Improved heat dissipation for hot spots in MWT laminates

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ABSTRACT

The effect of leakage current in H-pattern and MWT laminates is investigated by thermal imaging. Degradation of the laminates was assessed by visual appearance and by the IV power output. The laminates were exposed to a reverse voltage for up to an hour. Depending on the leakage current, the laminates were locally heated. When the temperature reaches above the lamination temperature, severe damage occurs instantly. For similar leakage current, we observe a smaller temperature increase in MWT laminates than in H-pattern laminates. A possible mechanism for the reduced effect in MWT laminates is given.

1. INTRODUCTION

ECN Solar Energy has developed a high-efficiency module process, based on back contact MWT cells and a conductive back sheet foil, with a combined low temperature interconnection and lamination step. The module manufacturing process is suitable for thin wafers, allowing for significant cost reduction.[1]

Higher cell efficiencies in combination with a trend towards 72-cell modules increase the maximum power point current and voltage per bypass diode. [2] This results in increased power dissipation during the IEC-61215 hot spot endurance test. For example, a partially shaded cell in a 24-cell string with 19% efficiency cells will be exposed to 40% more power dissipation, compared to a shaded cell in a 20-cell string of 16%-efficiency. In addition to the magnitude of the current that flows under a reverse voltage, the distribution of this leakage current I_{leak} is also important. In the literature, I_{leak} is also referred to as I_{rev}. If the cell contains hot spots, heat dissipation will be localised which might result in thermal damage of the cell or the laminate. [3]

2. EXPERIMENTAL

2.1 Sample selection

We investigated potentially adverse effects of leakage current on single-cell laminates. N-type MWT and H-pattern cells with I_{leak} ranging from 0 to 8 A were selected. These cells are representative of the variety of hot spot patterns as identified by voltage modulated lock-in thermography (VoMoLIT). The VoMoLIT images are shown in the left-hand columns of Fig. 1-3. Typically in H-pattern cells one or two single hot spots or lines are visible. In contrast, in MWT-cells, the current flows mainly through the vias.

2.2 Leakage current exposure set-up

The laminates were exposed to a reverse voltage of -10 V in the dark for up to one hour at a base temperature of 50°C. IR images of the back sheet side were taken during the exposure to quantify and visualise the temperature increases, as shown in the right-hand columns of Fig. 1-3. The maximum observable temperature of the camera was 160°C, just above the typical lamination temperature of EVA.

The experiment was stopped if a premature failing of the laminate was observed, e.g. delamination of the back sheet foil or cracking of the glass.

Before and after exposure the IV power output of the laminates was measured and EL images were taken to assess the presence or absence of damage.

3. RESULTS

3.1 Low leakage current

The VoMoLIT and IR images for two cells with I_{leak}≈0.5 A at -10 V are shown in Fig. 1. For ease of comparing, all VoMoLIT pictures and all IR images are shown on the same temperature scales. The IR scale ranges from 40°C (black) to 160°C (white).

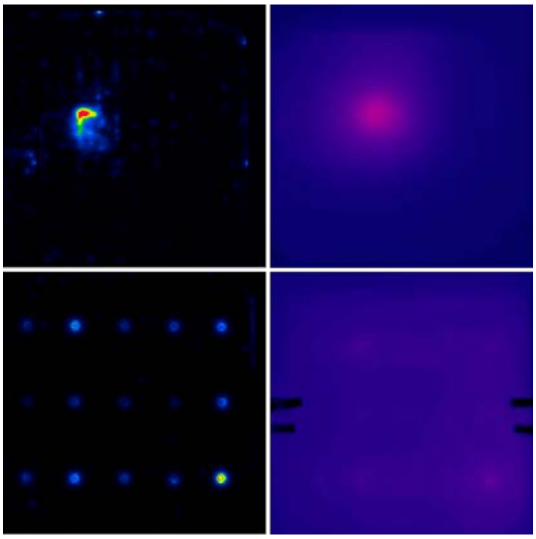

Fig. 1 VoMoLIT (left) and IR (right) images of samples with low leakage current, showing n-type H-pattern (top) and n-type MWT (bottom). The temperature scale for all VoMoLIT pictures is the same; the IR images are also all on the same scale.

