

# POWER CHANGE IN AMORPHOUS SILICON SOLAR MODULES INDUCED BY LOW TEMPERATURE ANNEALING AND IRRADIANCE

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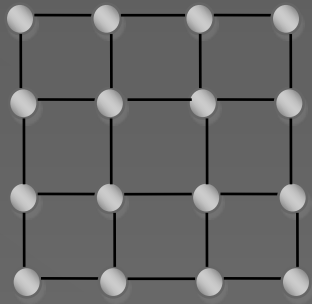


# Outline

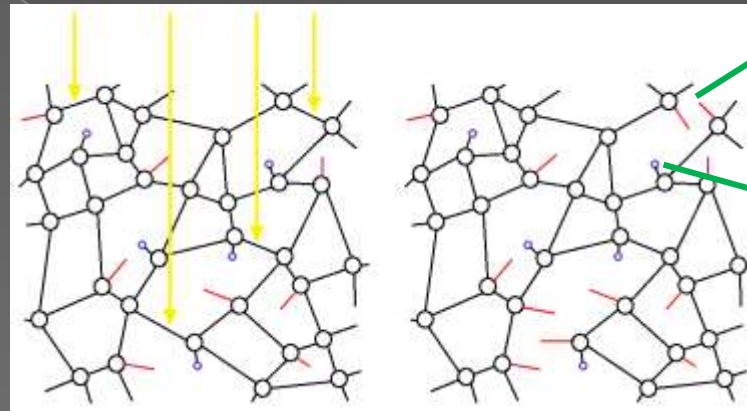
- ◉ Metastabilities
- ◉ Experimental scheme
- ◉ Pretreatment
- ◉ Annealing
- ◉ Arrhenious Behaviour
- ◉ Conclusion

