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Project summary

This project has successfully developed new technologies for n-type silicon solar cells with efficiencies well above 20%, and which are compatible with mass production. Transfer of these technologies to industry will therefore help to further drive down the cost of PV modules in terms of $/Watt, making solar electricity more affordable, and more competitive with conventional electricity sources.

Solar cell production worldwide is currently dominated by the use of p-type silicon wafers. However, it has been established than n-type wafers offer some important advantages in terms of wafer quality – namely, they are much less affected by the presence of the most important defects and impurities that occur in p-type wafers. This project sought to exploit this advantage by developing new production technologies that allow high efficiency n-type solar cells to be made using industrially suitable techniques. New n-type technologies using the standard two-sided contacting design have been developed in collaboration with Trina Solar, and new processing methods for simplified fabrication of all-rear contact n-type solar cells have been developed.

Project scope

The project had two major components. The first involved a close collaboration with Trina Solar, the second largest module manufacturer worldwide, and the largest module supplier in the Australian market. Through this project, ANU and Trina Solar have jointly developed a low-cost process for the fabrication of n-type silicon solar cells using traditional production tools. These cells have metal contacts printed on both surfaces, and have a similar design and production cost to the industry standard p-type solar cells. However, due to the superior electronic quality of the n-type wafers, it is possible to reach higher cell efficiencies on n-type wafers.

In the second part of the project, we have developed new processes for the fabrication of even higher efficiency n-type solar cells based on a cell design in which all of the metal contacts are on the rear side. This approach reduces shading losses normally caused by the metal fingers on the front, but also requires very high quality wafers to maintain high efficiency. Such cells are generally quite complicated to fabricate, making them more expensive in production. In this project we have explored new methods to simplify the production of such rear-contact cells, therefore reducing their cost. Specifically, the new methods were: the use of ion implantation to introduce dopant atoms into the wafer surfaces, to replace the standard thermal diffusion steps; the use of liquid-jet guided laser processing to produce localised doping at low temperature; and the use of a new technique (known as sputtering) to produce thin layers of amorphous silicon for making high efficiency hybrid amorphous/crystalline silicon solar cells.

Outcomes

The collaboration with Trina Solar has led to the development of a simple and robust process for the fabrication of n-type solar cells using a traditional two-sided metallisation design. The process features a boron-doped front surface coated with a bi-layer stack of aluminium oxide and silicon nitride. The rear side has a phosphorus-doped region with a thin layer of silicon nitride. Metal contacts occur through the thin film layers. Using this new process, we have achieved efficiencies of 21.6% in the laboratory at ANU, and 20.5% on large area cells produced at Trina. These values are well above the standard cell efficiencies of around 19% for p-type substrates.

In the second part of the project, we have explored new methods for simplifying the production of higher efficiency rear-contact solar cells. The most promising of these is the use of ion implantation to introduce dopant atoms into the wafer surfaces. Ion implantation replaces the traditional high temperature dopant diffusion steps, and simplifies the fabrication sequence significantly, due to the fact that it allows perfectly single-sided doping, precise dose control, and permits attractive options for masking and patterning the doped regions. We have reached efficiencies as high as 21.7% for rear-contact solar cells in which all of the dopants are introduced by implantation. Analysis of our results indicates that efficiencies well above 23% should be possible with this approach. Liquid-jet laser doping was successfully used to fabricate 20.0% efficient double-sided contact solar cells. However, the complexity and reliability of this laser-based technique are likely to be significant barriers to the use of this approach in industry. The use of amorphous silicon layers deposited by sputtering was shown to have promise as a low-cost method for hybrid amorphous/crystalline silicon solar cells, although further development is required.

Effectiveness

The project was effective in building a strong partnership between ANU and Trina Solar, which will act as a foundation for expanded collaboration in the future. The project was also effective in developing new and innovative methods for reducing the complexity and cost of the n-type cell process, which necessarily involves more fabrication steps than the equivalent p-type process. There were, however, some significant challenges in transferring the techniques developed in the laboratories at ANU to the industrial setting in Trina Solar, due to the fact that the methods and equipment at the two organisations are in some cases quite different. Future projects of this nature would benefit from the availability of more industrially compatible equipment at ANU.

Transferability

The project has resulted in the development of new methods for accurately measuring the electronic quality of locally doped regions of solar cells. These methods will be valuable in the development of other silicon solar cell technologies at ANU and elsewhere. Through this project we have also been able to advance our cell fabrication capabilities at ANU to a new level, which will have broader benefits across our large research team for years to come. The use of ion implantation and sputtering for rear contact solar cells could also be broadened to other cell designs, such as the traditional two-sided metal contact design.

Conclusion and next steps

The project has succeeded in developing a new, simple and robust method for two-sided metal contact n-type solar cells in collaboration with Trina Solar, with efficiencies well above 20% on full-size cells produced at Trina Solar. This new n-type process is now being refined and tested on specialised R&D lines at Trina Solar, with the aim of implementing the technology in full production if it meets the required performance and yield targets. This would ultimately help to further drive down the cost of PV modules in the global market.

The project has also successfully developed to use of ion implantation as a method for simplifying the fabrication of rear contact solar cells. Efficiencies of 21.7% have already been achieved in an all-implanted rear contact solar cell made at ANU, and this approach is likely to lead to performance values above 23% in the near future. We intend to further develop this promising technology, and aim to commercialise it with industry partners in the coming years.