www.globalsolartechnology.com

The Global Journal for Solar and PV Manufacturing Professionals

GLOBAL SOLAR TECHNOLOGY

Volume 3 Number 7 July/August 2010

TURNING CIGS THIN FILM INTO ACTUAL SOLAR COLLECTORS—A CRITICAL STEP

THE EFFECT OF THE FIRING PROCESS ON THE ENERGY CONVERSION EFFICIENCY OF SOLAR CELLS

NOVEL THIN-FILM CRYSTALLINE SI SOLAR CELL APPROACHES

PERFORMANCE CHEMICALS IN CELL MANUFACTURING

Hansjoerg Lerchenmüeller Interview inside

NEW PRODUCTS

INDUSTRY NEWS

INTERNATIONAL DIARY

Turning CIGS thin film into actual solar collectors—a critical step

Colin Weightman, Comco Inc.

Microabrasive blasting is coming to the forefront as an economical technology that effectively and safely handles these final-step processes for a growing volume of thin-film manufactures. This paper offers an overview of microblasting technology and its integration into automated copper indium gallium (de) selenide (CIGS) thin film photovoltaic (PV) cell production lines.

Keywords: Thin Film, CIGS, Microabrasitve Blasting, Edge Deletion, Selective Layer Removal

Comco Inc.
2151 North Lincoln St.
Burbank, CA 91504
818-841-5500
Fax: 818-955-8365
www.COMCOinc.com

Overview of CIGS technology

CIGS process (copper indium gallium (di)selenide) is the fastest growing area of thin film PV (photovoltaic) technology today. As is well known, CIGS uses basic semiconductor technology to deposit the various material layers onto a substrate, all designed to catch, absorb and contain solar power and then release it back as useable electrical energy. It is being developed in many forms and on many types of material substrates, from highly flexible to rigid.

While not completely competitive to the more mature technology of silicon (Si) as far as total power output efficiency, the technology is gaining ground because of lower production cost, lower cost per watt efficiency and the flexibility to be used in areas where crystalline panels simply do not offer the design options, such as BIPV (building integrated photovoltaics).

Unlike silicon, the structure of a CIGS cell is more complex. It is even more complex than its thin film siblings, cadmium telluride (CdTe) and amorphous silicon (a-Si). Though CIGS solar cells are not as efficient as crystalline solar cells, they were substantially lower in cost to produce until the recent drop in the cost of silicon. Despite this unfavorable change in the cost ratio between the two technologies, thin film in all its varieties is making steady gains on Si in some utility farm markets where actual land space is not at a premium. Being a direct bandgap material, CIGS has very strong light absorption qualities that make it very attractive for use in hot, arid geographies where silicon is adversely affected by the climate. Also, unlike Si, CIGS TFPV can be flexible which makes it very attractive for the BIPV market.

This flexibility lies in the fact that the active layer (CIGS) can be deposited in a polycrystalline form directly onto molybdenum coated glass sheets or steel bands or even on metallic ribbon structures. For BIPV, flexibility allows CIGS solar cells to conform to the structural design of the building, rather than forcing the building to adjust to allotting regimented space to flat, silicon panels and racks.

Edge deletion in progress

Figure 1. The unique properties of high-energy abrasive particles make microblasting ideal for CIGS solar cell applications. It cuts without heat or vibration and can selectively remove layers without damaging underlying layers or surfaces.

Figure 2. Testing nozzles, angles, pressures and distance between the solar cell and the blast can be done manually and the data used to create fixturing for the automated system.

While CIGS films can be manufactured by several different methods, including vacuum-based processes, sputtering, co-evaporation and even electroplating, the end result is the same: a receptacle that gathers in sunlight and transforms it into usable energy. While this statement is quite overly simplified, that is the desired end result.

One aspect of final CIGS cell production still must be met to complete the picture-the power must actually get out of the cell. Electrical contact must reach through the deposited layers. This can involve final processing in one or both of two areas: edge deletion and selective layer removal.

Edge deletion and selective layer removal

In the edge deletion process, the solar cell manufacturer needs to get down completely to the substrate layer. On a glass panel, for example, all of the layers down to and including a small amount of the glass may need to be removed to ensure that there is no conductivity between the solar layer and the edge of the glass. This allows the cell to be isolated in its mounting fixture and is governed by the UL requirements.

The layers need to be removed below a certain conductivity range. One of the processes commonly used is laser. The challenge faced with this method, however, lies in the ability to circumscribe the cell and remove all the layers without melting into the glass or other substrate.