# Metastabilities in amorphous silicon PV modules

## Structure



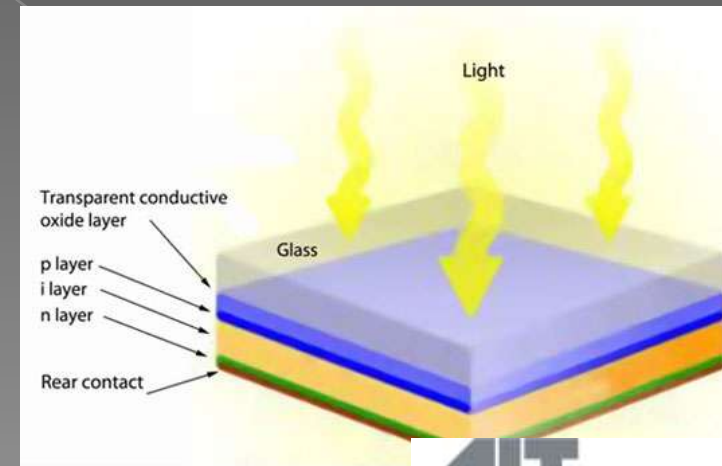
Crystalline



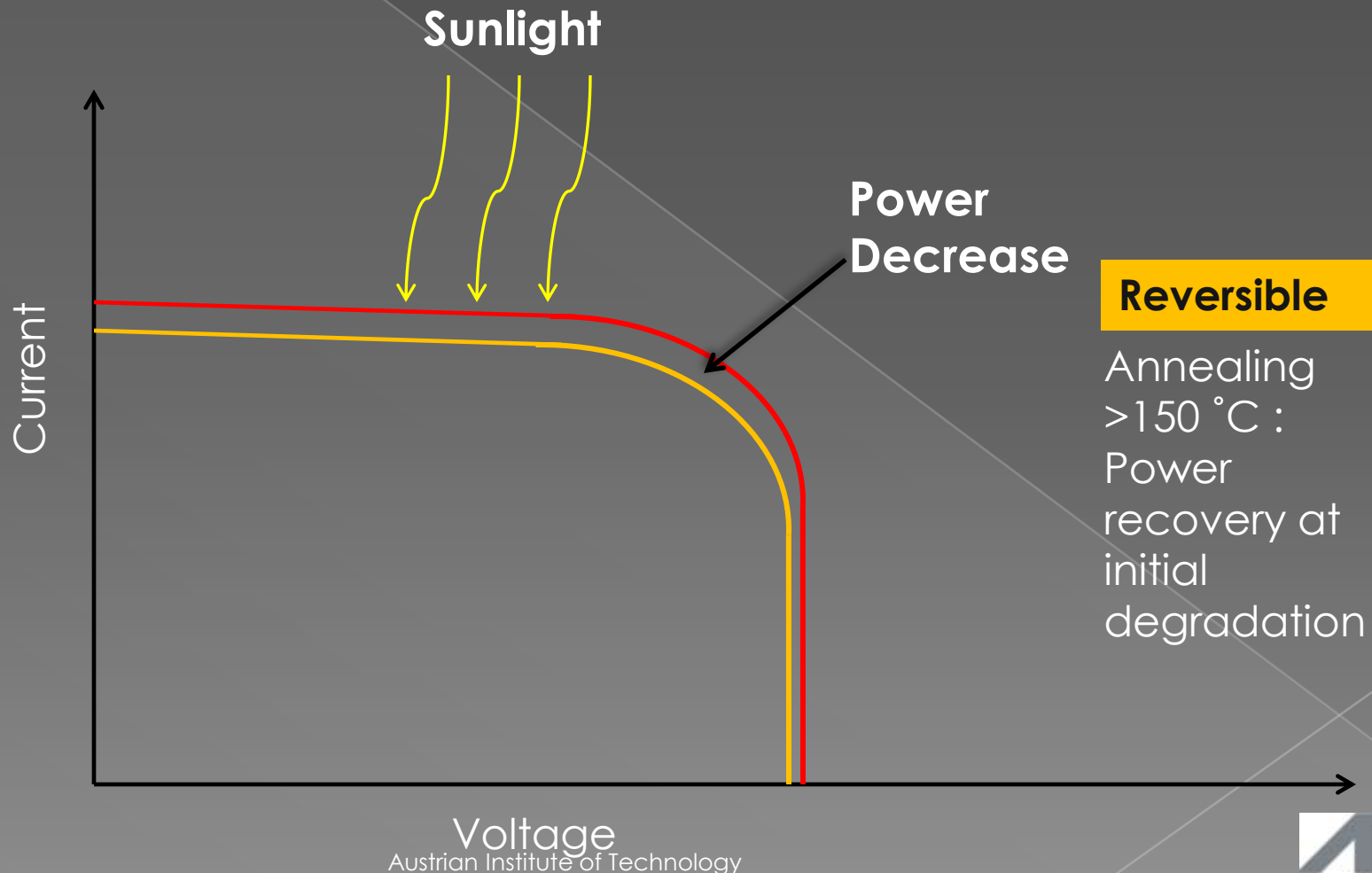
Amorphous

Dangling bond

Hydrogen atom

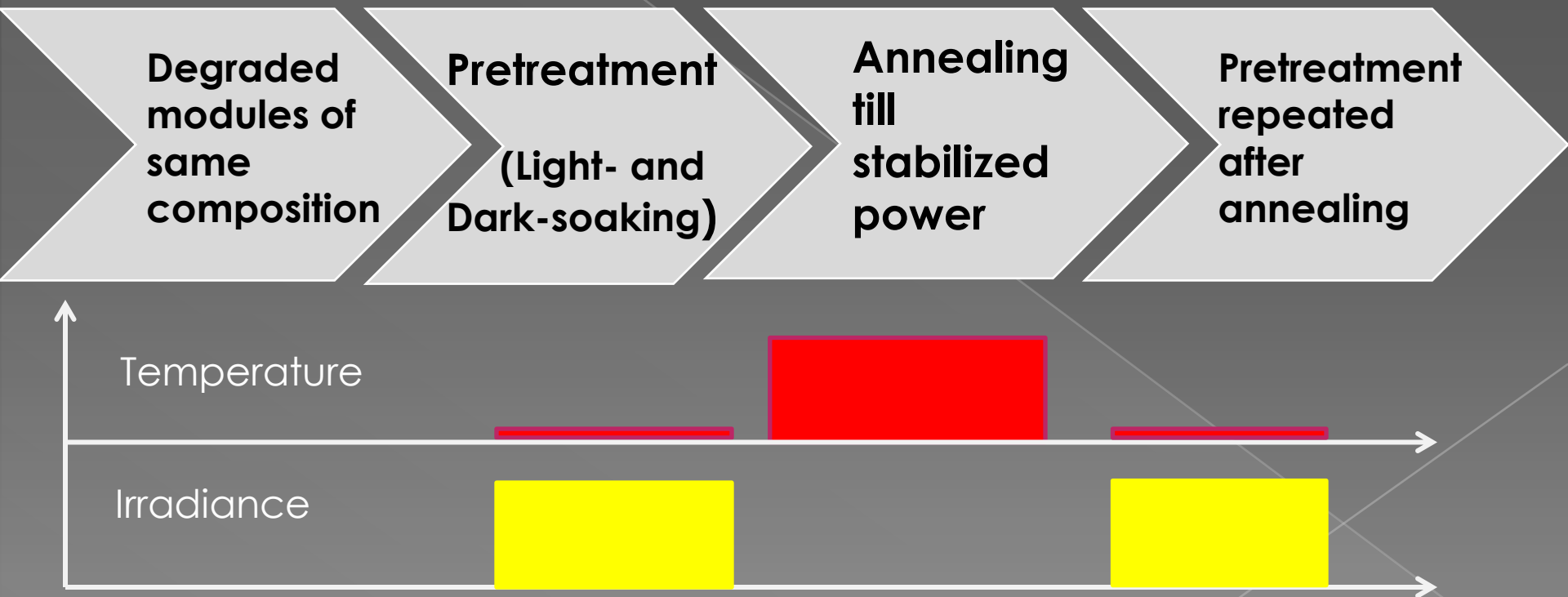


