TUNING THE SOLAR SPECTRUM: GREEN-TO-BLUE LIGHT UPCONVERSION

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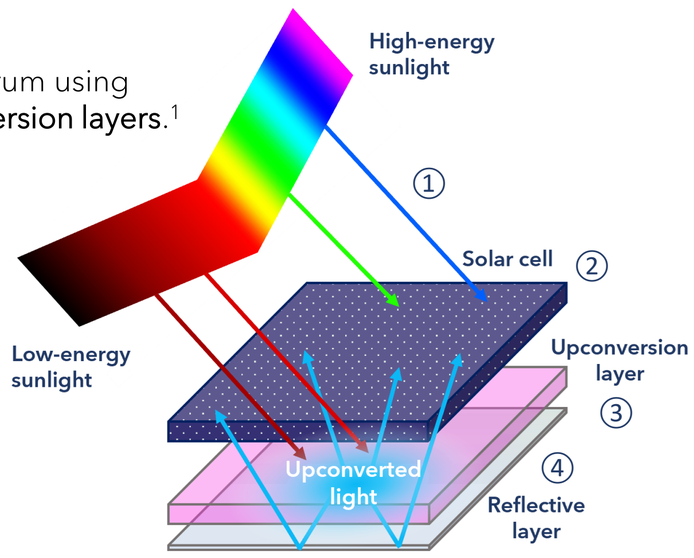
1 Why should we tune the solar spectrum?

Harnessing the sun's energy using **solar cells** will be crucial in providing renewable, clean, and low-cost electricity. Current solar cells have not reached their full potential of efficiency and can only harvest a **small portion** of the sunlight that reaches us.

We are able to tune the solar spectrum using *spectral converters* such as **upconversion layers**.[1]

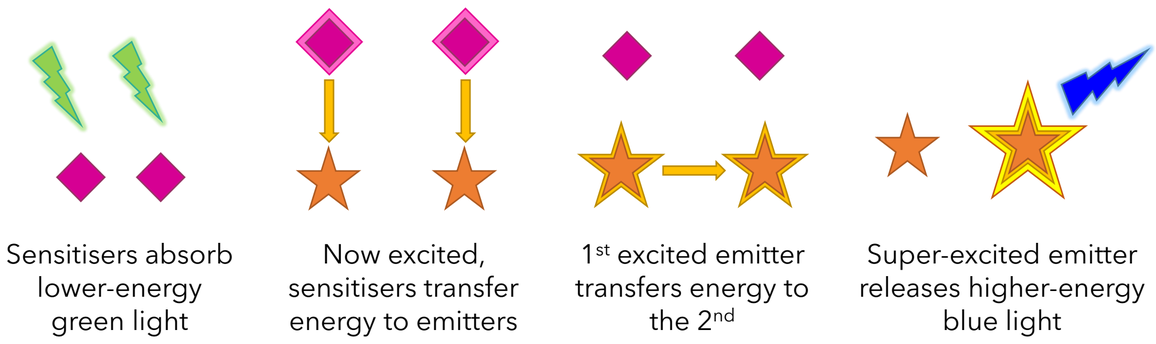
1. Sunlight hits the solar cell.
2. High-energy light gets used while the low-energy light passes through.
3. Low-energy light is upconverted to a higher energy in the UC layer.
4. Upconverted light is reflected back to the solar cell where it is used.



Tuning the spectrum this way can **improve solar cell efficiency by up to 10%.**

2 How does it work?

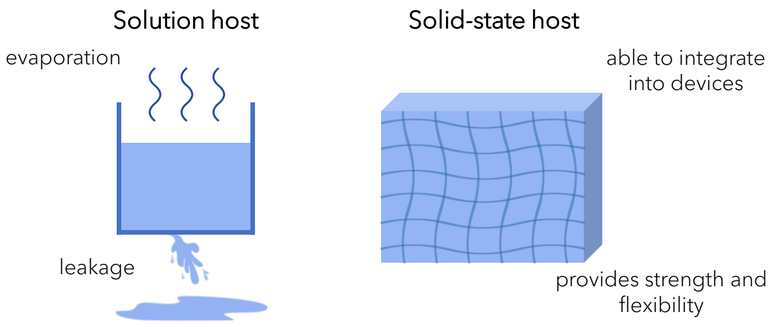
Triplet-triplet annihilation upconversion (TTA-UC) is a process by which **two** lower energy waves of light are converted to **one** high-energy wave of light.[1]



TTA-UC can **overcome the limits of solar technology** and reduce energy waste.[2]

3 Challenge: How can we design this practically?

This process relies on the sensitisers and emitters **physically colliding** with each other.



In solution, things move very fast leading to high TTA-UC activity ... BUT this is **not** practical for solar cells.

Solid-state is practical, but TTA-UC is much less effective due to **slower collisions**. Emitters and sensitizers must be able to move around within the host.[2]

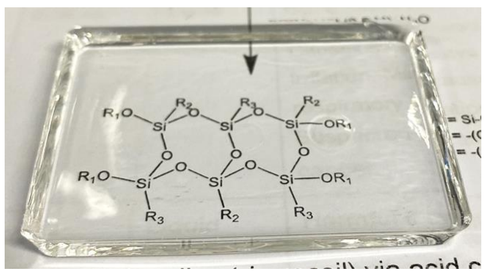
Oxygen from the **air** can stop TTA-UC using a process called *quenching*. The system must be protected from oxygen.

