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Experimental results on c-Si PV module delamination using a thermal process

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As penetration of photovoltaic modules into the energy generation mix grows and continues to accelerate, this global scale photovoltaic module deployment will lead in the near future to a waste problem, once PV modules start reaching the end of their serviceable lives (IEA, 2017). However, a cost effective and environmentally friendly way to recycle and/or reclaim valuable portions of PV modules, particularly the photovoltaic cells, is not yet known. The recovery of intact module contents is possible only after the delamination of PV modules, which poses a great challenge. Currently, there are three main approaches to delaminate PV modules: mechanical, thermal, and chemical treatments. However, only the thermal and chemical treatments offer potential for recovering the main components and materials of a PV module close to their original state (i.e. unbroken and undamaged). Both approaches are meant to attack the encapsulant (EVA) with the thermal treatment also potentially degrading the tedlar backsheet. This paper presents experiment results that were performed to examine and evaluate the delamination of PV modules using a **thermal treatment**. The thermal delamination process is based on separating module layers through the decomposition of EVA (ethylene vinyl acetate) and backsheet under high temperature.

First a TGA (Thermo Gravimetric Analysis) measurement was conducted on EVA and backsheet samples. The TGA indicated that the decomposition of EVA has two steps between 300℃ ~ 500℃, as shown in Figure 1. Based on this results, the heating profile, also shown in Figure 1, was designed with a ramp-up rate of 5℃/min to minimise glass breakage due to rapid temeprature change, while an annealing temperature of 480℃ allows the complete decomposition of EVA. Figure 2 shows the recovered intact cell, glass and metal contacts from a double-glass sample with a size of 5x5cm. The same heating profile was applied to a one-cell glass-backsheet module with size 20 x 20cm (see Figure 2). However, in this case the heating profile resulted in a broken PV cell, which suggest that the thermal treatment must be adjusted based on the module characteristics and size. The breakage of the cell is caused by the trapped between the cell and glass/backsheet from EVA decomposition process, while produces acetic acid or acetate. This issue was tackled by (Lee *et al.*, 2018) using a glass and backsheet patterning method that can release pressure as gas is created and it proved to be effective in prevent cell breakage. However, this approach fails to meet the goal to recover the solar glass intact as the patterning is made by creating penetrative cuts through the glass and backsheet.

Figure 1. TGA test for a glass-backsheet silicon module (left) and heating program (right)

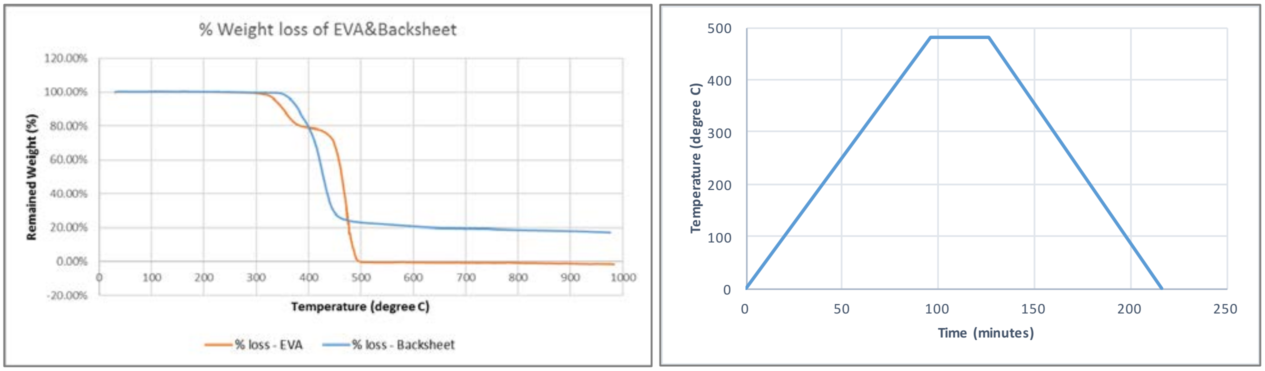
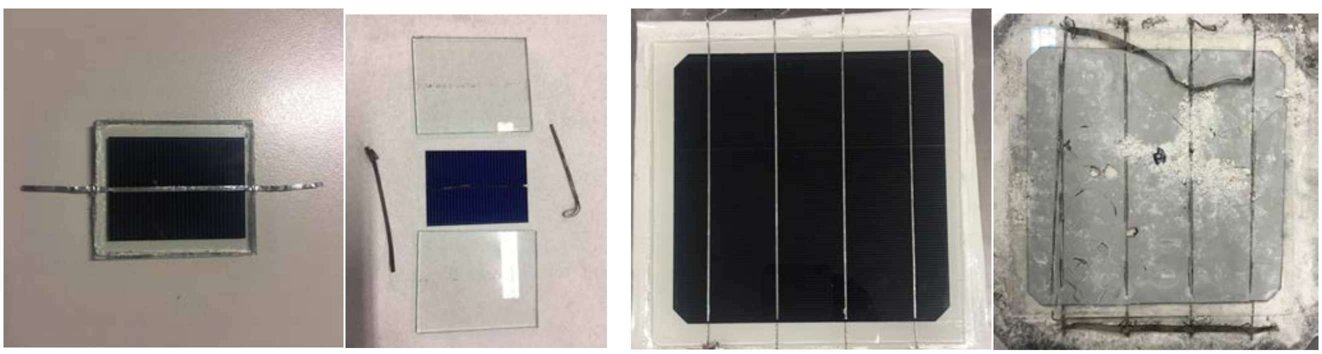


Figure 2. Recovered intact cell from mini-module (left) and broken cell from one-cell module (right)



Results shown that the thermal process requires a precisely designed heating profile that can eliminate the volume of released gas due to decomposition of EVA. Hence, several heating programs were developed and tested, including step-heating and repeated-heating profiles to minimize sudden and large production of gases. However, further research is required to minimize the breakage issue with thermal processes.

At the same time, based on the difficulties and limitations met during the delamination process, some suggestions for improving the recyclability of PV module are made based on different module designs, such as rescale the silicon cell size to minimize the breakage, or looking for a new encapsulant material that can be removed without significant releases of gas.

References

Lee, J. K. *et al.* (2018) 'Simple pretreatment processes for successful reclamation and remanufacturing of crystalline silicon solar cells', *Progress in Photovoltaics: Research and Applications*, 26(3), pp. 179–187.

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