Inception and Prevention of Sustained Discharges on Solar Arrays

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OUTLINE

- Motivation
- Historical overview
- Physics of sustained arcs
- Prevention of sustained arcs
- Test with aged RTV
- Limitations on tests with temporary sustained arcs
- Degradation caused by (sustained) discharges
- Conclusions

Table 1. Arc inception parameters.

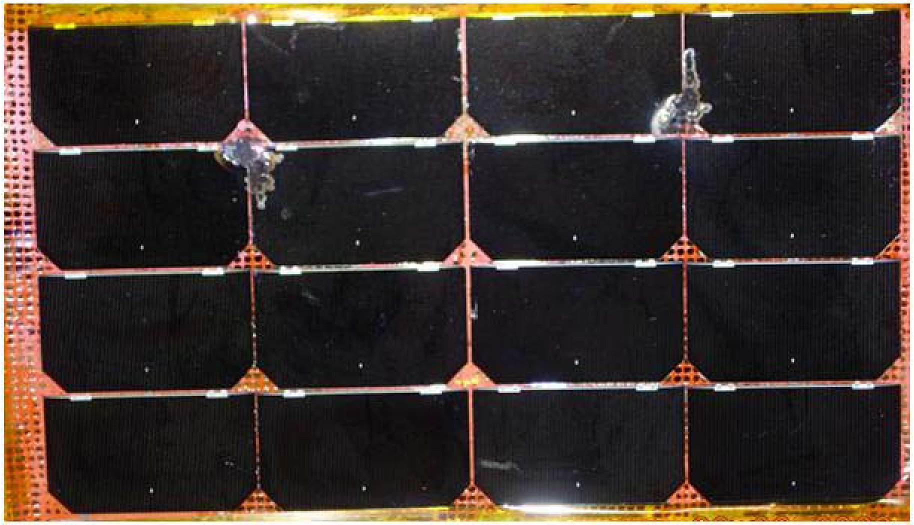
Sample No.	PA V	SA Incep. V	SA Incep. A	Capac uF	PA A	PA us	Environm.	Ref.	Comments
1	250	60	2.0	0.22	12	20	LEO	Vayner et al.,	Tecstar, 3x12 cells
2	265	80	1.6					JSR, 2004	Si and 3J
3	280								
4	340								
5	300(530)	>120	>4						
6	170	80	2.25					10th SCTC, 2007	
7	200	120	2.0	0.15	10	20		Vayner@Galofaro	Flexible design
		120	2.25	0.15			Low temp -70 C?	21th SPRAT,2009	
8	200	50	2.0	0.15					Toshiba 3J
9	200	50	2.6	0.15					

1	First Idea of SA							Levi et al., ESA WPP-23,1990
2		75	3	1	4	20	GEO	Levi et al., 6th SCTC, 1998
3	110	70	2	1	16	40	LEO	Katz et al., 6th SCTC, 1998
4	110	80	2.25	1	16	40	LEO	Snyder et al., 6th SCTC,1998

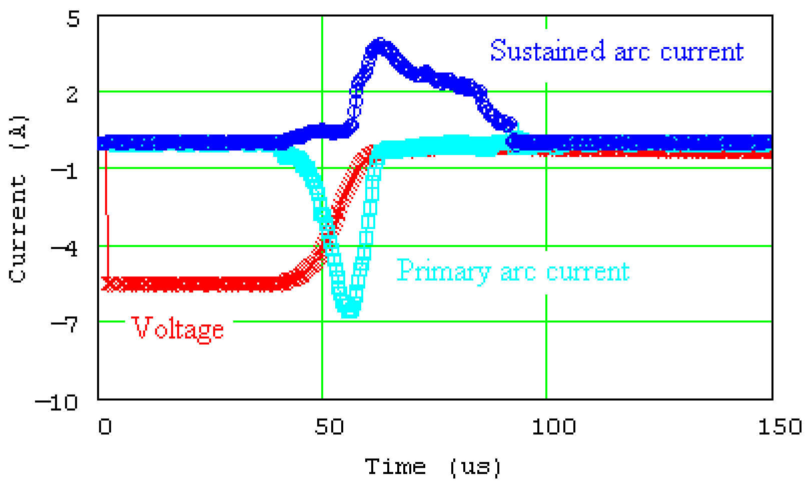
Kapton Pyrolysis, USING RTV for prevention (U≥160 V; test for EOS AM-1)

Levi et al, 7th SCTC, 2001: SAS thresholds do not depend on additional capacitance (>330 pF); Kapton is not important for initiation; 2 A current limit; optical spectra for GaAs cells

1	110	2	0.063	LEO	Kitamura et al, 10th SCTC, 2007
	110	2		GEO	



Obviously, arc plasma consists of different species



SAS 100 V, 1.6 A. Bias -550 V.