# Degradation

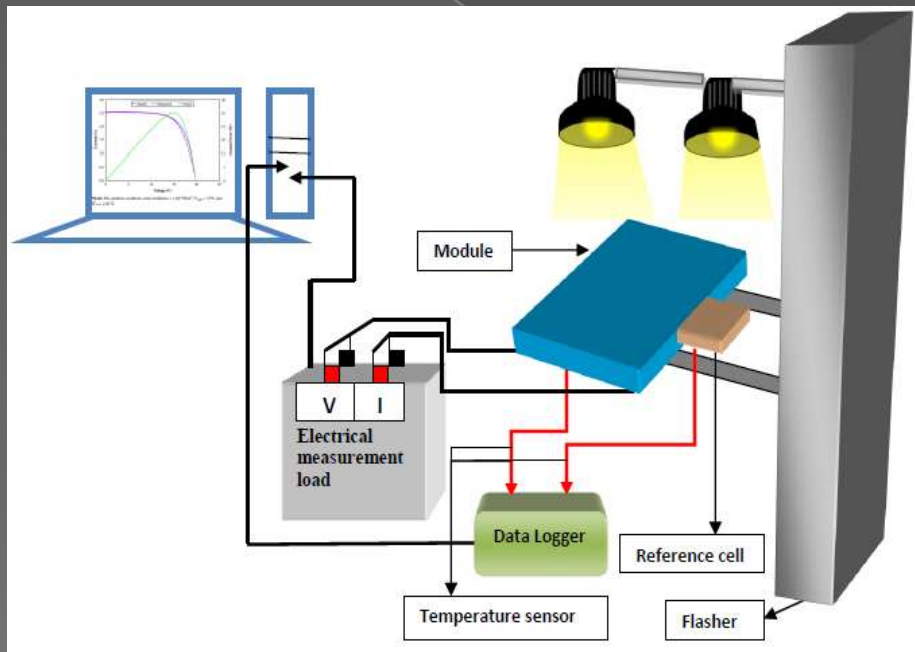


# Experimental Scheme

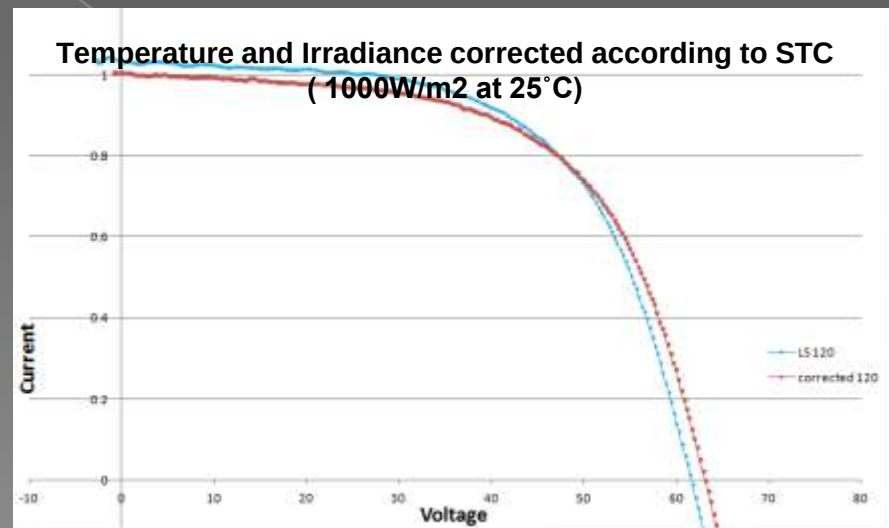
- The basic protocol for analyzing effect of temperature at 60-70°C and ~ 50 W/m<sup>2</sup> irradiance.