The H-pattern cell exhibited a single spot with only a weak VoMoLIT signal. During the one-hour exposure to -10 V, the "hot spot" appears in the IR image with a maximum temperature T_m=77°C. The VoMoLIT image of the MWT cell shows all vias, with varying but low intensity. In the IR picture, these vias are just detectible above the ambient temperature of 50°C with a maximum at T_m=62°C.

After one hour at -10 V, the laminates did not show any visual signs of damage. The power outputs of both laminates were also unchanged within the experimental accuracy. Other laminates with I_{leak}<1 A confirm that small increases in temperature (T_m<100°C) cause no damage at all for both MWT and H-pattern laminates.

3.2 High leakage current

Fig. 2 shows the VoMoLIT and IR images for two cells with high leakage current I_{leak}≈7 A. The shunt in the H-pattern cell (top left) saturates the camera. Also all vias in the MWT cell (bottom left) are clearly visible. The corresponding IR pictures show the same pattern for each cell as the VoMoLIT.

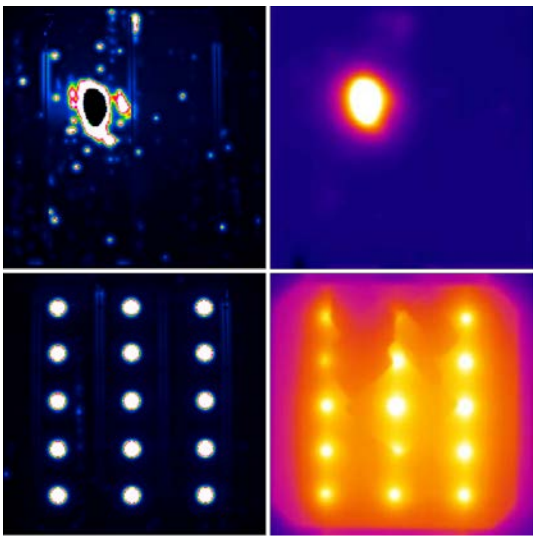

Fig. 2 Same layout as Fig. 1, showing samples with I_{leak}≈7 A. (top left) the black centre of the "hot spot" is due to saturation of the camera.

The laminates reach temperatures above the lamination temperature (T>150°C) for both cell types when I_{leak}>4 A (power dissipation > 40 W). These temperatures are reached within a few minutes and cause severe failure of the laminates: the glass is fractured; the back sheet forms a large blister or the surface of the solar cell becomes discoloured.

Power output measurements showed rather modest decreases of up to 3%. Nevertheless, these laminates would fail the IEC visual criteria, as damaged cell surfaces, delaminated back sheets and fractured glass were observed. Also EL images show cracks in the wafers. The EL signal at the hot spot was significantly reduced.

3.3 Intermediate leakage current

We have shown that at power dissipation >40 W all laminates fail as surface temperatures reach >160°C. For power dissipation <10 W, only modest increases of 10 to 20°C are seen without any effect on output and appearance. The following section will focus on samples with I_{leak}≈1.0-4.0 A (dissipation 10 - 40 W). Typical results of the leakage current test in the dark of these laminates are summarised in Table 1.

Table 1 The leakage current, maximum observed temperature and change in power output of three laminates.

type	I_{leak} [A]	T_m [°C]	Δη [%]
H	2.6	>160	+0.06
MWT	3.1	105	-0.02
H	1.3	110	-0.05

Two cells with I_{leak}≈2.5-3.0 A are displayed in the VoMoLIT images of Fig. 3. They clearly show the vias in the MWT cell and the hot spots (linear shaped) in the H-pattern cell, though in both samples the associated heat dissipation is lower than in Fig. 2.

