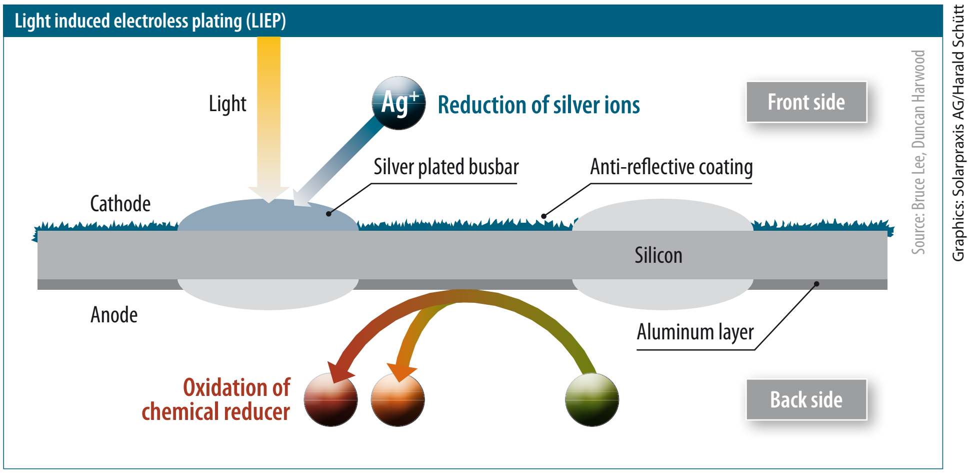

Schematic of the plating deposition reaction.

Cell metallization

Light induced electroless silver plating: Bruce Lee of MacDermid Photovoltaics Solutions and Duncan Harwood of D2Solar report on a series of tests that were performed to determine what effect, if any, light induced electroless silver plating may have on the soldering process, conductor adhesion, and overall cell and module reliability.

As the photovoltaics industry continues to mature, increasingly significant market forces have come into play relating to cost, performance, and reliability of PV products and systems.

For the foreseeable future PV manufacturers will be working to drive down materials and operating costs while at the same time increasing the overall efficiency and reliability of their products in order to remain competitive in the global marketplace. This is a familiar environment to those of us that have been involved in other "immature" industries and participated in their growth from relatively small niche markets into broad-based commercially viable entities. It is an exciting and sometimes tumultuous journey.

Within the PV supply chain there are many segments that contribute to the overall success of the end product and its relative performance. Inputs from the refining of silicon all the way to the system installer have a direct and important contribution to success and ultimately a satisfied customer.

In this review we will examine the contribution of a relatively new cell metallization process called light induced electroless silver plating (LIEP – light induced electroless plating). LIEP is a unique silver plating process that can be used as a cost effective alternative to the normal paste metallization methods.

Compared to conventional LIP silver plating (LIP: light induced plating), the non-cyanide LIEP silver process does not require electrical contact to the cell in order to deposit silver on the conductors. This unique feature results in significant capital equipment cost savings since the plating tool doesn't require anodes, rectifiers, or electrical contacts. The LIEP silver process utilizes a method of depositing silver whereby light is used to energize the cell which in turn plates the silver metal ions from the solution onto the front side fingers and busbars. See Figure "Light induced electroless plating" for a schematic of the plating deposition reaction.

The LIEP silver is selectively plated on the front side grid so no silver is wasted on backside features or on electrical contacts that can plate up. The typical LIEP

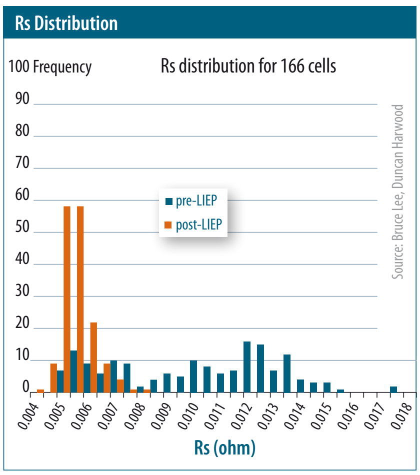

Chart 1: Fill factor distribution.

