Photos: Dow Corning

Guy Beaucarne leads a research & development unit working on new materials for the solar and electronics industries, based at Dow Corning in Seneffe, Wallonia, Belgium.

"Cell interconnection techniques will have to change at some point"

Interview: **pv magazine** caught up with Guy Beaucarne, whose team at Dow Corning has developed an electrically conductive adhesive especially for use in the PV Industry. The adhesive could lead to the creation of thinner cells, and significantly reduce the manufacturing cost of solar modules.

pv magazine: ***Could you begin by briefly explaining what Electrically Conductive Adhesives (ECA) are, and the role they play in the solar PV industry?***
Guy Beaucarne: Electrically Conductive Adhesives (ECAs) are a means for electrical interconnection, putting two components into electrical contact. Interconnection in solar is typically done by soldering; solder materials are melted, brought into contact with the parts that need to be connected, then cooled and solidified. In a solar module, soldered joints connect the electrodes of the solar cells to copper ribbons. ECA is an alternative – basically a polymer that, when cured, creates an adhesion to the substrate it is in contact with, and also contains a lot of conductive particles which increase the electrical conductivity. Interconnection materials have two functions: They need to adhere to the material they are attached to, and they need to conduct electricity. There are different types of solar ECAs. The most common ECAs are based on epoxy polymers. Dow Corning has developed one based on a silicone material, which capitalizes on silicone's intrinsic reliability and flexibility.
It is when you depart from the traditional module structure that you encounter problems with soldering, for instance, if you want to make modules with very thin cells. Soldering involves pretty high temperatures. Because of the large mismatch in coefficients of thermal expansion between the cell and the ribbon, you create stress when cooling down after the soldering process. Where cells are very thin and therefore fragile, you will encounter breakage problems. This is the main reason why average cell thickness is no longer decreasing at the rate it did in the past. It is stagnating, and road maps keep postponing the evolution towards thinner cells. ECAs could provide a solution to this, as the bonding occurs at lower temperatures.

So ECA can help drive thinner solar cells. What are the advantages of this?
Thinner cells save on materials and thus save money, but it is not so easy to achieve this with traditional interconnection technology. ECAs can also be useful in conjunction with temperature-sensitive solar cell structures. Heterojunction cells are a typical example of this; these have an amorphous silicon-based emitter, whose cell structure can be destroyed at the high temperatures associated with soldering. Here, ECAs can provide a useful alternative.
Another area where ECAs provide advantages over soldering is with back contact cells utilizing a conductive backsheet (CBS). Instead of using ribbons you use a patterned metal foil. Cells are placed on to the foil by a pick and place process, but a conductive material is needed to make the connection between the cells and the foil. In that application, the best choice is ECA, and this is where Dow Corning was first active in the field of solar ECA. We collaborated with Dutch research center ECN who had been developing CBS-based modules for a long time, and based on Dow Corning's decades of experience in conductive adhesives for electronics, we developed a dedicated silicone ECA for solar applications, called PV-5802. It is still early days for this tech-

nology but performance and reliability data of back contact modules with our silicone ECA have been excellent.

ECA is also used in shingled cell modules, a new structure that is becoming increasingly important to the industry. What are they and how does ECA technology come into play here?

Shingled cell modules are modules in which no copper ribbons or foils are used. The cells are narrow strips, and you directly connect the rear of one solar cell with the front of the next cell in the string, placing your cells in a shingled structure, like tiles on a roof.

Soldering is a really bad idea for shingled cell structures. In a traditional module, when cells move a little as a result of thermal mismatch in the module, the ribbon allows for relative movement, and becomes a little flatter, or a little more bent. But there is no ribbon in shingled cell modules, so all relative movement has to be taken care of by the by the elasticity of interconnection joints. Solder materials are very stiff, which does not work well for this type of design, as excessive stress will appear in the string and there can be breakages and loss of contact. Soft materials are the way to go. This is why silicone ECA, which is more flexible than all other interconnection materials, is a good choice.

Metallization wrap through and automated module assembly techniques are becoming more commonplace in the solar industry. What benefits do silicone-based ECAs bring to these processes?