Voltage and current thresholds?
What is essential (and what isn't?)
How to prevent?
How to test against inception?

For pure metal electrodes

$$h = \int_0^{t_d} j^2 dt = \frac{D \cdot c}{\rho} \ln \frac{T_{ex}}{T_0} = (0.6 - 2) \cdot 10^9 \ A^2 s \cdot cm^{-4}$$

Threshold currents were measured for many metal cathodes, and the results were in a good agreement with theoretical estimate [22]. Respective magnitudes varied from 1 A for aluminum cathode to 2 A for titanium one. Moreover, threshold current increased 2-2.5 times when cathode temperature was decreased to 4 K.

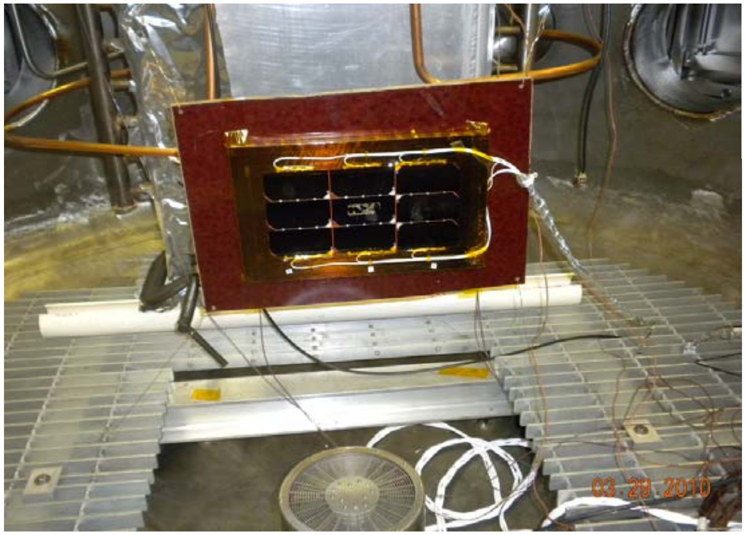
$$\ln \overline{\tau}(I) = \alpha + \beta \cdot \ln(I)$$

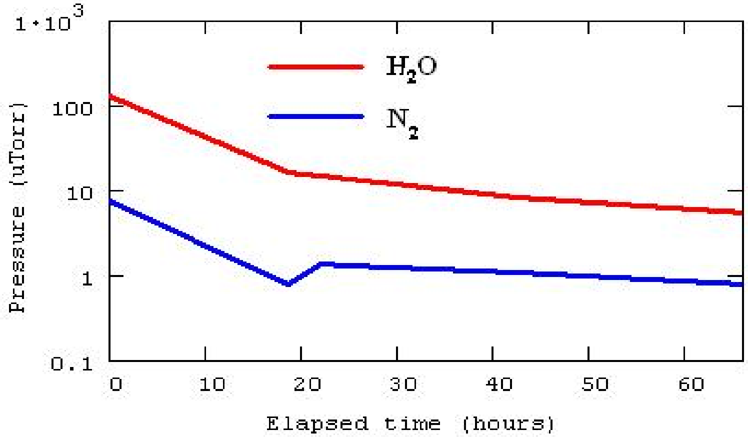
Smeets, P. "Stability of low-current vacuum arcs", J.Appl.Phys., Vol.31, 1986, pp.575-587.
29. Rene, P., and Smeets, P. "The Origin of Current Chopping in Vacuum Arcs", IEEE Trans. On Plasma Science, Vol.17., No.2. 1989, pp. 303-309.

