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Top 5 Solar Energy Advances Using Perovskites

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For years, special kinds of semiconductors called perovskites have promised revolutionary improvements compared to traditional silicon solar cells. Perovskites could hold the key to higher efficiency at lower costs. In some cases perovskites have been shown to offer a 250% performance boost. But scientists have been working on this tech since the 1990s. What do we have to show for it today? This feels like yet another piece of over-hyped, planet-saving tech, perpetually 10 years away from adoption, right? Maybe not … they might finally be on the market before the end of this year. Let's look at 5 perovskite solar panel advances since the last time we talked about it.

Perovskites are yet another example of old technology that's just starting to get some traction in the world of renewables. How old? Well, it was first discovered all the way back in 1839 and is a family of materials with the same crystal structure as calcium titanium oxide ($CaTiO_3$). However, it wasn't until the 1950's that they saw use in fuel cells, superconductors, and other applications. Even then it would take another half-century before they were first used as the optical absorption layer in solar cells.

So why are so many people hyped about using perovskites in solar cells? I won't go into all the details, but I've covered a lot of the specifics in another video. But in a nutshell, as abundant as silicon is there's a theoretical limit to the efficiency we can achieve. It's referred to as the Shockley–Queisser limit, but perovskites can go a bit beyond that limit … and they promise to be dramatically cheaper and easier to manufacture.

If perovskites are so cheap and efficient, why aren't they everywhere? Well, the first issue is lifespan. Currently perovskites just can't stand up to the 25 year warranty of silicon cells. Oxygen, moisture, and heat can all reduce perovskite's generational output and lifespan, and unfortunately, a solar panel sitting outside all day is going to face a lot of oxygen, moisture and heat. And this can happen quickly, with some perovskite cells reduced to just 80% capacity in 2 years or less. A far cry from silicon's 25 years and beyond. To prevent this, a capping layer of lead is usually applied to the cell, but lead is of course heavy and toxic. And as these shorter-lived cells age, breakdown or get discarded that lead can escape and harm the local environment.

So, has anyone addressed these challenges? Has there been any meaningful progress or new innovations that bring perovskites closer to reality and retail? In a word: yes. Let's look at 5 advances.

First up, a study led by Chunlei Guo, a professor of optics at the University of Rochester (my home town), suggests perovskites have the potential to become radically more efficient. Over the course of their research, Guo and his team found a way to massively boost perovskite's carrier diffusion length. By replacing the glass surface you'd usually find in perovskite cells with a metal or a metamaterial composed of alternating layers of silver and aluminum oxide, the researchers created a sort of electron-mirror. This mirroring effect ended up increasing performance by 250%.

Before we get too hyped up, let's clarify that this isn't a direct 250% jump. Broadly speaking, solar panel efficiency usually refers to Power Conversion Efficiency (PCE), which is the percentage of solar energy shining on a PV device that's converted into usable electricity. In this case, we're talking about how long the electrons essentially bounce around inside the cell before they dissipate … or the carrier diffusion length. That's where the 250% jump is happening.

If that's a little confusing, consider the off-shore turbines we explored in a recent video. Just because we double the wind turbine's radius doesn't mean we get a straightforward three, four, or five times power increase. There's a lot of changes to internal components beyond the blade size that impact the final output result. It's the same with these cells. Just because we vastly increase the photosensitivity, doesn't mean that we vastly increase the final power output.

However, this is still a noteworthy development because it opens the door to far more advanced perovskite cells down the line. Here's why. Typical solar panels are essentially two oppositely charged semiconductors stuck together, forming a neutral zone. Ideally, incoming photons of sunlight knock electrons out of the neutral zone, and then the solar panels' electrodes capture that as usable electricity. Grossly oversimplified, but in a nutshell that's what's happening. The problem is that these recently freed electrons often recombine with their polar opposite or their respective semiconductor layers before the electrodes can capture them, which seriously hampers their ability to actually make electricity.

But when Guo and his team added a metal substrate below the perovskite layer, they found that the free-ish flowing electrons within the metal layer moved to mirror the recently freed electrons in the perovskite. This ultimately kept electrons free longer, which meant more opportunities for their charge to be collected. Theoretically, this should allow the cell to generate more energy with the same sunlight and ultimately to be more efficient. It's especially cool because other methods for achieving similar results require complex chemical engineering. Instead, this approach involves a simple, stable piece of metal.

While we're on stability, let's look at the second advance from researchers at North Carolina State University. They've discovered a very Star Trek-sounding way to enhance the perovskites' durability. Remember that perovskites are multi-crystalline materials. That means that when you're "growing" a perovskite, the material forms as a series of crystals or "grains." These grains are responsible for absorbing light and generating the charges that become an electrical current.

Normally, ions find their own path through the perovskite grain, causing tiny chemical reactions and molecular changes that shorten a cell's lifespan. However, the NCSU group found that by channeling the ions into defined routes between crystals, which they call grain boundaries, they formed a sort of ionic desire path. Told you it sounded Star Trek-y! By moving through these designated lanes instead of bouncing around, the ions cause less harm to the cell, leading to more stability and longer lifespans.

