Interview

An Experienced Perspective

Alex Bradley, DuPont Photovoltaic Solutions

Investigating Module Performance in the Service Environment

Alex Bradley is a principal investigator for DuPont Photovoltaic Solutions, studying material reliability in service environments over time. He obtained a PhD in chemistry from the University of New Hampshire in 1997 and was a postdoctoral fellow with the Council on Science and Technology at Princeton University before joining DuPont in 2001. Dr. Bradley is an industry representative on the Standards Technical Panel for UL 1703, the equipment safety standard for flat-plate PV modules and panels, and serves as the American Chemistry Council's alternate representative on the *National Electrical Code*–Making Panel No. 4 regarding PV installation, the panel responsible for *NEC* Articles 690 and 705.

Courtesy DuPont Photovoltaic Solutions

Alex Bradley, DuPont Photovoltaic Solutions A principal investigator for DuPont, Dr. Bradley runs the company's Fielded Module program, which studies how modules and materials perform over time in the service environment.

At Solar Power International 2012, Bradley moderated a panel called "Standardization of Codes for Solar Project Development." SolarPro *staff met with him afterward at the DuPont booth on the floor of the Orlando Convention Center.*

SP: While DuPont is a household name, some people may not be familiar with its role in the solar industry. Where does DuPont fit into the value chain?

AB: DuPont has a historic place in the solar industry. The company was an original supplier to the Jet Propulsion Laboratory research program sponsored by the US Department of Energy, which developed many of the original specifications for PV modules. We donated our Tedlar polyvinyl fluoride [PVF] film for PV backsheet and EVA encapsulant materials. The goals of the study were to develop a 30-year module—one that met the functional, safety and reliability requirements for large-scale terrestrial deployment of PV—and to derive the appropriate balance between system cost and system life and reliability.

Now, more than 30 years later, DuPont products are used to manufacture both crystalline silicon and thin-film PV cells and modules. We provide films, resins, encapsulation sheets, flexible substrates, conductive pastes and silicon inks, as well as high-performance seals for solar cell manufacturing equipment and wet-etch additives for semiconductor texturing.

SP: What kind of work do you do as a principal investigator?

AB: I'm heading up our Fielded Module program, in which we're going out into the service environment and looking at how our materials and our competitors' materials have performed over time. In our minds, that's the true test of performance.

This is a unique initiative, one that provides us and system owners with a significant amount of information. By virtue of being a 200-year-old company, our material science capability is well established, and we can leverage our experience from other industries. DuPont PV materials have been out in the service environment for well over 30 years. Since we haven't changed the recipes for some of our materials very much, we can learn a lot by understanding how these materials perform over an extended period of time and throughout the module lifetime.

SP: How does this approach differ from other methods of performance testing?

AB: For the most part, the industry uses accelerated aging tests to try to predict the quality and reliability of PV modules. These tests can include thermal cycling, damp heat exposure, humidity-freeze cycling, hail impact analysis, static and dynamic mechanical loading, and so forth. I have colleagues at DuPont who perform accelerated aging tests on a mini mockup structure, and they beat the heck out of the test modules to establish relative durability.

The limitation to this approach is that we can generate failure modes that aren't seen in the service environment. What we want to understand is how modules perform in the real world. If accelerated aging tests generate other types of failures, this isn't really helping us or helping the industry. We still lack a fundamental understanding of how these results relate to module performance in the service environment. We can test for anything, but what do the results truly mean?

SP: What is the process used for the Fielded Module program?
AB: Basically, I'm always looking for modules that have been deployed in different environments and in different applications—for example, roof mounted versus ground mounted—and have been in service for different periods of time. All of these things have an effect on the rate of degradation.

It's an interesting dynamic. When I first started the program, no one would let me in the door. They'd say, "You can't come inside the fence," and "No, you can't do that." So, we now have ten PV systems installed at DuPont locations worldwide. Some of these installations function as living labs, where we're using a systems approach for our own learning, so that we can understand module degradation and material performance in detail. At the same time, we're gaining access to other facilities that will provide additional learning opportunities.

SP: So when you're testing these modules, are you bench-testing them? Are you doing laboratory testing or field testing?
AB: I have a whole analysis and characterization plan that we benchmarked against Sandia National Labs. They published a lot of good work to establish the process we go through. We do flash testing to get the I-V curve and understand the power degradation. Then we start trying to identify the root cause of the degradation. For example, we have thermal imaging and electroluminescence imaging to see if there are cracked cells or hot spots. We test for electrical insulation and material properties as well.

We go through an in-depth, nondestructive analysis in our North America Applied PV Lab. Then, if need be—I'm a chemist by training—I actually destroy the module. We have a destructive analysis protocol so that we can look at the chemical degradation as well. Sometimes degradation is not on the outside; it's on the inside. So there's no other way to characterize it other than to crack that egg open and see what's inside.

SP: How do you go about doing that?
AB: What we do is actually quite interesting, and I'm not taking any credit for that. Here again our process is benchmarked against Sandia. The process is called *coring*, like taking an ice core out of Antarctica. We pull out that core. We polish it. We perform a cross-section analysis using a scanning electron microscope. That gives us the thicknesses of each individual layer. Then we do a point chemical analysis of each layer, and we look for degradation problems. It's intense, and some people think I'm a little crazy for doing it. But I love to learn and I'm very interested in it.

SP: Are the older modules displayed here at your booth all products that you have tested for performance?
AB: Yes. These modules are all about the same age—somewhere between 10 and 12 years old—but they have different material sets, and you can clearly see that the protective materials have performed differently.