As an alternative, microblasting technology allows the user to affect the surface finish and remove all of the layers at the edge away right down to the glass without heat or damage to the glass or other substrate. Once all the layers are removed of course, conductivity drops to zero.

For edge deletion applications the most common abrasive is alumina. This crystalline material quickly cuts through all of the thin film layers, down to the glass substrate. In the normal thin film deposition process the bottom layers are partially melted into the glass creating a transition boundary that must be removed to completely block conductivity. Microabrasive blasting is able to etch into the glass surface without creating micro-fractures.

Microabrasive blasting is seen as a common alternative to the use of lasers and grinding wheels. The blasting process can be seen as a middle ground between the other two processes. The process uses a non-contact approach that removes material at a consistent rate and is less dependent on the layer composition.

Selective layer removal is generally needed for new multi-layer thin film technology cells such as CIGS. Since these cells have multiple conductive layers, the manufacturer must locally remove the top layers without damaging the molybdenum (Mo) conductive layer coating the glass, metal or other substrate. Once the layers have been removed, a connector can be mounted, allowing the electricity to be harvested.

The challenge in this application is the need to remove a relatively thick layer of CIGS (1.5 to 2.5 microns), without damaging the much thinner layer of Mo behind it (0.3 to 0.4 microns). Through proper selection of the abrasive media and air pressure (PSI) the microabrasive blasting process can be made much more effective on the CIGS layer than the Mo. Consistent abrasive feed is critical in this application to completely remove the CIGS layer without damaging the Mo.

These are small and yet highly critical steps in the final cell production process and several methods have been used, with varying success, including lasers, machine cutting tools and grinding.

Microblasting technology overview

Microabrasive blasting projects a blast of clean, dry air mixed with highly pure, micron size abrasive media, delivered through a nozzle selected to suit the application. This must be performed in a vacuum activated chamber to remove the dust created by the process.

For most processes, microblasting remains a manual art that is performed by an operator within a clean workstation. The psi, media mixture and safety measures are automatic; an operator controls the direction of the blast. To eliminate operator variance, more automated systems are being developed by end users and as custom systems by microabrasive blasting equipment manufacturers.

Microabrasive blasting technology itself is well known in many industries ranging from electronics and machining to medical device finishing and aerospace. Because of its effective use in the semiconductor area, it was a natural choice for many thin film developers, who have a background in semiconductor technology. Since CICS is an advanced version of the same processing as seen in the semiconductor industry, microabrasive blasting is a natural fit for CIGS finishing applications.

Figure 3. A wide variety of abrasive media allows a selection to suit any application from precision cutting to gentle surface finishing.

Figure 4. Nozzles for microblasting are available in a range of materials, sizes and shapes to fit the specific applications. Openings run from .015 in. up to .125 in.

Recent advances in microblasting technology enable the equipment to flow very small abrasives at highly consistent rates. The growth of automated systems that can accurately position both single and multiple abrasive nozzles and nozzles and monitor process variables like media flow rates also offers expanded options for thin film processing.

The unique properties of high-energy abrasive particles make microblasting ideal for CIGS solar cell applications. It cuts without heat or vibration and can selectively remove layers without damaging underlying layers or surfaces. The ability of microabrasive blasting to do this without causing dimensional changes to the surrounding cell layers make it ideal for finishing applications. Propelling a very fine, dry-abrasive powder mixed with clean, compressed air through nozzles with openings as small as 0.018 to 0.060

Figure 5. An example of an automated in-line microblasting lathe in action.

inches, the pinpointed abrasive blast can be as tight or as broad as the application requires.

The affect can be altered significantly by changing the pressure or abrasive media. The two most common abrasive media used in the solar industry are glass bead, which has a gentle affect on a surface and aluminum oxide, which is highly effective at cutting through almost all materials.

Integration into automated CIGS thin film cell production lines

As noted above, most applications for microabrasive blasting are still conducted in a manual workstation. However, within solar applications and particularly within thin film area, the microabrasive blasting process is always integrated into an automated production line.

CIGS thin film production is an automated process, very similar to that seen in the semiconductor industry. The development of the PV material runs on an automated line, with the final product handled and indexed through this line.

Because how each CIGS manufacturer sets up a line tends to be highly proprietary, in most cases, the manufacturer will buy a high-end microabrasive blasting system and then integrate this into their own line.