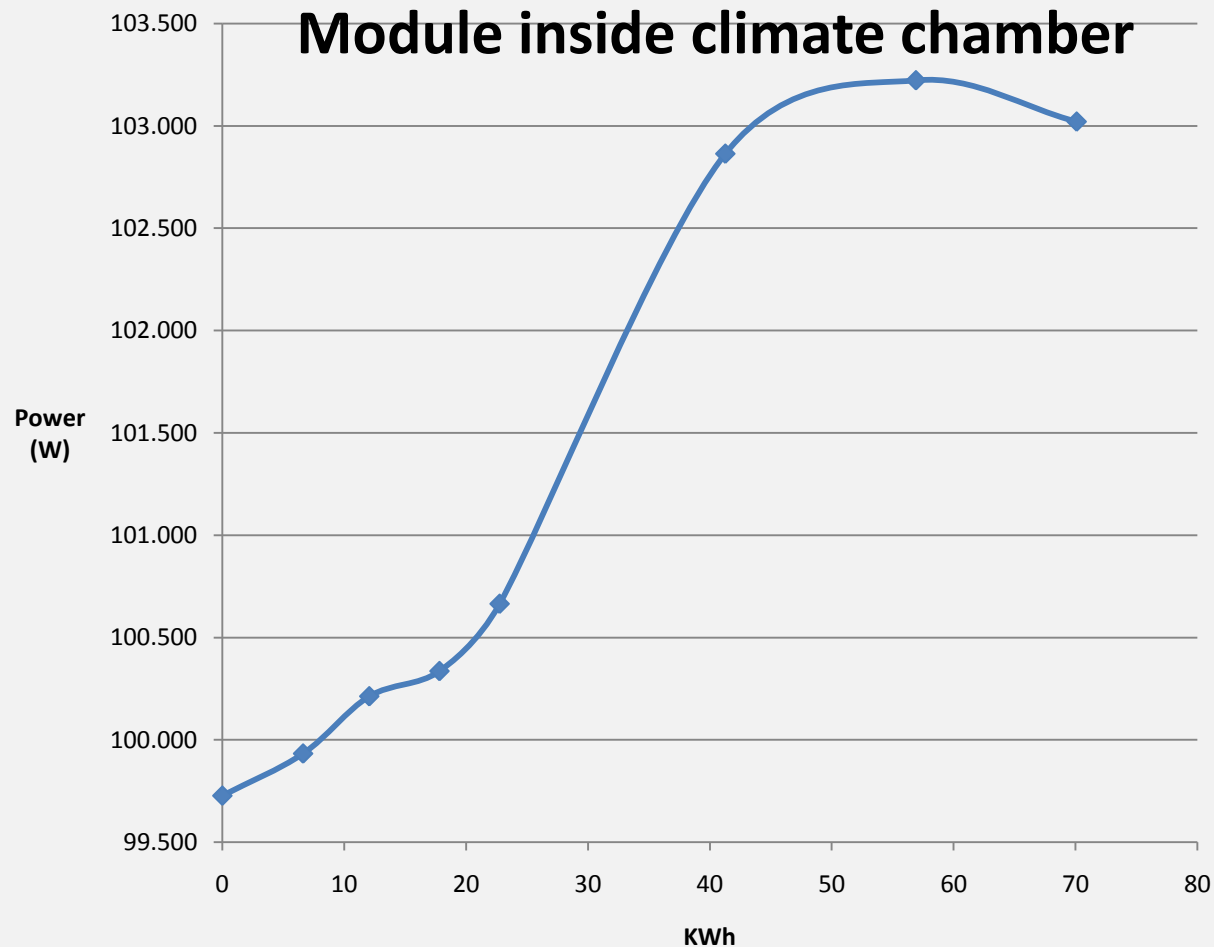
# Pretreatment Procedure



Data treatment  
according to IEC 60891



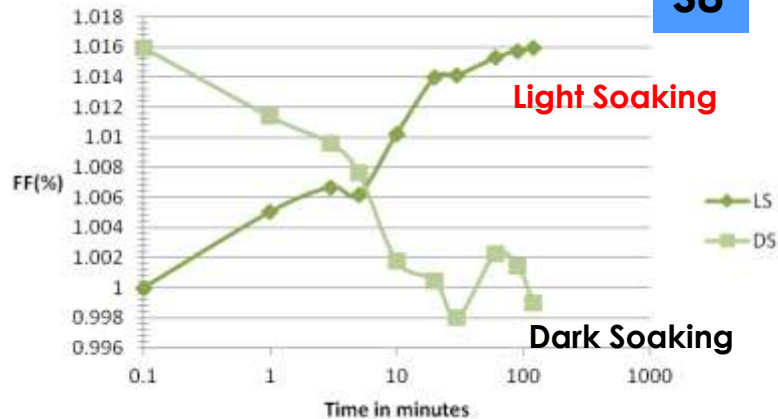
# Annealing at 65 °C



# Pretreatment results

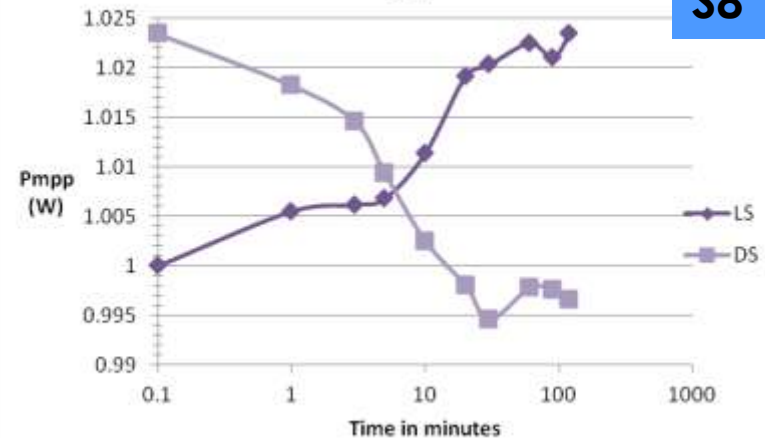
