AGEING OF AMORPHOUS SILICON DEVICES IN DEPENDENCE OF IRRADIANCE DOSE

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ABSTRACT

The ageing behaviour of amorphous silicon (a-Si) devices is investigated in dependence of different light and temperature conditions. Eight a-Si mini-modules are illuminated and kept at constant temperature in an environmental chamber. The ageing behaviour is characterised in terms of a temperature-dependent irradiance dose rather than the exposure time or irradiance dependence in order to investigate possible ageing dependencies of environmental strains and to develop models for device long-term degradation.

1. INTRODUCTION

The ageing behaviour of a-Si modules is typically characterised in two stages, i.e. a strong degradation in the beginning of the operating life (the Staebler Wronski effect [1]) and a smaller steady degradation afterwards. The factors driving either process have not been fully understood and quantified yet, especially not in a location specific dependence [2]. This work aims to contribute with the development of a new ageing prediction model.

Based on the thesis that the ageing processes can be modelled by an Arrhenius like behaviour, one can introduce a temperature dependent ageing. The parameter for this can be determined in the laboratory. An indoor light-soaking accelerating test for single-junction a-Si devices has been carried out and a dose model is presented here.

2. EXPERIMENTAL SETUP

The indoor test was set up in an environmental chamber to cool the devices (see Fig. 1). The chamber is separated into four sections with different light conditions. The first two sections utilise halogen lights at different intensities. The third section is equipped with cool white LED lights and the fourth one is left in dark condition (as a reference section). The different light sources have been included to investigate the possible secondary effects of different irradiance spectra on ageing. The chamber temperature is set to 25ºC. Module temperature varies nevertheless, as different irradiance profiles will cause different temperatures and rather small heat diffusers were chosen in this initial experiment. This test was running up to 1000 hours interrupted for *I-V* measurements at 0h, 100h, 250h, 500h and 1000h of exposure. The analysis of PV device degradation with respect to irradiance dose is based on these measurements. This means that ageing will be largely based on Staebler Wronski Degradation.

3. DEFINITION OF IRRADIANCE DOSE

An irradiance dose can be defined through an Arrhenius model as:

$$d = Ge^{-E_a/RT}\Delta t \tag{1}$$

where G represents the irradiance, T is the module’s operating temperature, Δt is the exposure time and R is the gas constant. E_a represents the activation energy for degradation process, which is assumed to be constant.

Fig. 1 Chamber setup for ageing test.

4. AGEING BEHAVIOURS VERSUS TIME

The ageing of device’s power at maximum power point (P_{MPP}) versus exposure time is shown in Fig. 2. Eight a-Si single-junction mini-modules (two for each section of the chamber) are used in this study. RS1 and RS2 are the devices in dark chamber, which show no degradation. LD1 and LD2 are devices illuminated under LED lights. They exhibit the largest degradation of up to 30% over 1000h. Other devices illuminated under halogen lights show less degradation between 18-24%, despite the higher amount of light being absorbed. The conclusion from this is that the quantity of light is – as expected – not the only driving factor in the ageing.

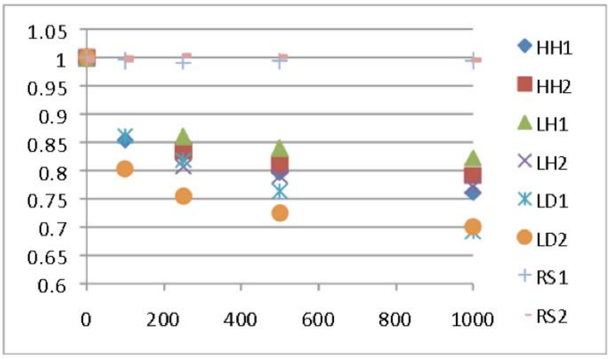

Fig. 2 Normalised P_{MPP} versus exposure time.

Different ageing behaviour has been observed for devices operating at different irradiance and temperature conditions. It is proposed to investigated this against the irradiance dose as defined in Eq(1), in order to gain a better understanding of the influencing factors for the differences in ageing rates.

