Beyond Silicon: Quality Control in the Perovskite Solar Revolution

Depending on your age, you may have memories of sitting in class with a solar-powered calculator and covering the sensor until the display slowly faded and finally died…only to come right back to life once you exposed it to light again. It was amazing!

Those little solar cells have gone through a few updates since then, and today they have become a not insignificant source of renewable energy for both businesses and homes. Globally, the solar sector went from generating 100TWh to 1000TWh during an 8-year period, an order-of-magnitude increase in less than a decade. But the jump from 1000TWh to 2000TWh then took only 3 years! (1) This has been driven by the obvious need for cleaner and renewable energies, but further catalyzed by a dramatic reduction in cost. In the late 1970's a crystalline silicon cell was about $77 per watt, which then dropped to a mere $0.13 per watt in 2018 (2) That's a pretty significant change.

But the traditional silicon chip approach is up against a new player trying to take the lead. Enter: *Perovskites*. In mineralogical terms this applies to calcium titanate ($CaTiO_3$), but in general terms it applies to any compound with that same type of crystal structure.

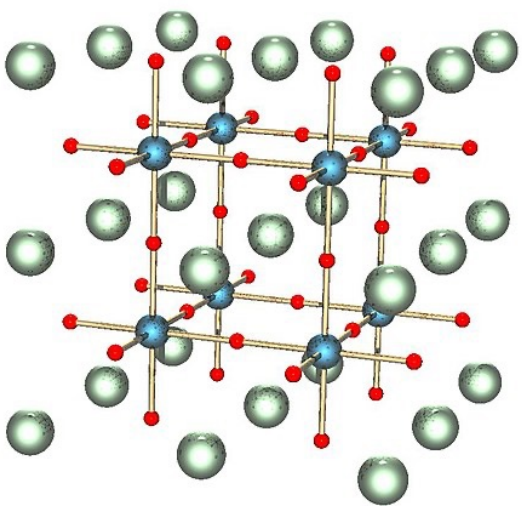


Figure 1: Perovskite crystal structure

This ABX_3 structure relies on A and B being cations and X as the anion. The most common material in this class is methylammonium lead trihalide, where methylammonium acts as the A, lead acts as the B, and some halogen such as bromine or chlorine acts as X. Before 2010 the solar-cell efficiencies of these materials were less than 4%; after 2020 this has jumped

to over 25% (3) They are relatively easy and cheap to produce and offer enough customization to be attractive across both general and bespoke application spaces.

But whether you're making solar cells or sneakers, as a manufacturer you need to ensure your products are made correctly and consistently. That's where spectroscopy comes in, because by using a rapid optical scan in the right wavelength range we can instantly detect defects and impurities. Perovskite materials have particularly interesting reflection profiles out in the NIR range, and we get a useful snapshot of coating quality in the 900 – 1700 nm region. This can be done using a standard reflection probe for tight point-measurements, or with an integrating sphere to characterize a broader area.

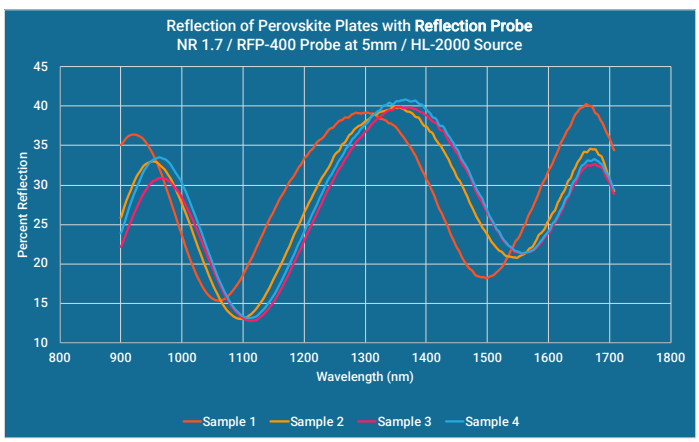
Picture 2: Reflection probe analyzing perovskite plate

