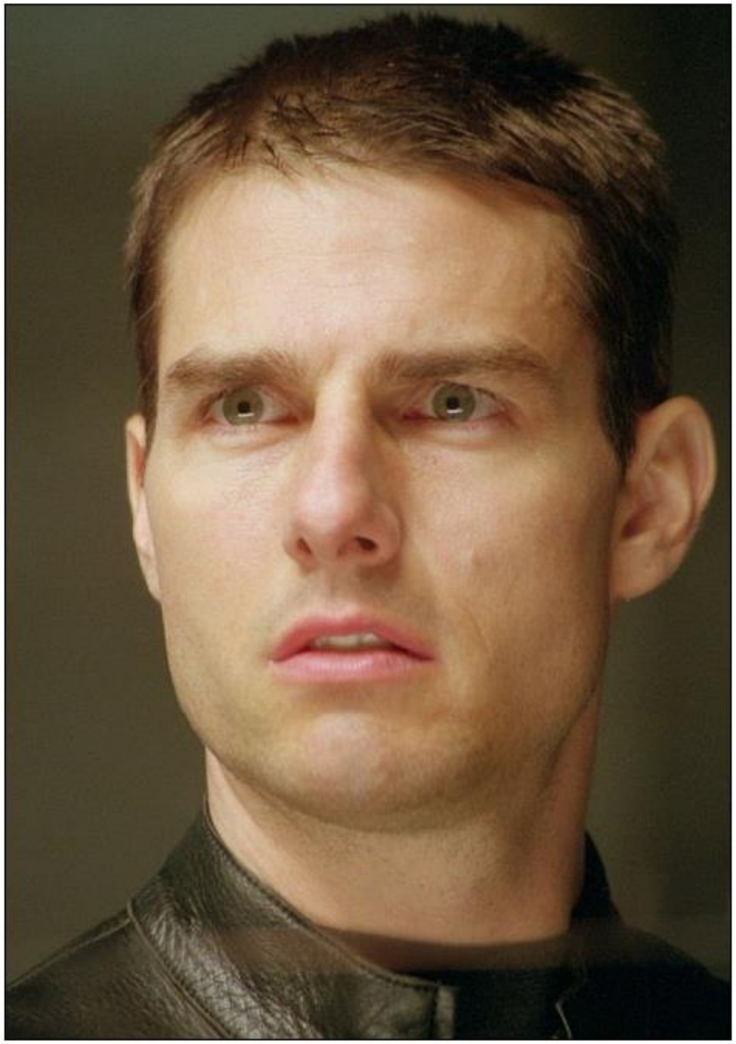
Gesture Device – The Future?

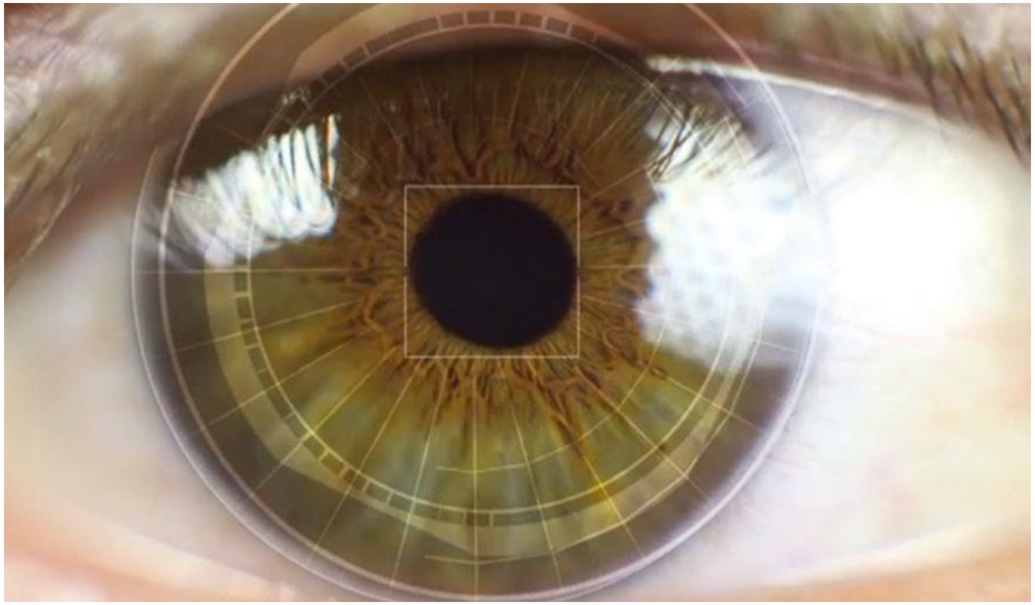
Image of the "Cicret" bracelet concept

Electronic Contact Lenses

© Image from “Black Mirror”