A **solid-state host** is needed for integration into a solar cell, but the design is tricky! Different materials have different benefits.

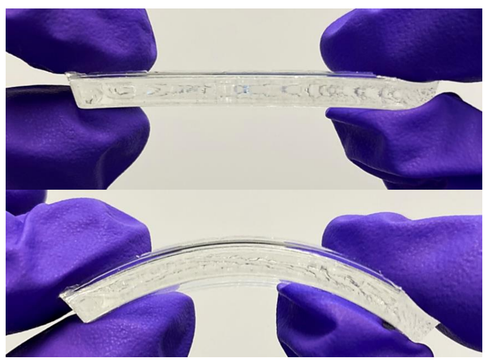
Inorganic glass	Organic polymer
✓ Transparent	✓ Aids faster collisions
✓ Strong	✓ Flexible
✓ Protects from oxygen	✓ Dissolves molecules
	✓ Made into any shape

Organic-inorganic hybrid polymers called **ureasils** get the '*best of both worlds*' and contain all of these benefits![3]

Inorganic glass and organic polymer combine to a form a **'bendy glass'** cross-linked material.



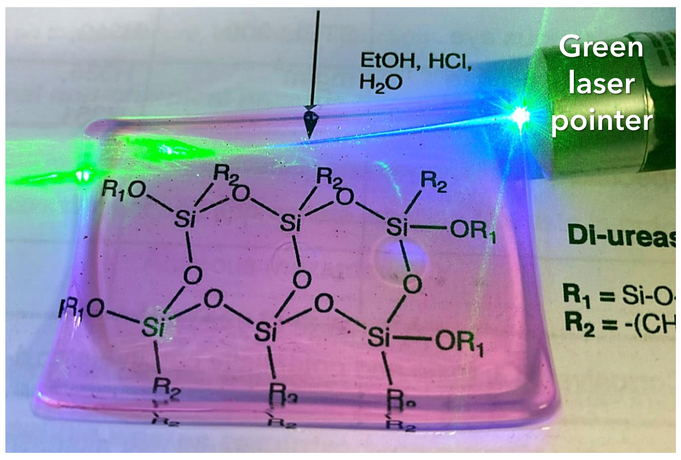
✓ Transparent

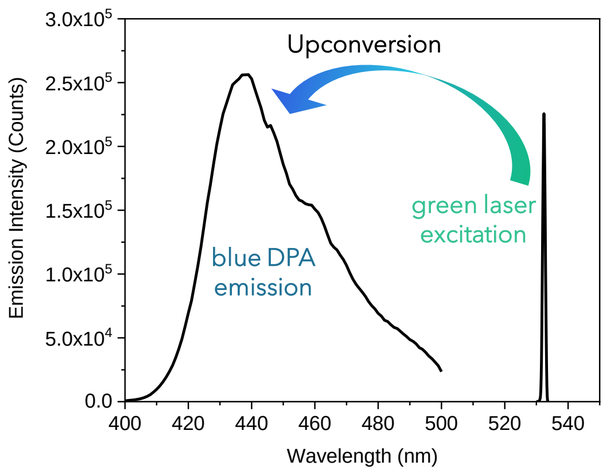


✓ Flexible

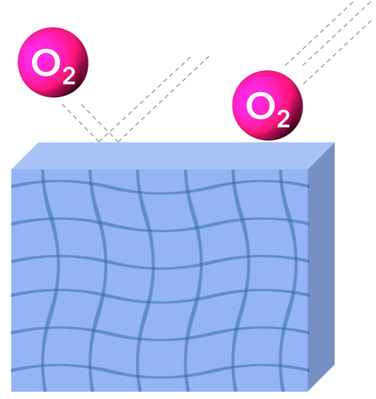
4 Results: How effective is this process?

Our results using the ureasil host system demonstrate high upconversion efficiencies of **up to 18%** (capped at 50% by the process), even in the **presence of air**. This is one of the highest TTA-UC efficiencies seen in solid-state without the removal of oxygen from the system.





- Silica in the ureasil host protects the system from oxygen, but O_2 does enter over time which leads to a decrease in TTA-UC activity.
- Reducing these effects will be key for long-term use.



- These results will inform the design of next generation organic-inorganic UC hosts, with the goal of further enhancing the efficiency and long-term stability and working **towards future commercialisation**. UC layers can be added to existing solar cells as a 'booster' without the need to replace the cells.
- Further investment and research into spectral converters is essential **to maximise solar energy capture** and will provide the planet with the tools it needs to deal with the current climate crisis.

5 Acknowledgements and References

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1. *J. Mater. Chem.*, 2012, **22**, 20817.
2. *Macromolecules*, 2021, **54**, 5287–5303.
3. *SPIE*, 2020, vol. 11367, p. 32.