5. AGEING BEHAVIOURS VERSUS DOSE

The dose varies with irradiance and temperature, assuming E_a is identical (e.g. 20KJ/mol) for the devices. The halogen lights generate larger irradiance than LED lights, but largely in the IR region. However, devices under halogen lights degrade not faster. On the contrary, LED lights cause greater degradation to devices as shown in Fig. 2. This is due to different spectra of lights and device degradation is caused by photons of large energies only. LED lights have larger contribution of high energy photons. The module temperature in first two sections under halogen lights is 51-54°C and 61-63°C, respectively. This is much higher than the module temperature under LED lights, which is 36-37°C. At this moment in time, it is not clear if the spectrum or the temperature is determining the rate of degradation. With the different irradiance and temperature profiles, the dose for different devices can be calculated and the ageing against dose is analysed (see Fig. 3).

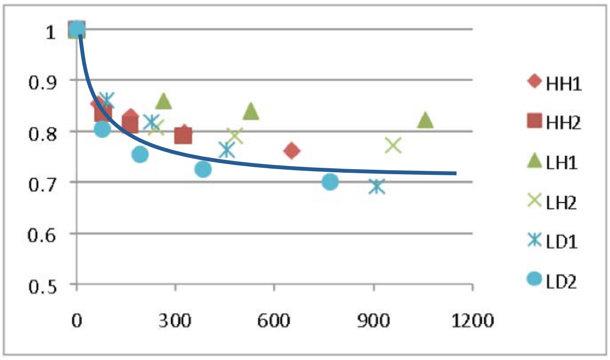

Fig. 3 Normalised P_{MPP} versus irradiance dose.

Fig. 3 shows a good agreement between the ageing performance and the dose except for two devices, i.e. SJ007 and SJ008, which are placed in the second section of the chamber with much elevated temperatures. They show a smaller average degradation rate (0.02%/Wh of dose) than the devices exhibiting low (SJ010, SJ011) and median (SJ002, SJ019) temperature profiles, whose degradation rate is around 0.034%/Wh. This can be explained by the annealing effect and devices recover their loss in power significantly when temperature is high [3]. This also confirms that the ageing in power has relative large temperature dependency as it is observed outdoors [4].

Thus, a model dealing with the annealing effect needs to be considered for a-Si devices operating at high temperature in future work.

6. ANALYSIS OF CARRIER LIFETIME-MOBILITY PRODUCT

The carrier lifetime and mobility product ($\mu\tau$) is considered as a degradation driven factor for a-Si devices. It is extracted from the *I-V* measurements [5] and analysed against irradiance dose (see Fig. 4). It demonstrates a very good agreement for all devices between the degradation in $\mu\tau$ and the dose. As indicated by the solid line in Fig. 4, all devices show the similar ageing behaviours and degrade 50% in the first 150Wh of dose, i.e. at the degradation rate of 0.33%/Wh. Then the ageing rate slows down to 0.016%/Wh afterwards.

The temperature dependence for the ageing of $\mu\tau$ is relatively small. Devices with higher temperature profiles seem to degrade less, but this trend is not as obvious as that of P_{MPP}.

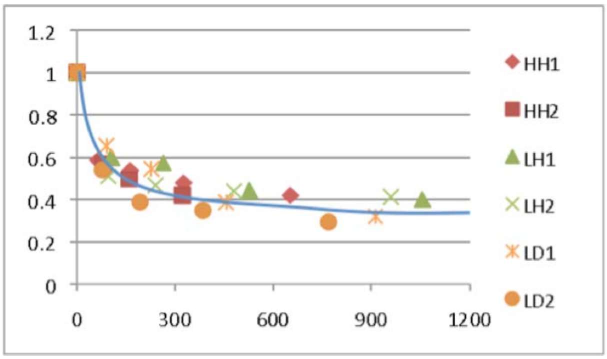

Fig. 4 Normalised $\mu\tau$ versus irradiance dose.

7. CONCLUSIONS

The ageing behaviour of a-Si single-junction devices in dependence of the proposed irradiance dose has been investigated. The ageing of P_{MPP} for devices at low or median temperature profiles shows a good agreement with dose. Devices with higher temperature profiles degrade slower. This could be due to thermal annealing counteracting degradation. Ongoing work is on characterising this by a second dose model. Ageing of $\mu\tau$ has relative low temperature dependence and thus shows a very good agreement with dose for all devices with different temperature profiles.

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