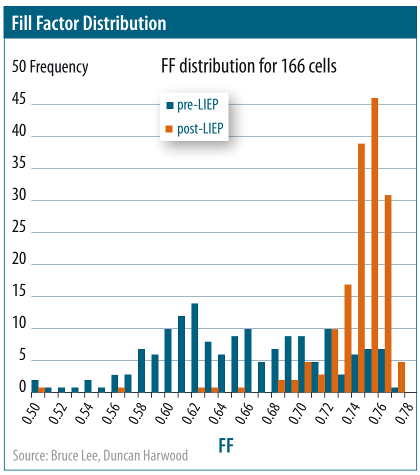

Chart 2: Series resistance distribution.

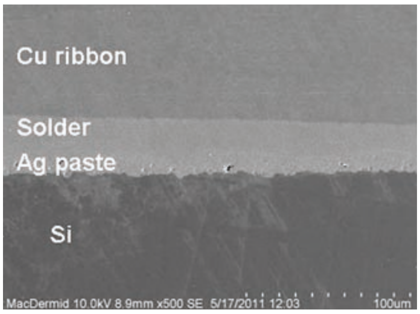

Figure 2: Solder joint with LIEP silver.

Figure 3: Solder joint without LIEP silver.

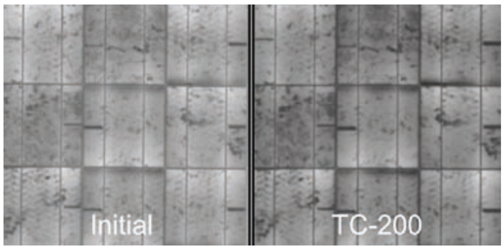

Figure 4: Module electroluminescence image without LIEP.

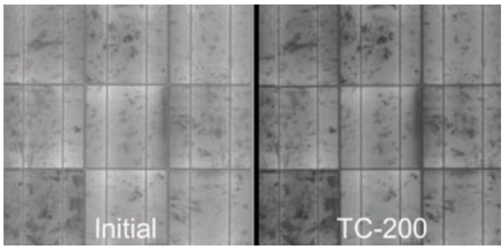

Figure 5: Module electroluminescence image with LIEP.

silver plating process sequence is: LIEP silver → Deionized rinse → H_2SO_4 rinse → Deionized rinse → Dry.

The primary application for LIEP silver (Ag) plating is paste reduction wherein a small volume of "seed paste" is screen printed to form the fingers and busbars. Typically the volume of a seed paste is about 75 % less than that which would be deposited using conventional silver paste. The function of the seed paste is to form an electrical contact to the silicon (Si) and function as the base upon which the LIEP silver is deposited. When utilizing the "seed and plate" LIEP technology the printed finger width is reduced to the 40 to 50 micron range as printed. After firing the cell is then plated with LIEP silver to build up the metal volume of the conductor and lower the series resistance (Rs).

The plated metal deposit of LIEP silver has much higher conductivity than any available silver paste so the plated deposit is typically around 60 milligrams (mg) per cell. The silver metal deposit of the LIEP process has a resistivity value of about 1.6 microohm per centimeter (μΩ/cm) whereby typical silver pastes have resistivity values of 3 to 10 μΩ/cm. The LIEP plated silver volume can be adjusted up or down to accommodate for the amount of seed paste used and maintain the overall conductor volume.