SP: What is the story with the module with a whiter backsheet than the others? It shows no visible signs of delamination.
AB: That is an AstroPower module made with a Tedlar PVF film-based backsheet. The company worked right down the street from us and was a longstanding customer of ours. This module came out of a 1.5 kW roof-mounted system in Delaware. The whole system was donated to us. We analyzed all of the modules in our laboratory, and they all got a clean bill of health. The modules all passed the wet leakage test, indicating that the system was still safe. The performance degradation was about 0.8% per year.

SP: What about this module with the yellow backsheet? The backsheet material actually looks jaundiced. Also, the membrane has delaminated in many places and is starting to crack.
AB: The backsheet polyethylene terephthalate, or PET, material on this module is completely discolored, and the material is embrittled. As you might suspect by looking at it, this module failed the wet leakage test, which means it's no longer electrically insulated.

This manufacturer decided to replace the traditional weatherable outer surface with a different weathering material, and you can see that was a poor design decision. The PET backsheet material didn't last quite as long. Clearly the design of the polymeric material wasn't a good choice. Although it was done to lower cost on the front end, this design isn't paying off on the back end. The primary function of a backsheet is to insulate the module for safety, but it also has to protect the module and ensure weatherability. This module is still supposed to last another 15 years, and, in my opinion, it's not going to make it to the finish line.

Interestingly, this particular manufacturer used the same PET backsheet material through three product generations—from a 70 W module to a 125 W module and eventually to a 143 W module. We've tested some of these sister products and found other degradation modes resulting in a loss of electrical insulation. So they carried that bad design and the problems associated with it through three different product iterations.

We look at that and conclude that materials clearly do matter. The challenge is that it takes so long to prove it out, and a lot of the accelerated aging tests may not be predicting it. Industry stakeholders sometimes have to grin and bear it for 10 years and wait to see how things eventually degrade. Unfortunately, that means a PV system owner, whether a small rooftop or large MW utility system, is unknowingly running a beta-test facility for unproven design iterations.

SP: A lot has changed in the decade since these modules were manufactured. The industry is more mainstream. Manufacturing capacity is much larger. Module construction has changed. How do you think today's products will hold up?

AB: The fundamentals of module degradation are still the same.Resistive losses will occur. These changes in short-circuit current, open-circuit voltage and fill factor have a deleterious effect on module performance. Solder bonds and interconnects are still going to fail; we see that in modules that are 4 years old and ones that are 30 years old. Cells are still going to crack—even more so now. The cells on these 10-year-old modules are 750 microns thick. They are like a hockey puck compared to cells nowadays, which are about 150–180 microns thick. What happens when a cell breaks? It starts to get hot. That is going to accelerate the degradation of the polymer.

So a lot of the fundamentals are still true, whether the technology is 20 years old or 2 years old. And unfortunately we're still going through these same issues. We're not learning that materials matter.

I was at an installation in Arizona about a year ago, and modules were still turning yellow on the front side. We thought we'd worked that out 20 years ago, but the same problems are occurring over and over again. That's what happens when you have new suppliers coming to the market that don't know how to formulate and choose the proper additives for their films.

The more things change, the more they stay the same. Take frameless modules, for example. One of the ways that companies tried to cut costs 10 or 12 years ago was to take the frame off. What happened? The modules delaminated. The adhesive doesn't stay on. So I'm walking around the floor of the expo hall here at SPI 2012, looking at all these new frameless PV laminates and thinking, "It's a shame, but 10 years from now they are going to be delaminating from the edge."

I also saw manufacturers turning the glass inside out again. This is textured glass, right? I saw a couple modules on display where the texture is on the outside, and the manufacturer is saying that the modules are going to capture more light. Well, once the things get dirty and grimy, it's harder to clean the dirt out of the pinholes in the surface of the glass.

It's like fashion: What's old is new again. That's part of the justification for our program, and for my participation in codes and standards committees. As an industry, we don't want to keep repeating the same mistakes.

SP: There is so much downward price pressure in the industry right now that it makes you wonder about the compromises that manufacturers are forced to make to remain competitive. There must be a tradeoff in quality, reliability and longevity. Do you think we will eventually see PV turn into a 10-year product?

AB: I hear people suggesting this. They say, "Oh, the modules are so cheap that we'll just get rid of them after 10 years and put new ones up." But they don't consider the rework and scrap involved with that. You have to take those costs into account on the front end if you want to sell me that story.

SP: In the October/November 2012 issue of *SolarPro* magazine, we published module specifications for UL-listed and CEC-eligible PV modules. Even after we filtered the table to include only modules rated 200 W or larger, there were more than 900 modules. What is your advice to the people who have to make purchasing decisions?

AB: I read that article and was also struck by the number of modules. I believe there were more than 60 manufacturers included in that table. Every one of those companies is probably saying: "My product is the best. It performs the best. This is the product you should be buying."

Obfuscation is here! People don't know what to choose. They are coming to our booth and saying, "You have to help me understand what I should buy." We're helping them understand that materials matter.

You have to dig deeper into the module. You have to ask more questions about what it's made of and how it's consistently manufactured. What are the cells? What are the edge seals? What is in the backsheet? What are the protective materials? There are a lot of different EVAs—the vinyl acetate content varies. There are different types of backsheet materials and different backsheet constructions. But you can specify any of these if you know what you want.

A move to transparency would really help the industry. Right now modules are black boxes with a watt number. But people are hungry for more information. One of the reasons we're here at SPI 2012 is to provide education and awareness, to help people become sophisticated buyers and installers of modules and systems.