This can be done easily because there is a protocol in the semiconductor industry, a certain form factor and a specific handling process that is required. The most common scenario is where the CIGS manufacturer has a system integrator either set up the full automated line or, at minimal, integrate the automated microabrasive blasting system into an existing line. The microabrasive blasting equipment manufacturer acts as a consultant.

Typically, the CIGS manufacturer needs to learn about the microblasting process, and the equipment supplier works with them to make sure the process is smooth and working efficiently. Again, cell finishing tends to be somewhat proprietary, and depending on the actual substrate or any specific technology used, the microabrasive blasting integration set up tends to be slightly different at each installation.

Selecting a microabrasive blasting system that has been carefully engineered to operate in an automated environment is critical. But even after installation, some customization is commonly needed for the application.

Depending on the rate of use, throughput, and so forth, options such as different abrasive hose materials may need to be considered. These can range from standard polyurethane to stainless steel. However using stainless does limit all the lines to fixed positions. The trade off is that stainless lines last 10 times longer than polyurethane.

Other blasting variables such as nozzle location (i.e. the distance from the tip of the nozzle to the surface of the cell) must be determined. As the nozzle is moved away from the part, the spray diameter will increase. The nozzle must be placed so that the media is focused on the exact area that needs to be removed.

Nozzle shape also affects the spray pattern of the nozzle. Microabrasive blasting nozzles are available in many different sizes and shapes, from small round to large rectangular. Rectangular nozzles offer the ability to increase spray width in one direction without increasing the overall blast diameter.

These variables combined with pressure, abrasive flow rate and blast duration, create the proper profile for each type of material removal. Integrating machinery from different vendors to create unique automated systems is something that takes full understanding of each process. But, through the integration of all the various manufacturing operations, the end result is a product that is more cost effective, less operator dependent, and uniform in quality.

The system integrator needs to carefully study the current process, looking for variables that might affect the microabrasive blasting process. Simple tasks are often much more complex than they appear. The skill of the operators must be taken into consideration and duplicated as much as possible with an automated system. Testing nozzles, angles, pressures and distance between the solar cell and the blast can be done manually and the data used to create fixturing for the automated system.

Materials and techniques

Glass bead or aluminum oxide are the abrasive media typically used for these two applications. They create very different results in the actual material removal process, so it depends on what is being removed and where, and if only selective layers are being removed, or all of the layers are.

Figure 6. A wide range of microblasting formats are available for integration into customized automation production lines, depending on the end result desired.

If trying to cut through a layer to isolate it, aluminum oxide has fast cutting properties. If the objective is to remove a lot of the thin film layers down to the conductive Mo layer, glass bead is more effective. Because the Mo layer has a certain amount of elasticity it's going to take the energy of the particle and absorb it and then give it back off again. It allows the glass beads to bounce, unlike some of the harder thin film layers, which crack or fracture when hit. In this case the goal is not necessarily trying to clean-cut off the material as much as trying to break it up and then the follow up with a vacuum process that will lift away the debris after shattering the layers above the Mo. Using a high energy, energy sharp, harsh abrasive like aluminum oxide will cut away all layers, but it will also cut into the Mo layer.

Depending on the substrate—glass, metal, flexible ribbons or rolls—all would still be applicable for this glass bead type of process. But certainly, depending on the exact substrate the manufacturer would need to experiment with the abrasive media to determine the best selection.

Conclusion

Microabrasive blasting is coming to the forefront as an economical technology that effectively and safely handles these final-step processes for a growing volume of thin-film manufactures.

Looking at a basic analysis of cost saving in overall usable end product vs. other removal technologies, microabrasive blasting offers a higher level of precision than most mechanical methods for performing these processes and is typically less expensive than lasers. Microblasting offers reliable and consistent results without environmental issues associated with chemical processes.

The level of control afforded using the microabrasive blasting process ensures more quality connections without damage to the infrastructure of CIGS solar cells, helping to enhance the growth in product reliability for CIGS thin film in the growing solar market.

Colin Weightman is the director of technology at Comco Inc. During his tenure at Comco, he designed a new line of nozzles for abrasive blasting that provide a tighter focus and longer life than conventional nozzles. He also developed Comco's Applications Lab which provides sample parts testing to prove the microblasting process. Following a stint as technical sales manager Mr. Weightman has returned to a more research-based role. He works directly with clients to find ways in which microabrasive blasting can solve problems faced in the manufacture of new technologies such as those found in the emerging solar industry.