An additional application for the LIEP silver plating process is for the recovery of high Rs B Class cells. In most cell manufacturing facilities there is a certain percentage of cells that suffer from high

Change in peel strength with temperature cycling

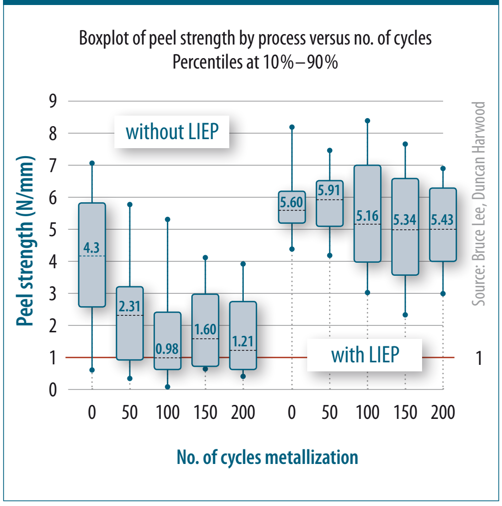

Figure 6: Measurement of peel strength as a function of temperature cycling shows a significant difference between cells manufactured with and without LIEP.

Initial peel strength comparison

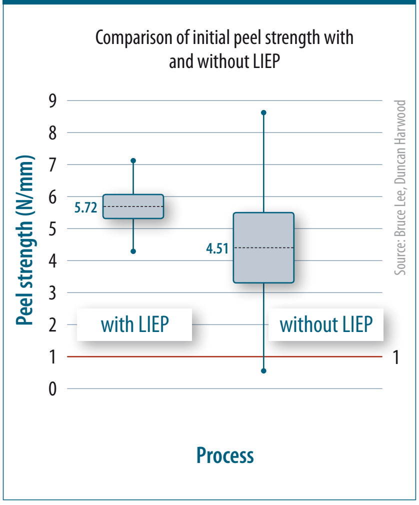

Figure 7: Comparison of the initial peel strength showed that the LIEP process not only produced higher median peel strength values but with less variation.

Change in module performance during temperature cycling

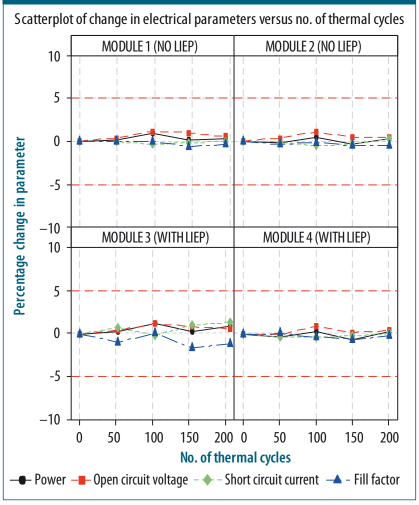

Figure 8: After 200 temperature cycles from -40°C to 85°C both groups of modules were comfortably within the IEC-61215 degradation limit of -5 percent.

Rs which directly affects the overall efficiency of the cell. This is often due to variations in the screen printing process resulting in a non optimal silver paste deposit. Thin silver paste and "skips" in the silver paste are the predominant defects seen. Many of these types of cells can be salvaged and the efficiency increased dramatically by processing these cells through the LIEP silver process. Chart 1 and Chart 2 represent fill factor (FF) and Rs data from a typical population of B Class cells produced by a commercial cell manufacturer. Note the distinct narrowing of the distribution in FF and Rs values.

Reliability

Cells processed with LIEP silver can have distinct and measurable reliability advantages.

Since the LIEP silver deposit is pure silver, the formation of reliable solder joints becomes much easier which in turn lowers the overall thermal load the cell must endure during soldering. The solder joint formed during soldering is also much more uniform and does not exhibit the voids seen in typical soldering to silver paste. See Figure 2 for a cross-sectional view of a solder joint with LIEP silver and Figure 3 for a view of a solder joint without LIEP silver (both on page 63).

In order to quantify the effect LIEP silver has on overall cell and module reliability an experiment was designed and executed at D2Solar, an independent testing and reliability laboratory, using cells produced in a commercial cell production facility.

The reliability of a tabbed cell is primarily characterized by the solder peel strength. Figure 9 shows the configuration used for measuring solder peel strength in a 180 degree configuration.

