OVERVIEW ON THE USE OF LASER PROCESSING TECHNIQUES FOR HIGH-EFFICIENCY SILICON WAFER SOLAR CELLS

D.V. Tran and A.G. Aberle
Solar Energy Research Institute of Singapore (SERIS), National University of Singapore
4 Engineering Drive 3, Singapore 117576, Singapore

ABSTRACT

Laser processing techniques are improving rapidly and are increasingly employed in a variety of industries, including the photovoltaics (PV) industry. This paper provides an overview on the various laser techniques that have been used for developing highly efficient and industrially applicable silicon wafer solar cells.

1. METHODOLOGIES AND RESULTS

Presently, about 90% of all solar cells are made from mono- or multicrystalline silicon wafers. The standard metallisation method is based on screen printing (Ag grid on the front, blanket Al electrode on the rear). A typical screen-printed Si wafer solar cell is shown in Fig. 1 [1]. This solar cell has contributed significantly to the massive growth of the PV industry, with annual growth rates of over 30% during the last decade. However, the solar cell structure of Fig. 1 has major deficits with respect to short-circuit current (poor blue response, poor near-infrared response, large shading loss) and open-circuit voltage (poor rear surface recombination velocity), limiting its PV efficiency potential. To achieve higher efficiencies, solar cells with novel features are required.

Some of the potentially new features of silicon wafer based solar cells include: reduced wafer thickness, reduction of shading losses, improvements of the electrical and optical properties of the front and rear contacts, reductions of surface and bulk recombination, and, most importantly, reduced cost of production. Laser processing is increasingly being used in the PV industry and has been shown to have a lot of potential to improve the efficiency and lower the cost of production of the solar cells.

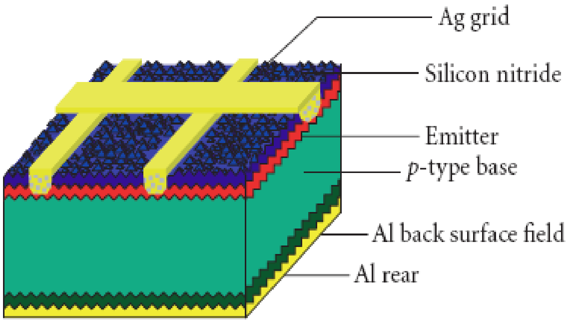

Figure 1: Screen-printed Si wafer solar cell [1].

The most established laser application in Si solar cell production is the edge isolation step [1]. A laser with nanosecond (ns) pulses and a wavelength of either 1064 nm or 532 nm can be used to electrically isolate the shunt path between the front-side emitter and the rear-side base contact, by scribing a 10-20 µm deep groove into the wafer. This process step improves the fill factor (and thus the efficiency) of the cells. The laser-based edge isolation step is becoming a standard process in the fabrication of screen-printed Si wafer solar cells, due to its potential for low cost and high throughput.

An early application of lasers to silicon wafer solar cells was the Laser Grooved Buried Contact (LGBC) cell shown in Fig. 2. The LGBC cell was invented in the 1980s at the University of New South Wales (UNSW) and has successfully been commercialized by BP Solar who operate a factory in Spain for such cells. BP Solar achieves LGBC cell efficiencies of 17-18% in production. The LGBC cell overcomes the main disadvantages associated with the front surface metallisation of screen-printed cells, namely poor blue response, large shading loss, and poor conductance of the grid lines. The LGBC cell improves these drawbacks by making grooves (~20 µm wide and ~30 µm deep) at the front surface by using an infrared or green laser with ns pulse duration. The grooves are then filled with copper using an electroplating process. As the grove is narrow, it reduces the shading loss of the solar cell. Also, because the conductivity of plated copper is higher than that of screen-printed silver, it helps to increase the efficiency of the solar cell.

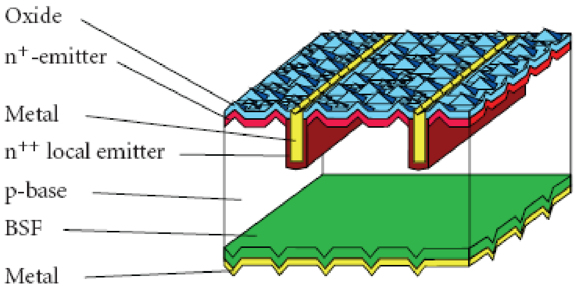

Figure 2: Laser Grooved Buried Contact (LGBC) solar cell [2].

While the LGBC cell improves the efficiency of the solar cell by modifying the front contact of the cell, the Laser-Fired Contact (LFC) technique developed recently [3] increases the cell efficiency by modifying the cell's back contact. It has been demonstrated in the 1990s that the Passivated Emitter and Rear Locally diffused Cell (PERL) can achieve an efficiency of as high as 24.7 % [4]. The most important features of this cell are a rear surface that is passivated by a dielectric layer (normally by thermally-grown SiO_2) and point-like contacts between the rear metal electrode and the rear surface of the Si wafer. This reduces surface recombination losses of minority carriers at the rear surface. For this cell, the point contacts are usually made by a photolithographic technique. The LFC technique recently invented eliminates this expensive photolithography step and creates point contacts with high throughput using scanning optics. The laser is again an infrared laser with ns pulses. Each laser pulse alloys the metal with the silicon through the dielectric layer. With the LFC technique, solar cell efficiencies of above 21 % have been demonstrated [3].