Experimental Setup

Spectrometer	NR 1.7
Light Source	Tungsten-Halogen
Fiber	600µm NIR
Sampling Accessories	400µm NIR Reflection Probe / Integrating Sphere
Samples	4 Perovskite plates with variable manufacturing parameters

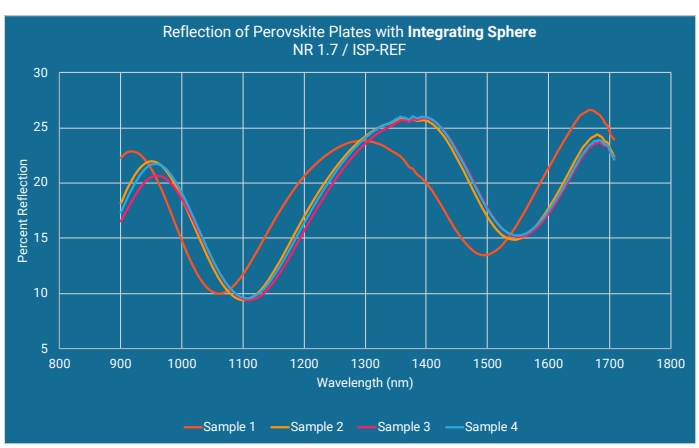
The primary benefit of a reflection probe is tight control over the exact point of interrogation, as well as ability to change distance and angle on the fly. But if the fixture is not set up tightly to prevent unwanted movement, those changes in distance and angle can lead to poor measurements. The integrating sphere has a wide 10mm port that will give reflection information for the entire area exposed there; this also maintains a flush distance and consistent 90° interrogation. This often leads to more repeatable measurements, although while losing ability to focus-in on a particular problem spot. For these reasons the reflection probe is often popular in research and laboratory settings, while the integrating sphere is valuable for rapid quality checks in a manufacturing environment.

The samples investigated here include 4 perovskite plates manufactured under slightly differing conditions. The exact differences are proprietary to the manufacturer but still establish a baseline in seeing how these changes appear in the spectral signatures. Looking at the reflection probe data we see a repeatable sinusoidal trend between 900 and 1700 nm. The first sample exhibits a 'blue shift' towards the lower wavelengths compared to the other three samples, which behave more similarly to each other.



Graph 1: *Response with **reflection probe***

Moving to the integrating sphere we thankfully see the same trends, which is good confirmation that both methods are valid. But with the integrating sphere we end up seeing smoother curves with tighter grouping of the latter-three samples. This ties into the increased repeatability mentioned earlier regarding the integrating sphere and highlights why this is valuable in a QC setting.



Graph 2: *Response with **integrating sphere***

These patterns are not just random, rather they are a fingerprint of how light interacts with the various layers in the perovskite

cell. By analyzing the positions and offsets of these trends, manufacturers can fine-tune film thickness, look for defects, and optimize the overall performance. Small spectroscopy setups, such as what is used here, are perfect for R&D and manufacturing environments, as they are small enough for the lab while rugged enough for the process line. This builds confidence that you will see the same meaningful results when transitioning between these settings, rather than working out conversions for a large system customized for your process. If you work with perovskites or similar technologies needing analysis at the lab bench and/or process line, reach out to learn more about how these systems align with your specific needs.

References

1 https://www.pv-tech.org/ember-global-solar-generation-exceeds-2000twh-2024/

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3 Kojima, Akihiro; Teshima, Kenjiro; Shirai, Yasuo; Miyasaka, Tsutomu (May 6, 2009). "Organometal Halide Perovskites as Visible-Light Sensitizers for Photovoltaic Cells". Journal of the American Chemical Society. 131 (17): 6050–6051. Bibcode:2009JAChS.131.6050K. doi:10.1021/ja809598r. PMID 19366264.