Fill factor

S8



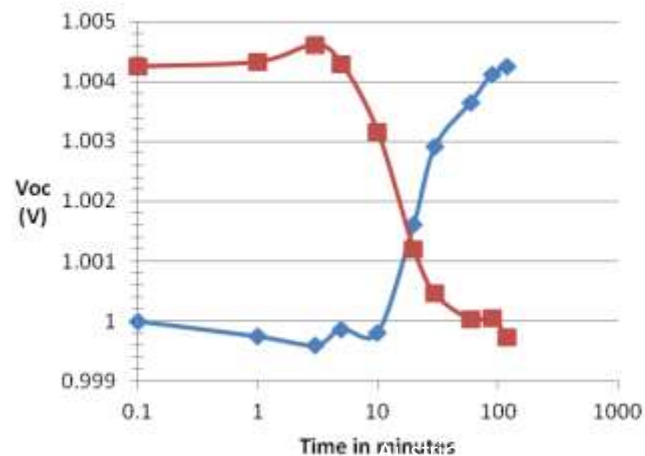
Pmpp

S8



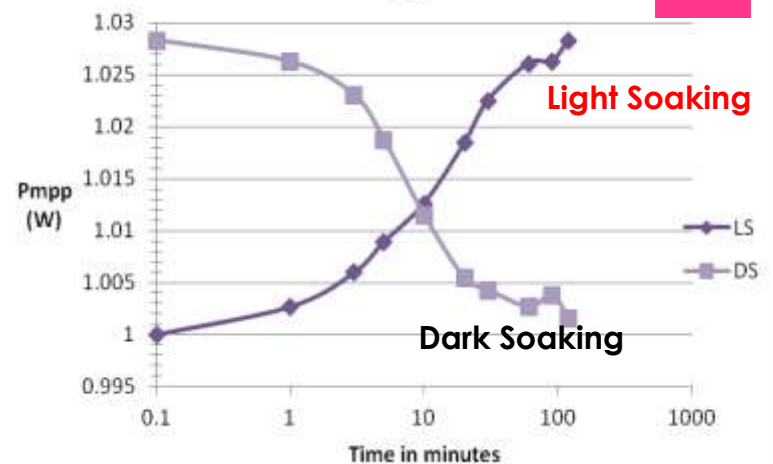
Voc normalised

S1

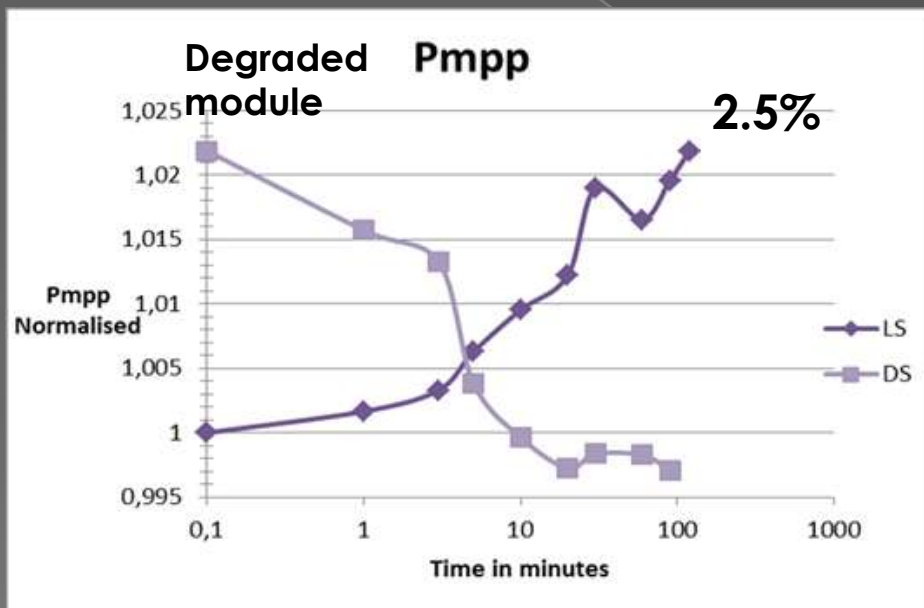
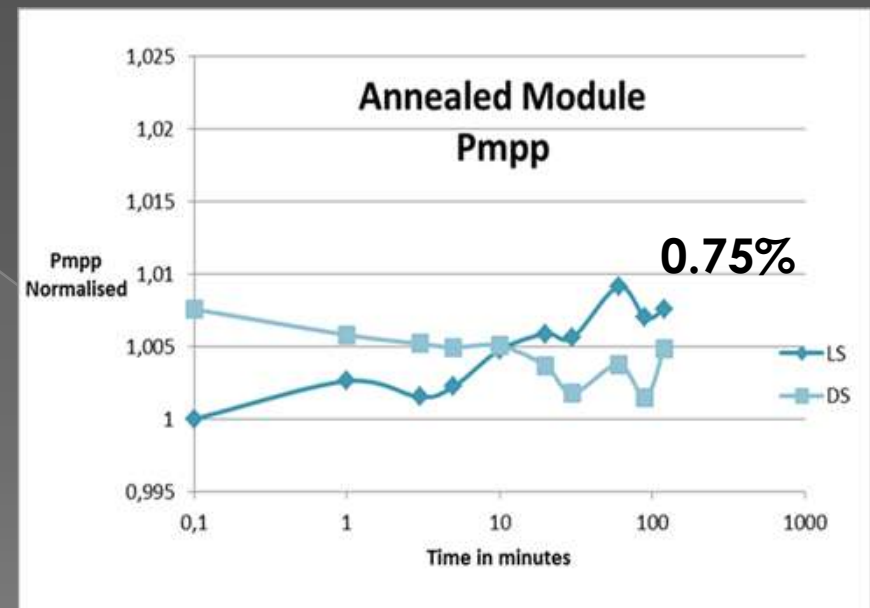