Cells manufactured both with and without LIEP were soldered using a 0.15x1.5 mm solder coated copper ribbon (Sn62Pb36Ag2 thickness 15-20 µm) using a low acid, low solid flux with solder tip temperatures from 700°F to 850°F. Comparison of the initial peel strength showed that the LIEP process not only produced higher median peel strength values but with less variation as shown in Figure 7. For reliability characterization, cells from each process were built into 3x3 modules and subjected to 200 temperature cycles from -40°C to 85°C. In addition, bare tabbed cells were exposed to the same condition and the peel strength measured at 50 cycle intervals.

Peel strength characterization

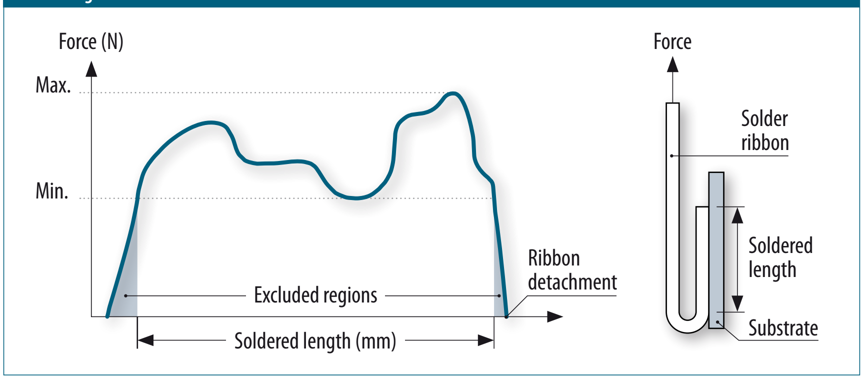

Figure 9: Measuring solder peel strength in a 180 degree configuration.

MODULE CONSTRUCTION

Layer	No LIEP	With LIEP
Superstrate	3.2 mm low iron glass (PPG)	
Upper encapsulant	0.46 mm EVA (STR 15420)	
Cell	No LIEP	With LIEP
Lower encapsulant	0.46 mm EVA (STR 15420)	
Rear Dielectric	0.2 mm TPE (Madico)	

Table 1: Modules were constructed with a typical glass-EVA-TPE configuration.

Modules were constructed with a typical glass-EVA-TPE configuration (glass – ethylene vinyl acetate – thermoplastic elastomers) shown in Table 1.

After 200 temperature cycles both groups of modules were comfortably within the IEC-61215 degradation limit of -5 % as shown in Figure 8.

Electroluminescence imaging of the modules were taken before and after temperature cycling and showed no evidence of interconnect deterioration, with examples shown in Figure 4 and Figure 5 (see page 63) for module 1 and 3. For the modules built without LIEP, print defects are clearly visible in the cells.

While no statistical difference is observed in module performance, measurement of peel strength as a function of temperature cycling shows a significant difference between cells manufactured with and without LIEP. After just 50 temperature cycles, the median peel strength for the non-LIEP cells has dropped by almost 50 %. In contrast, the LIEP cells continue to show stable peel strength up to 200 cycles. The data suggests that for long term field reliability and extended thermal cycling, LIEP processed cells may show superior reliability.

Conclusions

Cells from the LIEP Ag test group demonstrated significantly higher peel strength compared to cells not processed through LIEP Ag in all test groups including as-is and temperature/humidity conditioned cells. LIEP Ag plated cells demonstrated a much lower standard deviation in peel test results. There was no negative effect on modules built with LIEP Ag plated cells versus modules built with standard cells. Based on electroluminescence images it appears the LIEP Ag “repairs” some of the print defects or broken fingers. ◆

THE AUTHORS

Bruce Lee is the Global Applications Manager for MacDermid Photovoltaics Solutions based in Waterbury, CT, USA. MacDermid provides a wide variety of specialized plating and cleaning chemistry for use in the manufacture of PV cells.

blee@macdermid.com


Photo: Bruce Lee

Duncan Harwood is the CEO of D2Solar in San Jose, CA, USA. D2Solar provides design, development, testing and pilot manufacturing services for solar technology companies to help reduce cost and accelerating time to market.

duncan.harwood@d2solar.com


Photo: Duncan Harwood

The authors can provide a complete test report upon request.