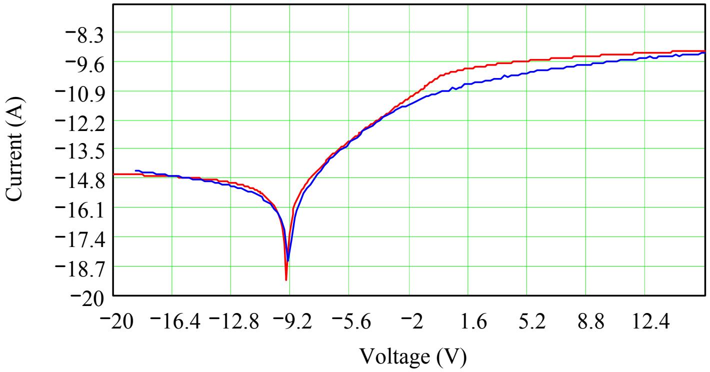
This method is based on the well established experimental data revealing sharp rise of pulse duration with increasing vacuum arc current [28]. The empirical relation is rather simple but not useful because of high β=10-15. Problems: wide statistical spread, not pure metal electrodes, complicated geometry and surface conditions.

In order to prevent sustained arcs on solar array the available current must be limited well below its threshold magnitude

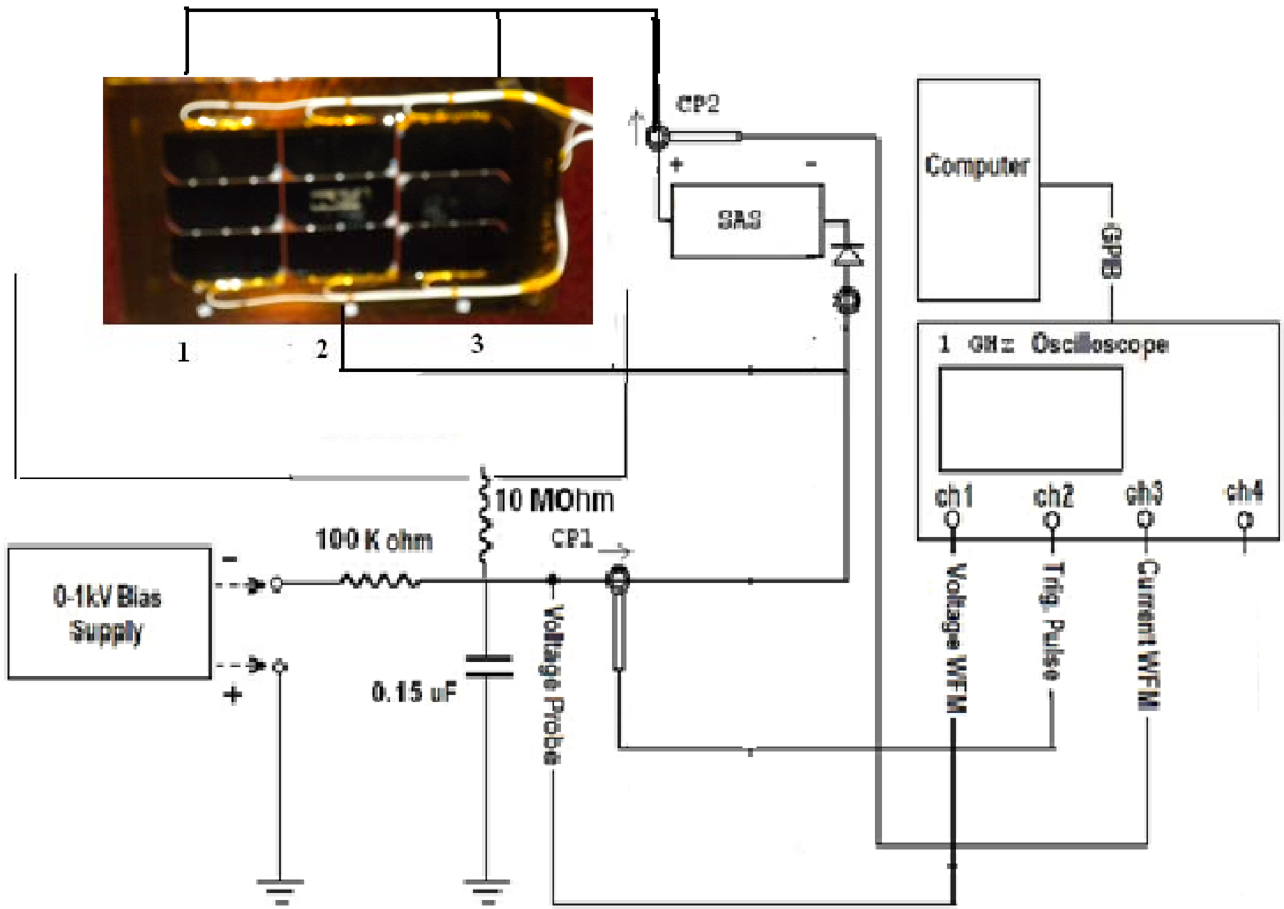
Sustained Arcs on RTV Grouted Sample



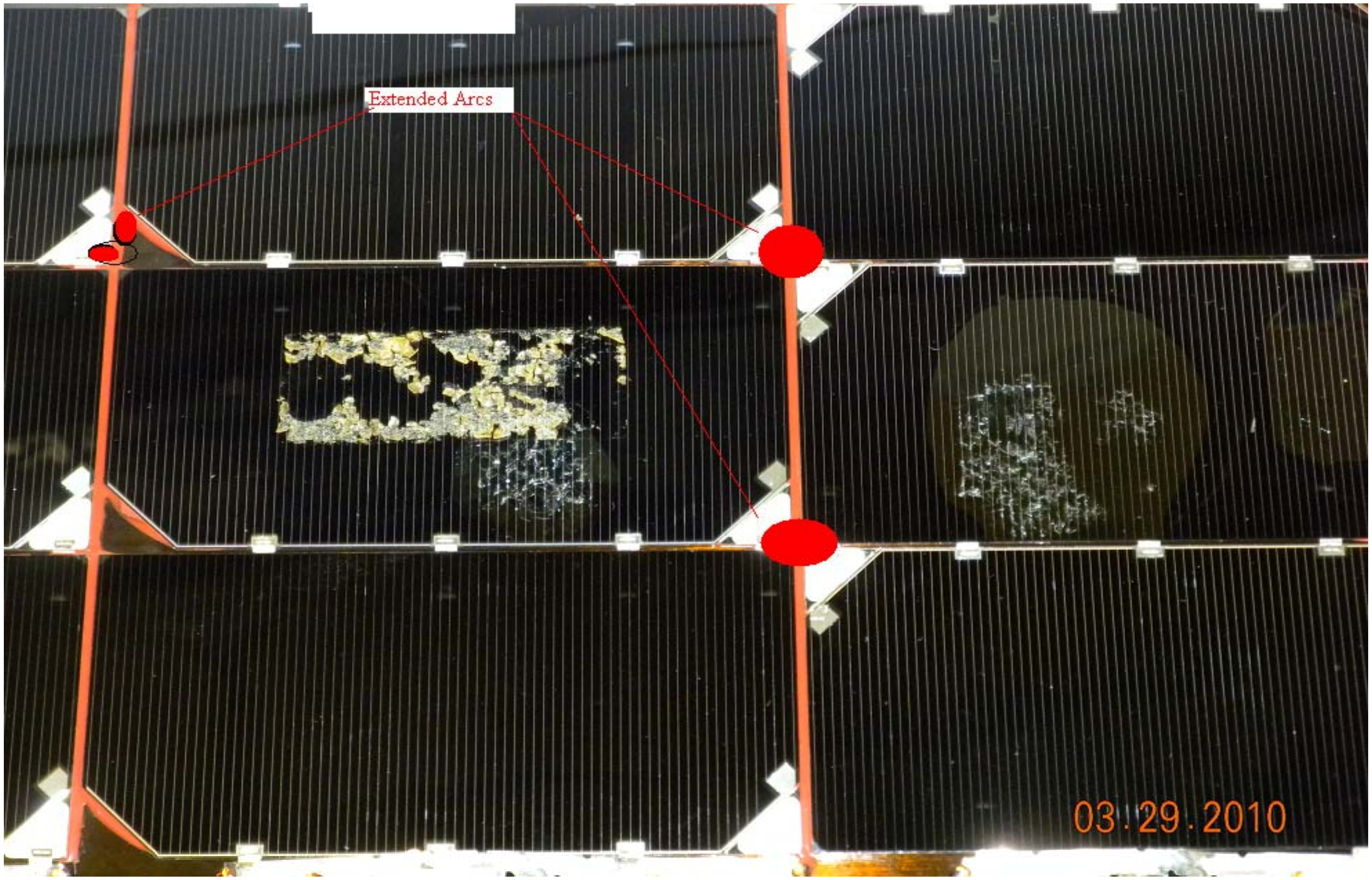




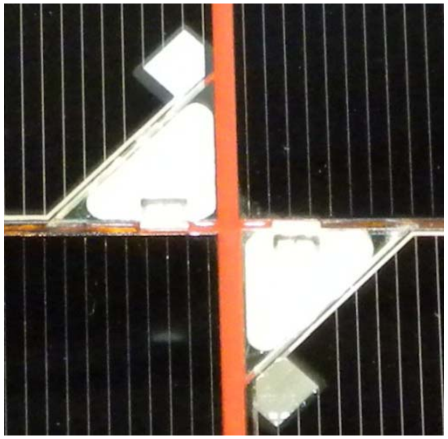
$n_e = 9 \cdot 10^5 cm^{-3};$ $T_e = 2eV$