Pmpp

S1

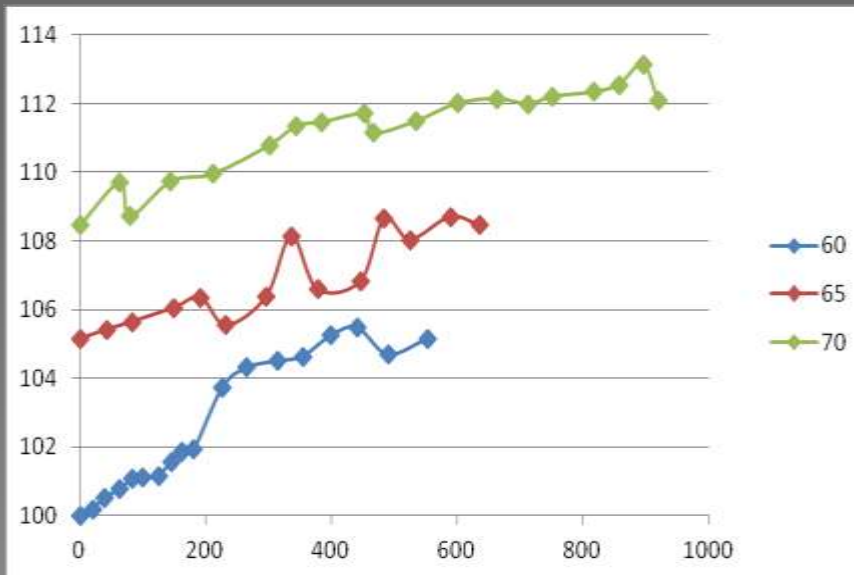
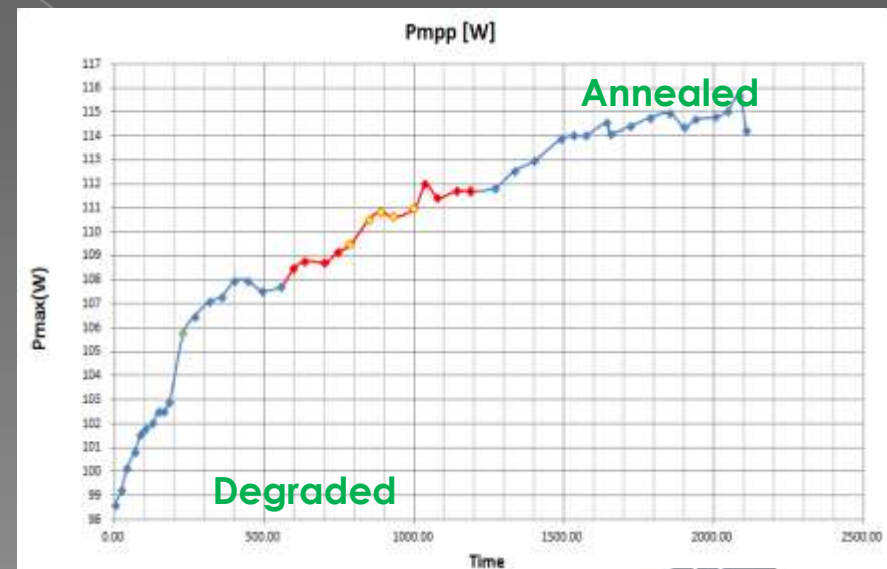