The third up is Luyao Zheng and his team out of Penn State, who've found a way to quickly and easily manufacture high-grade perovskites. The typical fabrication process for perovskites involves wet chemistry: the materials are liquefied in a solvent solution and then solidified into thin films. While very efficient for smaller applications, the process is slow and expensive, so it just doesn't scale up well. The solvents in the manufacturing process might also be toxic. So…not ideal. To get around these hurdles, the Penn State team created halide perovskites using a method called spark plasma sintering, or the Electrical and Mechanical Field-Assisted Sintering Technique (EM-FAST). Put simply, this technique involves applying an electric current and pressure to powders, causing a reaction that welds the powder into a new solid material.13

You know the so-called unbreakable iron triangle? “Cheap, fast, or good — you can only pick two?” Well, EM-FAST may have just broken it. One of the benefits of the EM-FAST process is that it has a 100% yield, i.e. all the powder you put down will be transformed into perovskites. Compare this to the 20-30% yields of more common “solution-based processing” and we’re already off to a cost-efficient start. The process is also able to create 0.2 inches of perovskite per minute. That might not sound like a lot, but what would have taken days or weeks can now be done in mere minutes! 13 EM-FAST? More like EM-SUPER-FAST. And this technique doesn’t seem to sacrifice quality either. As Zheng says: “Their properties can compete with single-crystal perovskites.” 13

There’s other benefits too. EM-FAST doesn’t use solvents, so there’s no need to worry about toxic materials. Plus, the sintering process can be performed in a way that’s similar to 3D printing, allowing for layered perovskites tailored to a wide array of jobs. This includes not just better solar panels, but also enhanced X- and γ-ray detectors.13 And even more innovative developments from EM-FAST could be right around the corner.

Speaking of environmentally friendly materials, for number four we have another exciting breakthrough from February. Like we mentioned earlier, perovskite cells unfortunately necessitate a capping layer made of toxic lead. But in seeking to make perovskite solar cells more eco-friendly, Professor Sum Tze Chien and his team from Nanyang Technological University (NTU) may have also found a way to make them more efficient, stable, and market-ready.

After a lot of testing, the NTU scientists used a “full precursor solution” (or FPS) method to coat perovskites with solutions containing metal halide salts and phenethylammonium iodide (PEAI). Among the caps made with this method, they found the most effective was a non-toxic, zinc-based compound called PEA2 ZnX4 (sorry to any sleeper agents I just activated). Able to convert 24.1% of the light captured to electricity, it comes close to the highest efficiency achieved so far by perovskite solar cells.16 As for the lifespan, the FPS-coated cells were able to maintain more than 90% of their ability to convert light into electricity for more than 1,000 hours of operation.15 For context, perovskite cells without this coating typically drop to around 50% power-conversion efficiency at just 300 hours.

That said, there just hasn’t been enough tests or even solid, agreed upon standards to really compare perovskites here. Let alone perovskites vs other types of solar cell, so it is difficult to say how good that really is. But good news, this method seems eminently reproducible. During testing NTU fabricated 103 FPS cells and they all performed in the same manner, which shows this isn’t a fluke.16

And finally, number 5 … is kind of a cheat. It’s a sublist to my list. It seems like one university after another is handling every issue you could think of from toxicity to longevity to cost. Sure, all this progress is exciting, but so far I’ve only mentioned laboratory breakthroughs. Does any of this have any real world applications? Is any of it on the market yet? Are we any closer to better solar panels now than we were last year? Absolutely! In fact, we’re closer than you might think. Recent financial support and new measures from both the U.S. government and the EU have contributed a lot to boosting various perovskite cell enterprises and helped them evolve past their pilot phases. This sublist is about commercialization.

Oxford PV, who we checked out last year, is planning the commercial launch of its perovskite-on-silicon tandem cell this year, predicting a conversion efficiency of 27% and an energy yield of 24%. If all goes well Oxford PV, and German partner Helmholtz-Zentrum Berlin (HZB), plan to expand their pilot factory near the German capital and scale up production to 10 GW by the end of the decade.19 And France is right behind them. The solar research center Le Institut Photovoltaïque d'Ile-de-France (or mercifully, the IPVF) has partnered with French manufacturer Voltec Solar to build a solar panel factory that will produce tandem 4 terminal combination perovskite-silicon cells. The partners aim to start production early next year and ramp up capacity to 5 GW by 2030.

Germany is currently the EU's largest solar market, so it's no surprise that HZB is double-dipping in solar. Last year, they teamed up with Qcell, a Korean solar manufacturer, to establish a pilot manufacturing line for silicon-perovskite tandem cells in Thalheim, Germany. This research project, tastefully named PEPPERONI (or Pilot Line for European Production of PEROvskite-Silicon taNdem modules on Industrial scale) aims to address perovskites' challenges and speed up the technology's mass manufacturing. The research side of this project is set to conclude in 2026, but by June of that year they plan to be ready to mass-produce perovskite tandem cells at competitive rates.

Finally, Toronto-based QD Solar boasts a great efficiency rate, and they're actually ready for the market. The company's spin-coated and slot-die-coated perovskite cells are designed with mass production in mind and boast efficiency ratings of 24% and 23.2% respectively. Better yet, they just had those numbers confirmed by a third party in February.

Ultimately, it's easy to see why so many people are optimistic about perovskites' future. Perovskite solar cells have emerged as a promising photovoltaic technology for many reasons. Headway is being made on addressing several of perovskites challenges and it looks like commercialization is finally happening. By the end of this year or next we should have some options on the market. As the developments we've talked about are incorporated into perovskite cells in the near future, we can expect that sector to keep on growing. And not a moment too soon.

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