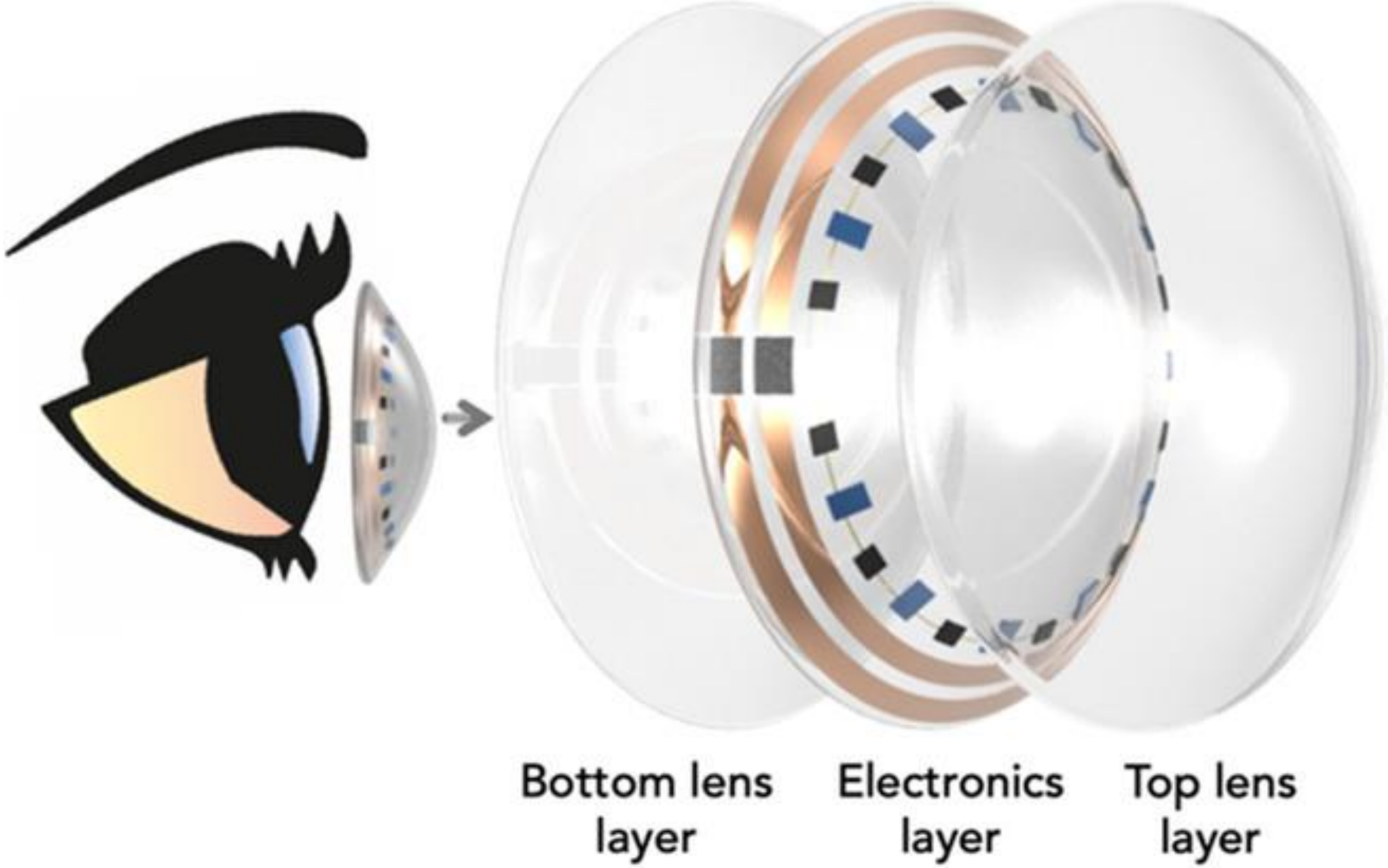


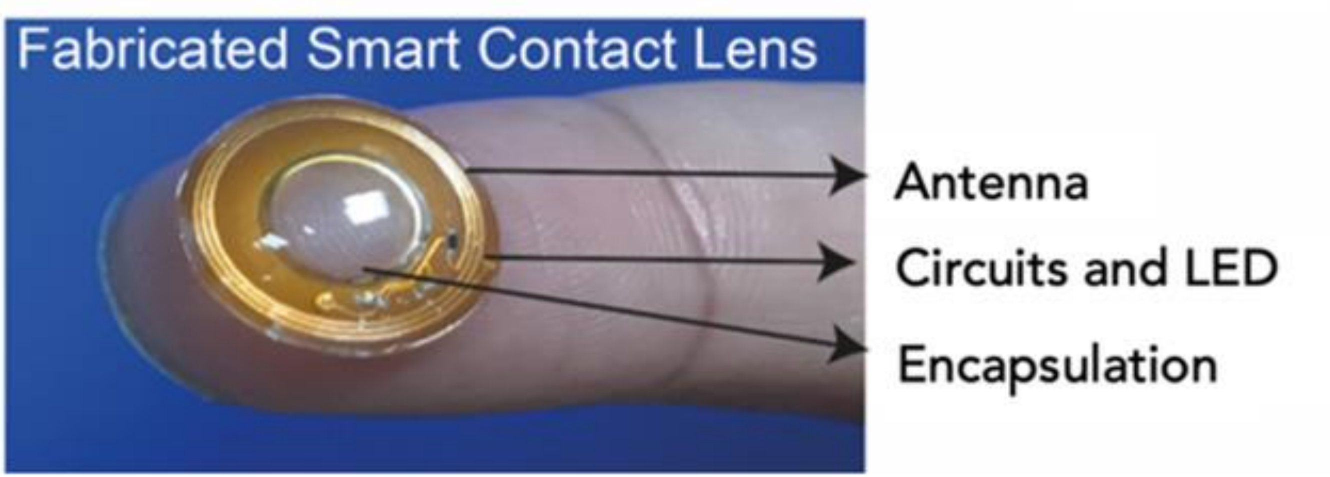
Tom Cruise in Minority Report: Characters in the sci fi film wear lenses which deliver information - and advertising - directly into their eyes



© Images from "Minority Report"

Electronic Contact Lenses





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