# Pretreatment amplitude before and after annealing

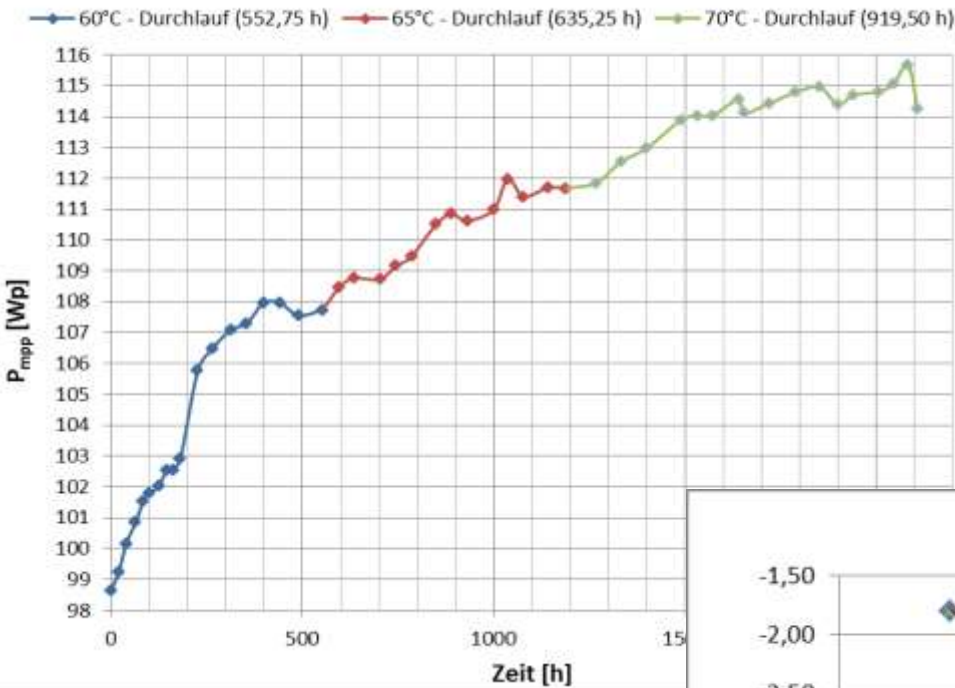


# Power change from Annealing

| Temp. [°C] | $P_{mpp}$ [Wp] | Absolute power Enhancement [Wp] | $P_{mpp}$ [%] | Relative power enhancement [%] | 116 Wp = 100 % |       |
|------------|----------------|---------------------------------|---------------|--------------------------------|----------------|-------|
| 25         | 98,6           |                                 | 100           |                                | 85,0           |       |
| 60         | 107,7          | + 9,1                           | 109,2         | + 9,2                          | 92,9           | + 7,9 |
| 65         | 111,7          | + 4,0                           | 113,2         | + 4,0                          | 96,3           | + 3,4 |
| 70         | 114,9          | + 3,2                           | 116,5         | + 3,3                          | 99,0           | + 2,7 |