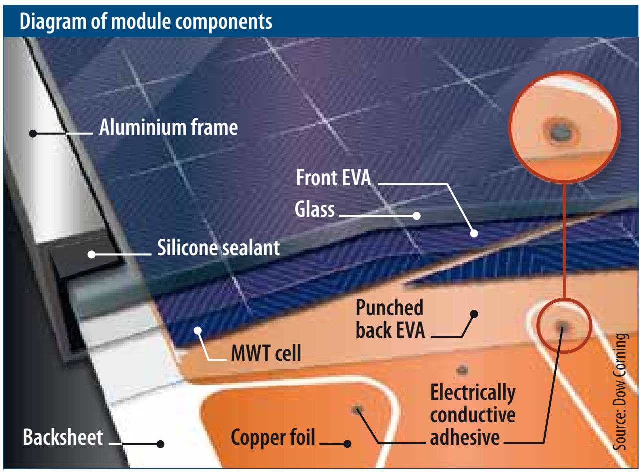
In a module, you are going to have some relative movement of the various components. A module consists of components made from different materials, with different coefficients of thermal expansion and responses to ambient conditions. They will move differently, and this is where the joint materials between the different components are really important. If you don't allow for some relative movement, stress builds up and eventually the joints will fail or the cells will break.

So you want soft materials, which allow relative movement. This means low elasticity modulus, and because of the many shear stresses present in a module, you want in particular a low G (shear modulus). This is where silicone materials have an excellent advantage, because they have an intrinsically low G. This interconnection material – the Dow Corning ECA PV-5802 – even though it is highly comprised of metals, has a low G and is softer than many other ECAs.

The mechanical properties of silicone do not vary greatly depending on temperature. Other materials, for example epoxy-based materials, go through the glass transition temperature in the operating temperature range; that means that when you go below a given temperature, typically 20°C, it goes into a glassy state and becomes very stiff. And that is not good for reliability. In contrast, a material that has its glass transition temperature well below the operating temperature range, like silicone, has more constant properties. This is the case for PV-5802, which has a low value of G that varies only slowly with temperature.

As the industry looks to adopt lower-cost conductive backsheet (CBS) materials, what challenges does this present to Dow Corning and its PV-5802 ECA?

It's a new technology. In the beginning there was no supply



Graphics: pv magazine/Harald Schütt

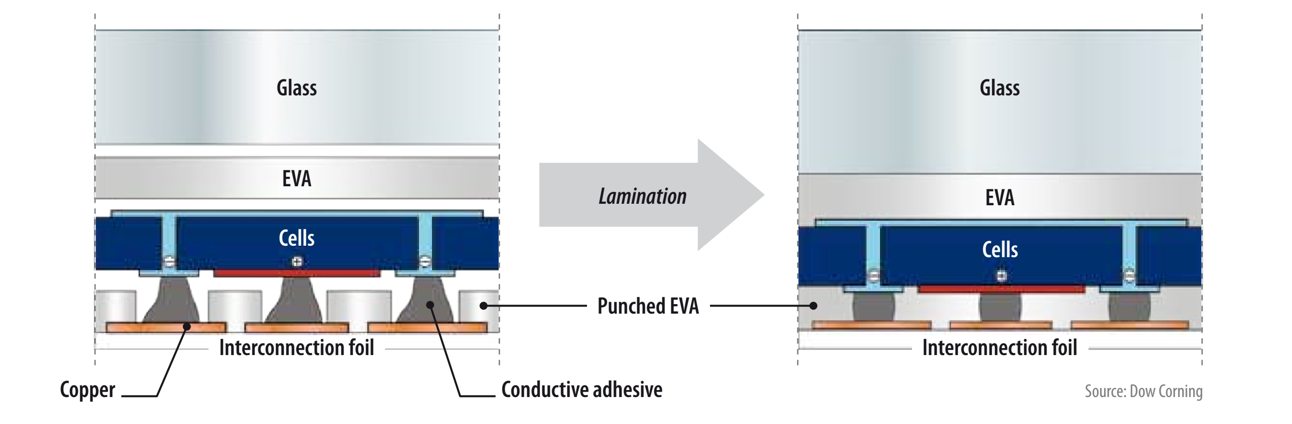
chain at all, and companies like ours developed materials in anticipation of a larger market. We have worked with CBS companies to try to make sure that our material was compatible with some lower-cost backsheets. An appealing approach to reduce cost is to produce CBS back sheets with aluminum foil instead of copper foil. Aluminum foil is cheaper, but to make a durable and stable contact on aluminum is very difficult with any interconnection technique, whether it is soldering or applying an ECA. This is because the aluminum surface oxidizes easily and can lose electrical contact.