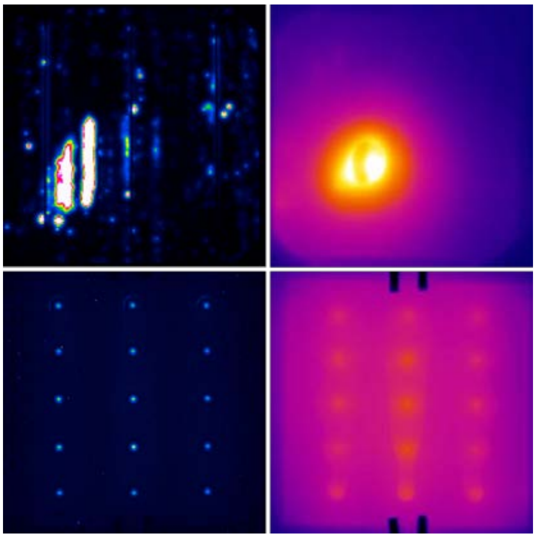

Fig. 3 Same layout as Fig. 1, showing samples with I_{leak}≈2 A.

The corresponding IR images, however, show a significant difference between the two samples. Whereas the hotspot feature of the H-pattern cell is translated to a big blister and an observed temperature of the back sheet of T>160°C, the MWT cell shows only moderately heated vias with T=105°C.

The data in table 1 shows that for similar I_{leak}≈2.5-3.0 A, the MWT laminate exhibits a lower maximum temperature. Similarly, an I_{leak}=1.3 A is sufficient for an H-pattern laminate to reach the same temperature T_m≈105°C as an MWT laminate with I_{leak}=3.1 A.

Intermediate values, I_{leak}≈1.0-4.0 A, MWT cell laminates showed a significantly lower T_m compared to H-pattern cell laminates. Surprisingly, this has no effect on the change in power output after exposure. Only in a single case, where damage to the front side, i.e. broken glass, was observed, did we also observe a 2% reduction in power.

4. DISCUSSION

In Fig. 4 the observed maximum temperature is plotted as a function of the leakage current. In all samples with T_m>160°C damage of the front or the rear side was observed. Front side damage is accompanied with a small 2-3% reduction in output power.

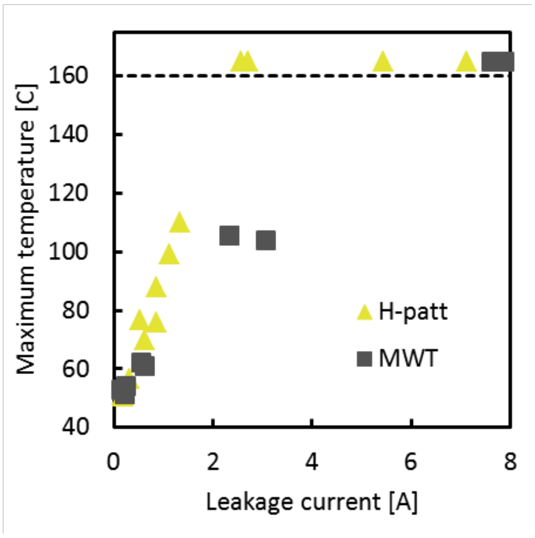

Fig. 4 Maximum observed temperature as a function of the leakage current for H-pattern laminates (triangles) and MWT laminates (squares). The dashed line indicates the upper limit of the camera.

As highlighted in Table 1, the temperature increase in MWT laminates is lower than in H-pattern laminates for similar leakage current. The maximum temperature increases by about 50°C/A for the H-pattern laminates, whereas for the MWT laminates the slope is 24°C/A. As the power dissipation P=VI in all laminates is proportional to I_{leak}, the magnitude of the power dissipation cannot explain the observed differences in T_m between H-pattern and MWT laminates.

The VoMoLIT images in Fig. 2 and Fig. 3 clearly show the differences in current flow patterns between H-pattern and MWT cells when a negative, reverse, voltage is applied. For H-pattern cells the current flows through a single spot. As a consequence the power dissipation is concentrated, causing the temperature to reach damaging levels when I_{leak}>2 A (as shown in the corresponding IR images). In contrast, in MWT cells the current is divided over all vias. This dilutes the local power density and thereby limits T_m for the same power dissipation.

5. CONCLUSIONS

To conclude, reverse voltage in MWT-back contact modules cause less thermally-induced damage than in H-pattern modules with similar I_{leak}, due to distribution of the power dissipation over the vias. Comparable results are expected for p-type solar cells. The results warrant a closer evaluation of the maximum permissible I_{leak} for commercial MWT cells relative to that for H-pattern cells.

REFERENCES

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