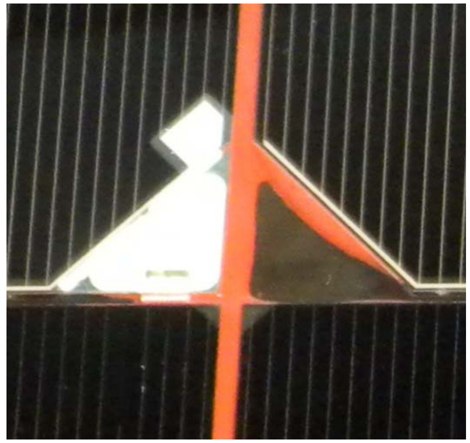


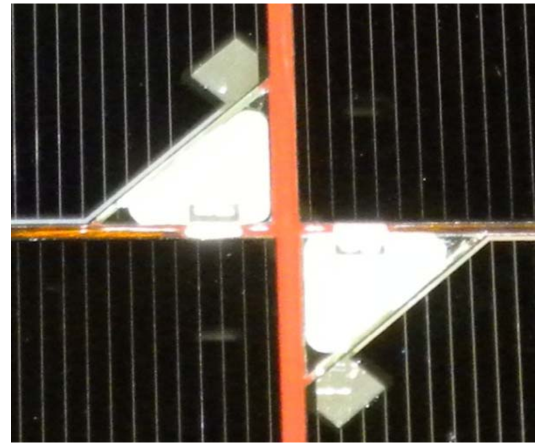
Circuitry diagram for sustained arc initiation and recording



Two strings are shown with sustained arc sites indicated by red circles.



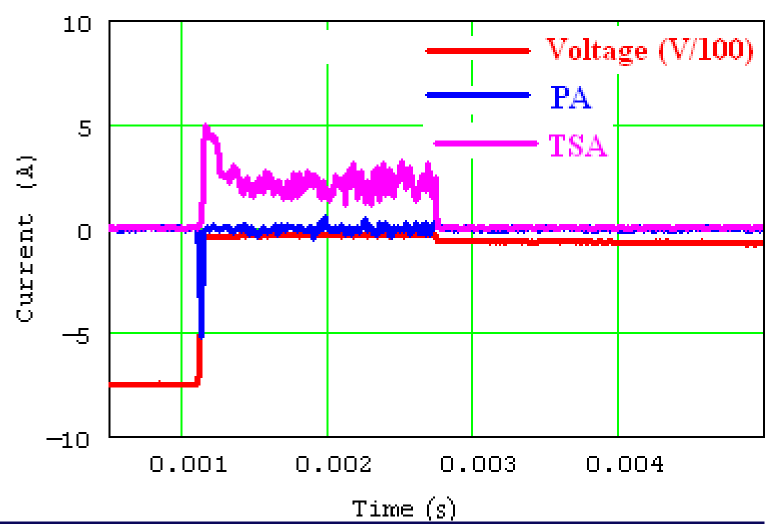




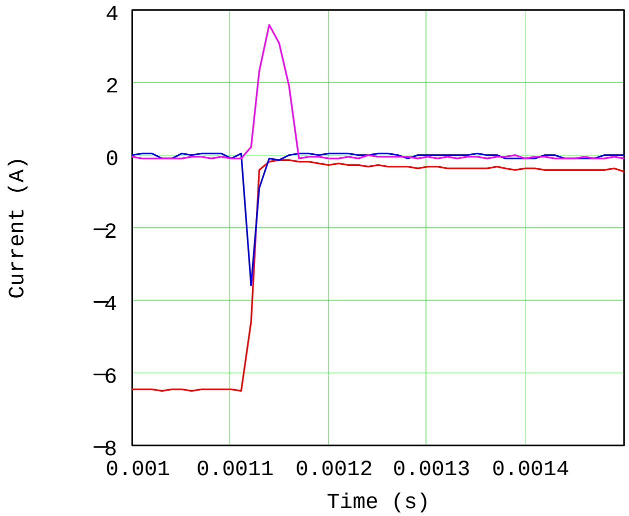
a) b)

Three images of areas with sustained arcs: no visual defects or cracks in RTV strips were found; a) before test; b) after test.