Research institutes and companies are working on coating the aluminum foil with a very thin layer of copper. We collaborated with a foil company and demonstrated that if you use an ECA on this type of foil you can get durable, stable modules. We have conducted several tests with different companies looking at different types of coatings to ensure that we had appropriate interconnection on different types of CBS. This is our contribution to solving the CBS cost problem for our customers.

Do you expect ECA advances to help push wider adoption of shingled cell structures?

PV-5802, Dow Corning's electrically conductive adhesive.

MWT module manufacturing: combined lamination – interconnecting step



Absolutely. It is a hot topic right now. A few companies are presenting such modules at trade shows – two were exhibited at Intersolar Europe last June. There is one Chinese manufacturer seemingly already in production, and several large U.S. PV companies are announcing very aggressive growth targets reliant on that module technology. These are signs that there is something there. The fact that renowned companies, known for their highly efficient products, are banking on shingled modules, gives me confidence that the idea is going to be more widely adopted. For these modules, you need ECA, ideally a soft ECA. The same results cannot be achieved with soldering.

Cost reduction is always a key topic along all parts of the solar value chain. So how can silicone-based ECAs play their part in bringing costs down, and to what extent?

Only a small amount of ECA is required in a module. Back contact modules based on conductive back sheets use just 5 grams – this is coming down to 3 grams per module, maybe even lower. ECAs, irrespective of use, are made of high value materials. You have to look at the total cost of modules. Higher throughput is one thing, and those companies developing shingled cell modules are looking at ways to optimize their costs. Compared with tin-lead solder there is a huge price difference for ECAs. But that's the difference between a commodity and an engineered, high value material.

Some structures, such as shingled cell modules, would not be possible with soldering. You can solder for a demo shingled cells module, but one that has to pass thermal cycling tests will need an ECA. In general, I believe that the way the industry does cell interconnection will have to change at some point, because it is intrinsically preventing the evolution towards thinner cells. Whether it's back contact modules with CBS, or shingled modules, or any other concept that will emerge, you will need to have a material that creates a joint at a lower temperature, and that is more flexible. That is what silicone ECAs can do, in the end they will enable lower cost modules through lower overall material cost.

What is the current market status of Dow Corning's PV-5802 ECA technology? Where has demand been strongest, and in which markets and applications can it have the most impact?

It is already a commercial product, and currently the application is mostly in back contact modules. At EU PVSEC 2015, I presented a joint paper with Finnish company Valoe. Although they are an equipment manufacturer, they have a pilot line to produce these modules for demo PV systems. They use PV-5802, and their modules are already showing strong performance in various locations. Other companies are presently installing equipment for back contact modules. Apart from that, the big plans that have been announced for shingled cell modules will create additional demand for high performance ECA. I am confident that this market will grow exponentially in the next few years, and I am convinced that, given the key advantages of flexibility and reliability of silicone ECA, Dow Corning will continue to play a key role.

Where are the next wins for Dow Corning? What are the challenges you face when looking to improve performance, efficiency and – of course – cost reduction?

For commercial success, we need market adoption. Dow Corning developed and commercialized this material in anticipation of the developing market. With a few years delay, it is coming. What we can do is improve ECA performance in the meantime, ensuring better adhesion and improved connectivity using less costly material. Dow Corning is looking at what is happening in the market to see which direction to take, but I am sure of one thing: Leading edge silicone materials will play an increasingly important role in PV because of the good match between silicone's intrinsic properties such as durability and flexibility, and the needs of PV power generation. ◆

Interview by Ian Clover

Shingled cells interconnection