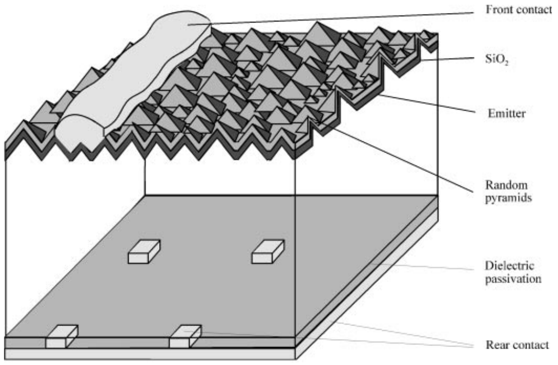

Figure 3: Laser Fired Contact (LFC) solar cell [3].

Very recently, a novel solar cell called "Rear Interdigitated Single Evaporation" (RISE) cell (Fig. 4a) and a modified version RISE-EWT (Fig. 4b, whereby EWT stands for Emitter-Wrap Through) have been developed [5]. An efficiency of over 21% has been achieved and the fabrication process has the potential to be transferred to production. These are all-back-contact solar cells and therefore the metal shading loss on the front surface is eliminated, boosting the short-circuit current. Lasers with the capability of generating wide ranges of pulse durations (from nanoseconds to femtoseconds) play a key role in making the back contact of these cells [5]. For the RISE cell, a laser is used to create a step height to separate the emitter and the base electrode in a simple way. A laser with ultrashort (picosecond) pulses has been demonstrated to effectively ablate a SiO_2 layer for contact opening without damaging the silicon substrate underneath. For the RISE-EWT solar cell, thousands of holes are drilled by a laser to create a connection between the n^+ emitter regions on the front and rear surface of the solar cell, see Fig. 4(b). The laser fired contact technique is used to create point contacts to the base of the solar cell, reducing surface recombination losses and thus increasing the efficiency of the cells.

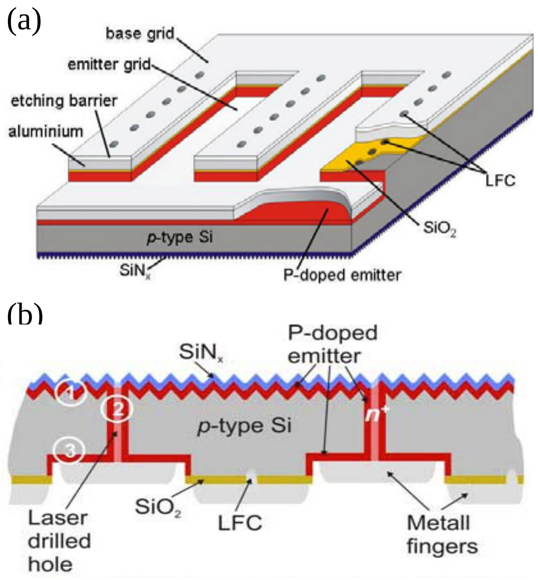

Figure 4: Rear Interdigitated Single Evaporation (RISE) solar cell (a) and RISE-EWT solar cell (b).

2. CONCLUSIONS

The laser techniques described above are just some of the possible applications of lasers in the PV industry. Si wafer solar cells involving laser processes are already in production, and several additional solar cell structures based on laser processing are expected to enter industrial production in the coming years.

REFERENCES

[1] D.-H. Neuhaus and A. Münzer, Industrial silicon wafer solar cells, Advances in OptoElectronics, **vol. 2007**, in: Special Issue "Recent Advances in Solar Cells", edited by A.G. Aberle.

[2] S.W. Glunz, High-efficiency crystalline silicon solar cells, Advances in OptoElectronics, **vol. 2007**, in: Special Issue "Recent Advances in Solar Cells", edited by A.G. Aberle.

[3] E. Schneiderlöchner, R. Preu, R. Lüdemann, and S.W. Glunz, Laser-fired rear contacts for crystalline silicon solar cells, Prog. Photovoltaics **10**, 29-34 (2002).

[4] J.H. Zhao, A.H. Wang, and M.A. Green, 24.5 % efficiency silicon PERT cells on MCZ substrates and 24.7% efficiency PERL cells on FZ substrates, Prog. Photovoltaics **7**, 471 (1999).

[5] P. Engelhart, N.P. Harder, A. Merkle et al., RISE: 21.5% efficient back junction silicon solar cell with laser technology as a key processing tool, Proc. 4th World Conf. on Solar Energy Conversion (Hawaii, 2006), p. 900.