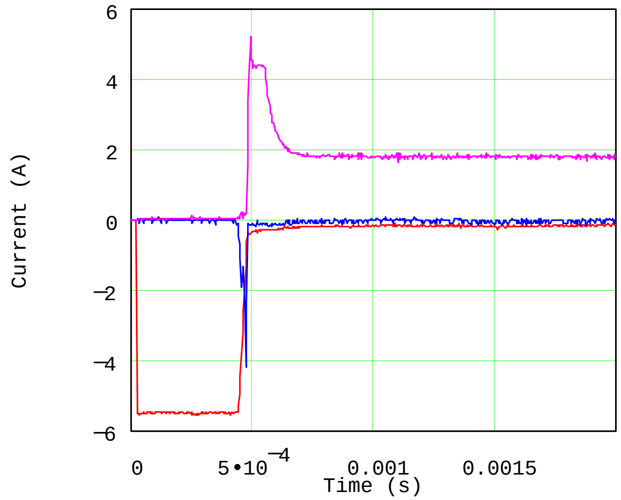
One example of TSA: Bias voltage -750 V; SAS voltage 120 V, and SAS current limit 2.2 A.



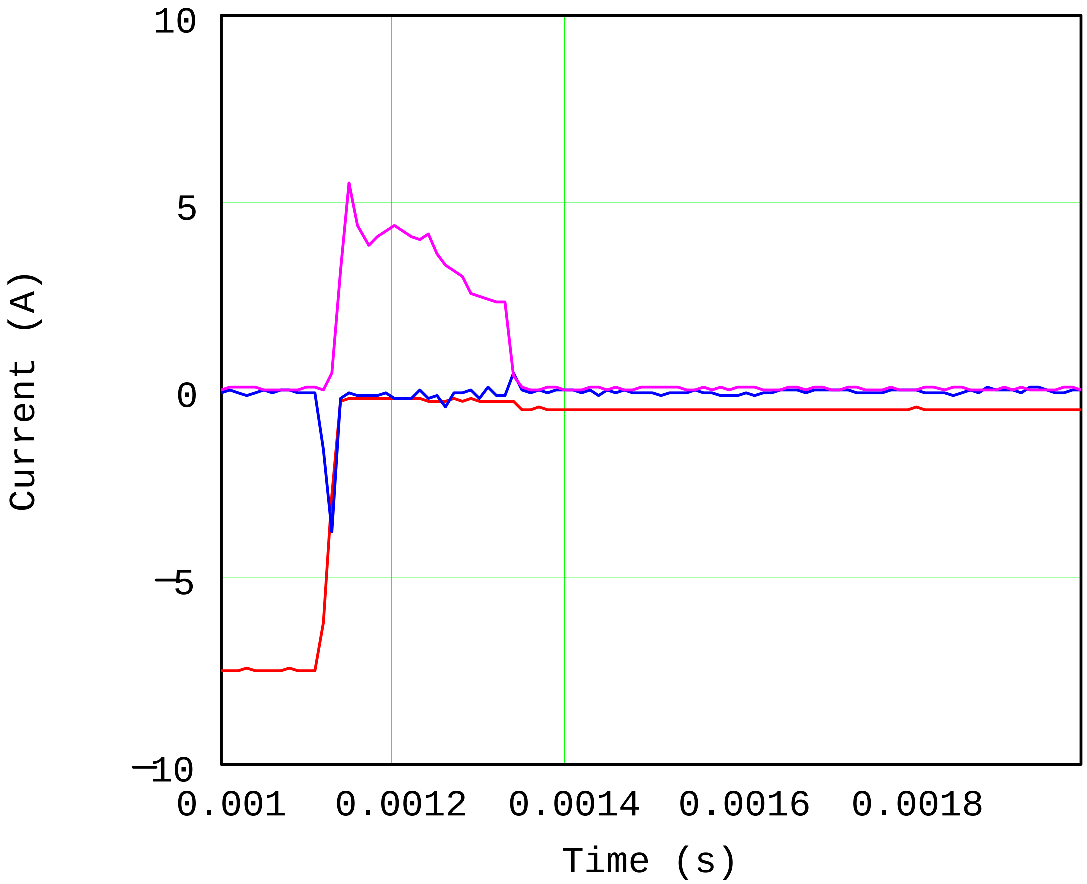
After initiation and registration of 540 primary discharges thirty temporary sustained arcs were separated and analyzed. It was found that the areas with blocking diodes are prone to sustained arc initiation. However, even with very high current limit of 2.2 A no permanently sustained arc was initiated. Most of TSA were really short. Therefore, even long duration TSA (>1.6 ms) cannot be used as confirmation of PSA possibility with higher current limit.