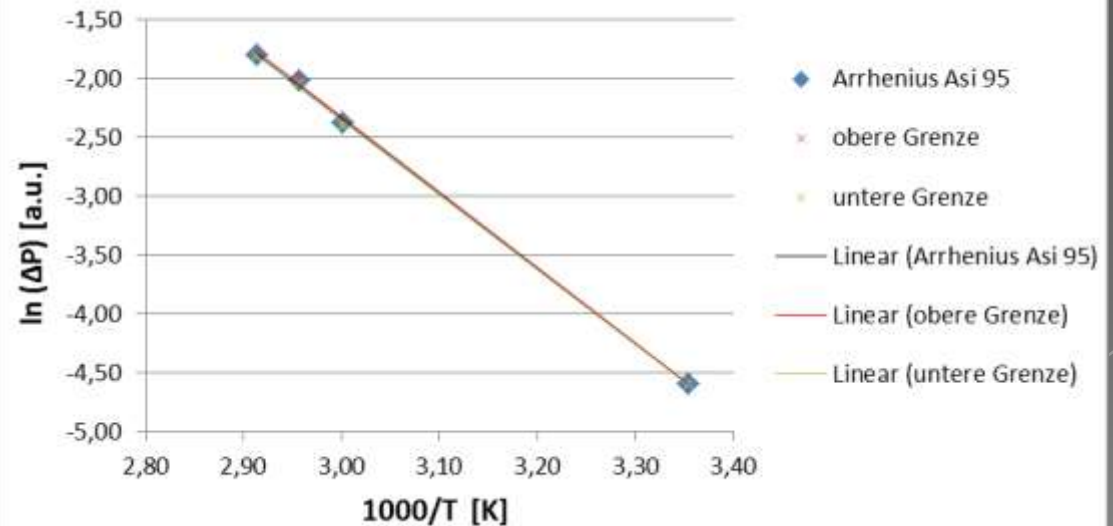


### Schott ASI 95

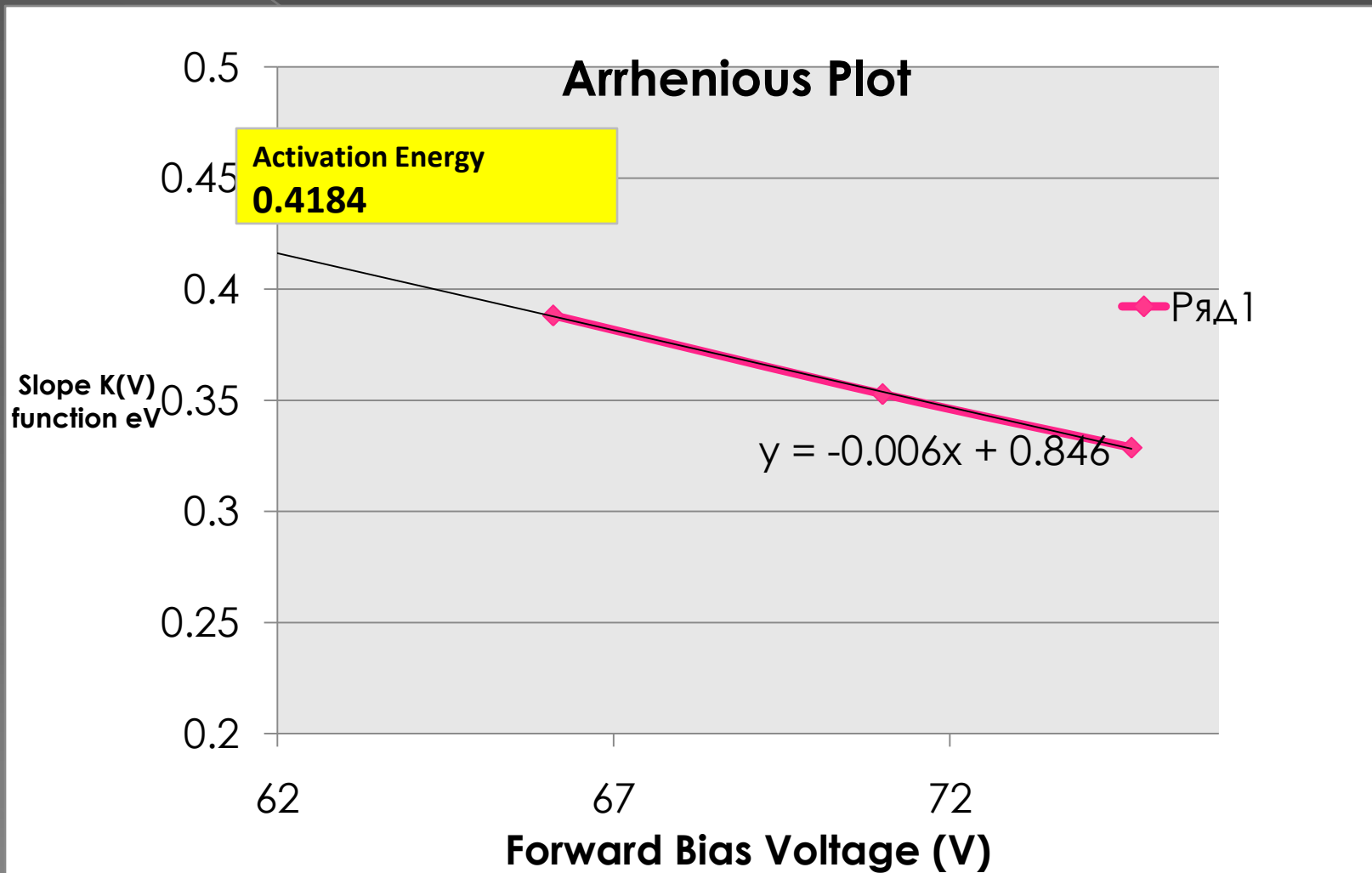


## Arrhenious Behaviour

### Arrhenius Schott ASI 95



# Activation energy for a-Si



# Possible reasons

- A change in power to its initial value suggests a change in structure.
- Studies say that Si-H<sub>2</sub> bonds generally reacts to low temperature.
- Si-H<sub>2</sub> bonds exist in shallow traps which correlate with having enough activation energy at low annealing temperatures.

# Conclusion

- Power change is dependent upon low level irradiance and temperature.
- Modules showed short term metatstabiliy.
- Need to be dark soaked before measuring.
- Low temperature annealing correlates to defects annihilation in a-Si.

# Thank you!

# IEC 60891 “Procedures for temperature and irradiance corrections to measured I-V characteristics ”



$$I_{corr} = I_{md,meas} + I_{sc,md,meas} \times \left( \frac{1000 \text{ W/m}^2}{G_{meas}} - 1 \right) + \alpha \times (25^\circ\text{C} - T_{md,meas})$$
$$V_{corr} = V_{md,meas} - R_s \times (I_{corr} - I_{md,meas}) - k \times I_{corr} \times (25^\circ\text{C} - T_{md,meas}) + \beta \times (25^\circ\text{C} - T_{md,meas})$$

$I_{md,meas}$ ,  $V_{md,meas}$ : the measured current and voltage points of the testing module

$I_{corr}$ ,  $V_{corr}$ : the corrected points corresponding to measured points

$I_{sc,md,meas}$ : the measured short-circuit current ( $I_{sc}$ ) of the testing module

$G_{meas}$ : the measured irradiance, which can be calculated from  $I_{sc}$  of the reference cell

$\alpha$ ,  $\beta$ : the current and voltage temperature coefficients of the testing module (in unit A/K and V/K)

$T_{md,meas}$ : the measured temperature of the testing module

$R_s$ : the internal series resistance of the testing module

$k$  is the curve correction factor, which relates to the fill factor of the PV module