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New Challenges in Photovoltaic Manufacturing

By Andreas Weisheit, Jean-Charles Cigal, and Greg Shuttleworth of Linde Electronics

Manufacturers of photovoltaic (PV) devices are under constant pressure to improve the cost per watt in order to drive market growth and compete with other forms of energy. Reducing manufacturing costs has enabled significant market growth, but continuing with this approach alone will meet with diminishing returns and profitability for manufacturers. Increasing the number of watts from the same device will also reduce the cost per watt, so there is a lot of recent attention on increasing efficiency. New materials and new applications are required to achieve these gains and this article describes some of the approaches being taken.

Backside Passivation

The photovoltaic effect relies on light generating free electrons from the photovoltaic material. Any loss of these electrons on their path to the electrical contacts reduces the efficiency of the device. Surface recombination, where electrons can combine with dangling bonds at the silicon surface, is one such mechanism and becomes more important to reduce as devices get thinner. Passivation of the surfaces ties up all the dangling bonds and provides a more neutral electrical surface to minimize electrical recombination. One material being studied as a passivation layer is aluminum oxide deposited by chemical vapor deposition (CVD) using tri-methyl aluminum (TMA). Results show that this process can lead to a one percent improvement in cell efficiency. TMA is routinely used for LED manufacture, and so the handling challenges are known but will be new to PV manufacturers.

N-Type Wafers

Traditionally p-type wafers as used by the semiconductor industry have been the substrate used for crystalline silicon (Si) solar cells. With the solar wafer market becoming important in its own right, manufacturers are now looking at what sort of wafers would be best for PV devices. P-type wafers are bulk doped with boron, but boron forms defects with oxygen present in the bulk material when exposed to light (a process known as light induced degradation) causing the efficiency of the cell to drop over time. Boron doped devices are also more sensitive to metal impurities, which can also cause recombination. N-type wafers, which are bulk doped with phosphorus, do not exhibit the same light induced degradation and, due to the difference in carrier type (holes rather than electrons), there is much less recombination due to metal impurities. The use of n-type wafers can lead to an increase in cell efficiency of up to one percent.

N-type wafers require the deposition of a p-type emitter, and boron tribromide (BBr3)

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is one material currently being studied as the boron source. This has similar properties to the phosphorus oxychloride (POCl3) traditionally used for the emitter with p-type wafers, and so it is only a material change rather than a material and process type change. Equipment manufacturers already offer the possibility to use either BBr3 or POCl3 with the same equipment, without or with only minor hardware modifications.

Dry Processing

Large tanks of wet chemicals have traditionally been used for cleaning, etching, texturing, and saw damage (from the wire sawing process used to slice silicon ingots into wafers) removal processes. The semiconductor industry has shown that dry processing, particularly as device dimensions reduce, offers more control and uses significantly less chemical materials, which makes safe treatment and disposal less of an environmental concern. As wafer thickness decreases, wafer handling in chemical baths becomes more problematic. Dry processing solutions already exist for thin single wafer mechanical handling from the chip packaging industry.

Wet processes also affect both sides of the wafer—as the devices become more complex, single-sided processing may be required. Thus companies are beginning to explore replacing wet processing with dry, and some have already implemented fluorinated gases for the texturing process. Clearly this is a significant change in both the process equipment and the materials required to manufacture PV devices, and, while this may not lead to a reduction in cost per watt in the current generation of devices, it is seen as an enabling technique for future high performance devices.

Selective Emitter

Traditional devices contain a uniform emitter layer on which contacts are deposited. Here, a balance needs to be reached between the high conductivity required at the contacts and the low conductivity that is ideal elsewhere. By selectively heavily doping only the area where the contacts will go, the cell efficiency can be increased by up to one percent. This does require a more complex process, and there are a range of techniques under investigation, including printing, laser treatment, or ion implantation.

Opportunities for Material Suppliers

While reducing manufacturing costs has enabled PV devices to reach a wider market and get closer to grid parity, a higher cell efficiency will also help lower the cost per watt. A wide range of new techniques to improve efficiencies are under investigation. Material changes and handling challenges are required for some of these, while for others, new techniques or a complete change in process technique is needed. Not all of the approaches described above may make it to mass production, however, the challenges of developing and delivering the required materials and the application know-how to better support the implementation of these processes provide many opportunities for material suppliers. ■

Andreas Weisheit is Head of Global PV at Linde; Jean-Charles Cigal is OEM Program Manager at Linde; and Greg Shuttleworth is Equipment Product Manager at Linde. For more information on Linde Electronics' innovative gas and chemical technologies for PV manufacturing, visit www.linde-gas.com/photovoltaics.

Linde is committed to developing new gas technologies to improve PV efficiencies.