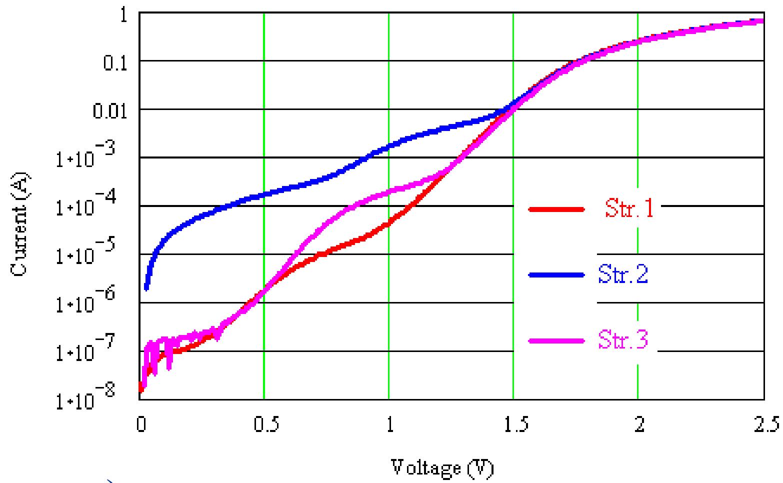
100 V and 2 A



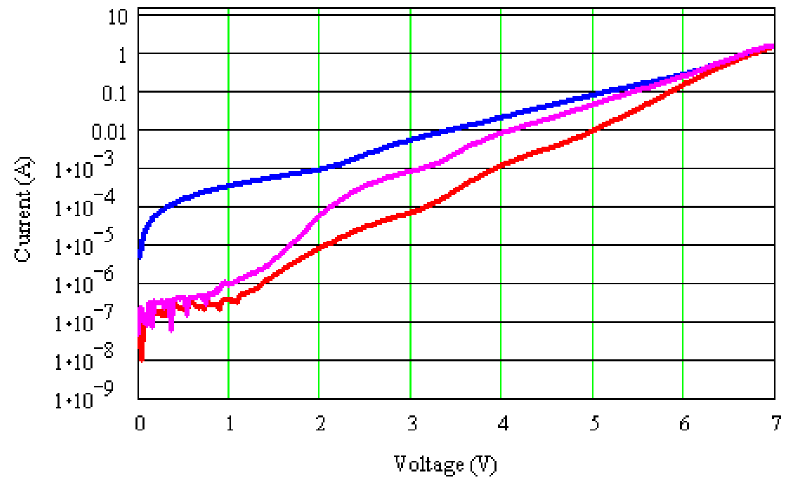
100 V and 1.8 A



Bias -750 V; SAS 120 V, 2.2 A.



a)



b)

Dark I-V characteristics: a) by-pass diodes; b) solar cells.

Solar cells performance.

Str.No/Data :	I_{sc} (mA) :	V_{oc} (V) :	Eff. (%) :	FF :	P_{max}(W) :
1	400.1	6.5	17.9	0.776	2.02
2	394.9	6.45	15.1	0.669	1.7
3	383.4	6.4	16.1	0.736	1.81

After all 540 arcs, radiation fluency, and thermal cycling, solar cells are found to be performing quite satisfactory

Conclusions

RTV grouting is very effective method to prevent a sustained arc between adjacent strings. A few years simulated space exposure did not worsen RTV properties in this aspect. The influence of TSAs on photovoltaic characteristics of the sample was certainly minor. In general, there is a good chance of performance degradation caused by arcing, and that is why the best practical approach to the problem is total prevention of arcing on solar array surfaces.

Acknowledgments

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