improving solar cell yield

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Despite the many proven benefits of renewable energy, the solar industry needs to reduce material content or process time and increase process yields to beat recessionary pressures

Manufacturers of solar cells have made heavy capital investment in plant and facilities as well as R&D and need to make a satisfactory return from investment. In times of falling sales the only opportunity to improve margin is through a reduction in manufacturing costs.

There are already three generations of photovoltaic technology currently being manufactured. Each successive generation has sought to reduce the manufacturing costs through reduction in raw material content through using cheaper substrates or making the active layers thinner. The downside to these cheaper production technologies is a reduction in the energy conversion efficiency.

The manufacture of first generation solar cells, ie those made from crystalline silicon wafers, is very capital intensive and uses large amounts of energy and aggressive chemicals. The resulting cells are size limited, extremely fragile and expensive. Although the basic material is cheap and plentiful the industry has been constantly striving to reduce the processing cost as well to increase the efficiency of energy conversion.

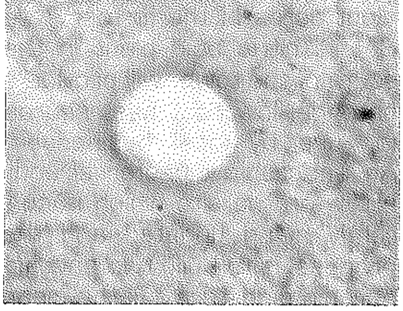
To this end a second generation of cells has been developed using lower cost, more robust substrates such as glass, ceramic and steel instead of silicon. To achieve the functionality thin film coatings of various materials such as cadmium telluride are deposited in a vacuum chamber. While the these materials are expensive they are only used in very low volumes and so the material costs of the cells are much reduced. This method of producing cells is also very capital intensive but can produce large area cells. However, with lower costs comes lower efficiency due to inherent defects in the process.

State of the art technology in photovoltaics incorporates organic and dye based solar cells. These new cell technologies can use very low cost plastic film substrates, which are coated or screen printed with a wet suspension containing the functional elements. Each coating is then dried before the next one is applied forming a multilayer functional assembly. The next step is screen printing of the collector circuitry using conductive ink. The environmental barrier layer is then laminated on top. All the manufacturing techniques used are low cost using equipment which is already in use in many other industries including the electronics industry.

However, driving material costs and processing costs down are not the only factors in reducing total cell manufacturing cost. The other key factor is process yield.

One of the main causes of poor yield in any type of solar manufacturing is the presence of dust and other contamination on the substrate being processed whether that is a silicon wafer, a sheet of glass or a plastic film. Traditional washing is feasible for cleaning hard substrates such as silicon wafers, steel or glass but

Dewetting of gold sputtered film



cannot be used with plastic films, thin film metallised substrates or moisture sensitive materials such as EVA. For these, a dry approach is required which also will not damage the surface.

The electronics industry has been focused on yield improvement over many years and has embraced a technology called surface contact cleaning and there are lessons to be learned from the electronics industry in improving process yield.

Contact cleaning

Contact cleaning is a very well-established yield improvement technique used by many high technology manufacturing operations to increase competitiveness.

The basic principles of contact cleaning involve a specially formulated elastomer roller rotating in contact with the substrate. In the solar industry there are four key processes, which are particularly susceptible to particulate contamination. These are screen printing, wet coating, vacuum deposition and lamination.

Screen printing

Screen printing using conductive paste, is the most commonly used method for making the collector circuits on conventional crystalline cells. This process is analogous to solder paste application on printed circuit boards prior to the assembly of the components. The issues, related to contamination, which arise in this process include the screen or stencil apertures becoming blocked with dirt result in incomplete ink coverage. Also if dirt becomes entrained within the ink deposit, it can volatilise during high temperature curing giving blow holes and much reduced conductivity or even an open circuit in the printed connector.

Wet coating

Similar yield issues arise in the wet coating of dye based solar materials where electron mobility is impaired by particles of contaminant leading to lowered efficiency. An additional defect generated by dirt in this application is called dewetting.

This happens when a particle of dirt alters the surface tension of the coating resulting in an area not covered by the coating.

De-wetting of gold sputtered film

This is particularly important for anti reflection coatings and encapsulation coatings. An equivalent use of wet coating technology in the electronics industry is the curtain coating of wet photoresist onto a printed circuit board. Surface cleanliness is vital for even coating.

Vacuum deposition

Vacuum deposition applies extremely thin layers of functional materials onto a substrate for thin film solar cells. These thin layers are particularly sensitive to dust which in the coating. This is a particular concern in the application of barrier coatings where pinholes provide a path for moisture to penetrate the barrier. Cleaning at unwind is key to minimising this type of defect circuit substrates actually install contact cleaning within the vacuum chamber to minimise contamination from the walls of the chamber falling onto the substrate.

Lamination

In the lamination of the EVA protective layer dirt on either surface is a potential site for failure of the bond, leading to degradation of the active layers resulting in reduced cell life. The dirt also generates a visual defect which impairs the efficiency of the cell through shadowing of the light onto the cell surface.

The electronics, automotive and architectural glass industries processes for contact cleaning to remove debris in the lamination process are similar to the encapsulated solar cell in EVA film.

Multilayer structures

In the electronics industry, reduction in defects of over 30% can be achieved with the uses of contact cleaning and similar benefits would be available to the solar cell manufacturing industry in processes, which are dust sensitive. The benefits are particularly significant where cleaning is performed before each coating in a multilayer construction such as in third generation organic photovoltaic cells.

Significant increases in yield can be obtained by incorporating contact cleaning into the photovoltaic cell manufacturing process.

Reducing defects and scrap levels not only makes commercial sense for solar cell makers but also significantly improves the sustainability of the whole process.