
# Reliability Testing Of High-Concentration PV Modules And Soiling Issues

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# 5.5 mm x 5.5 mm III-V cell on diffusion bonded copper substrate

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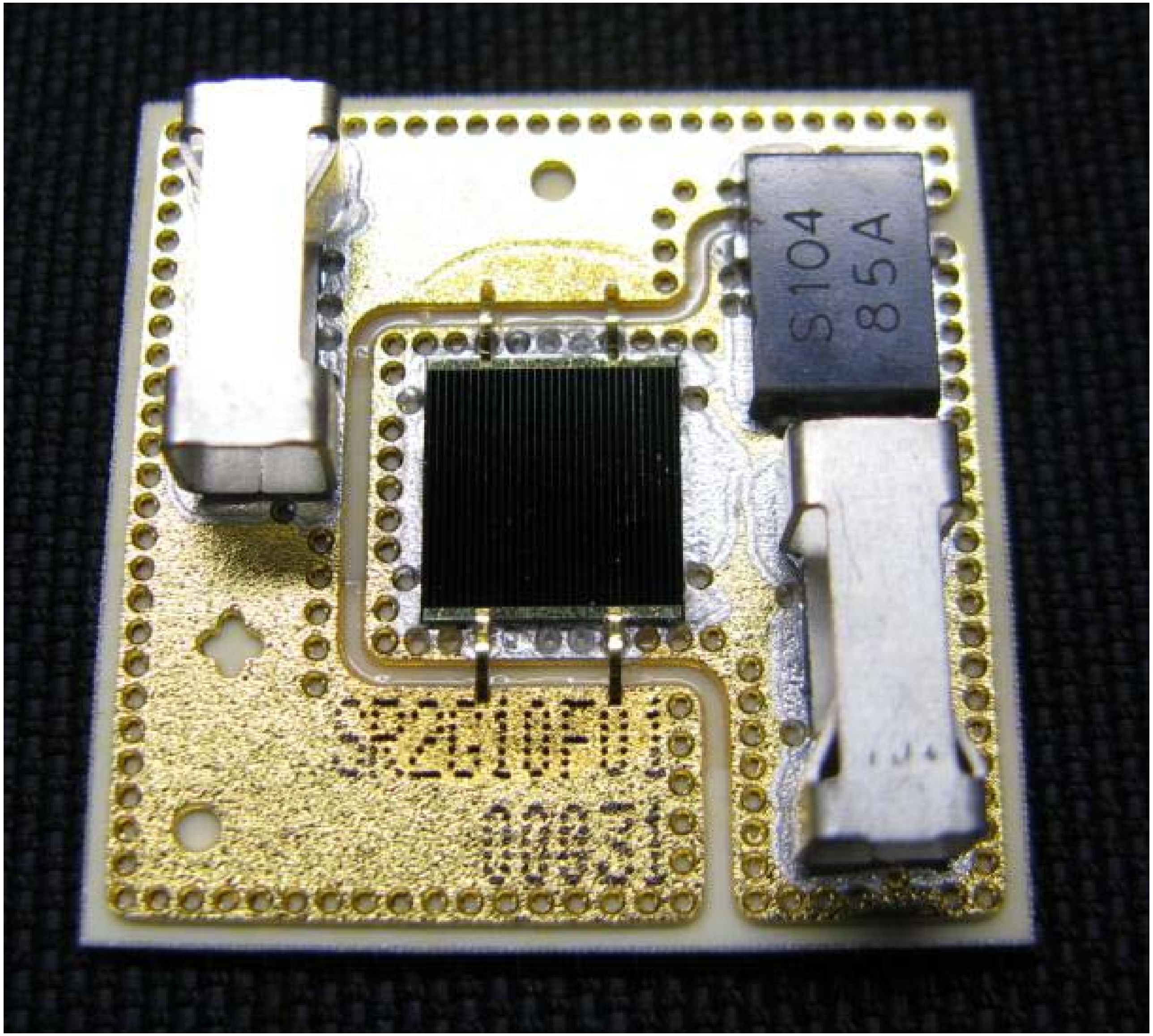
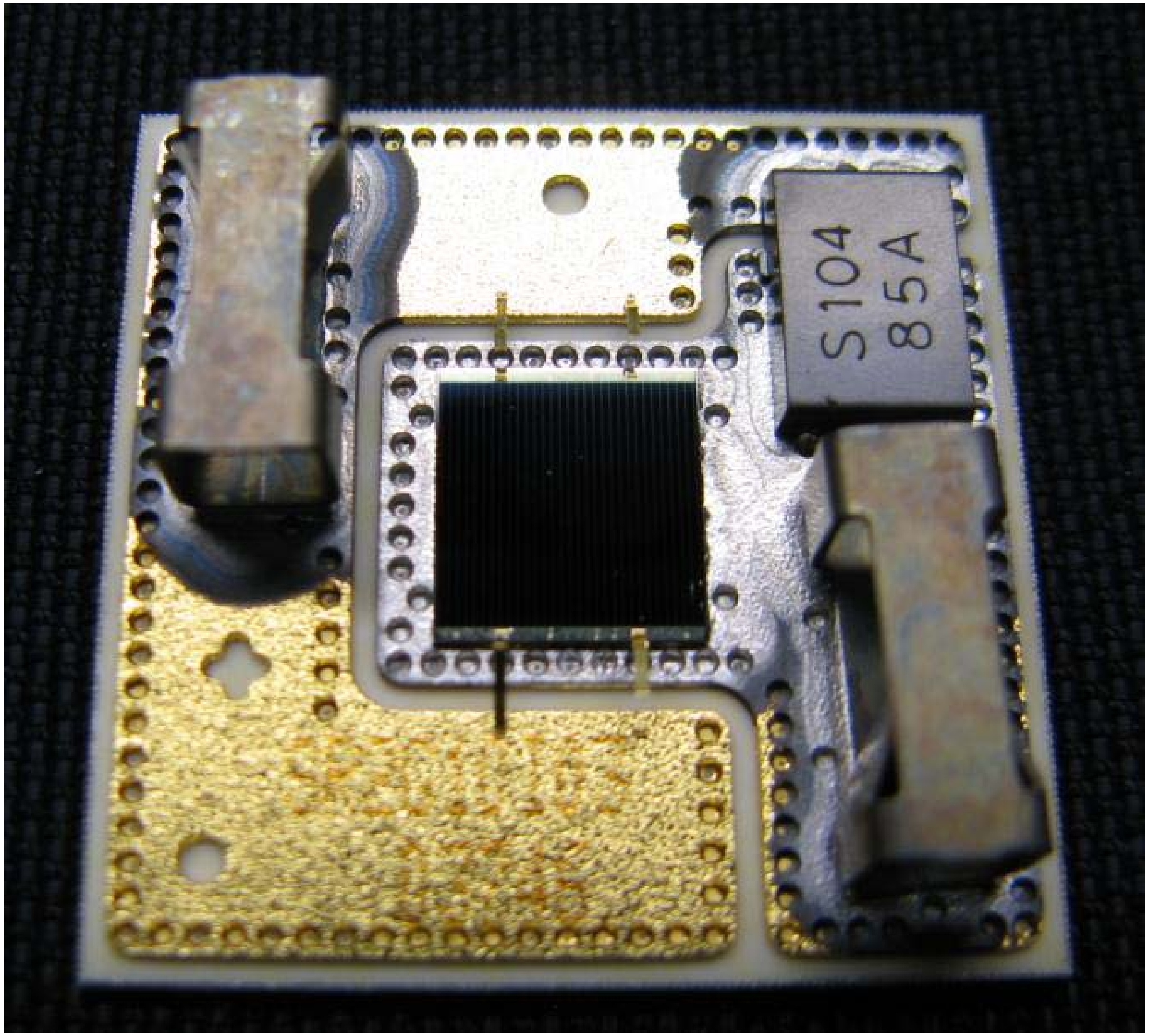


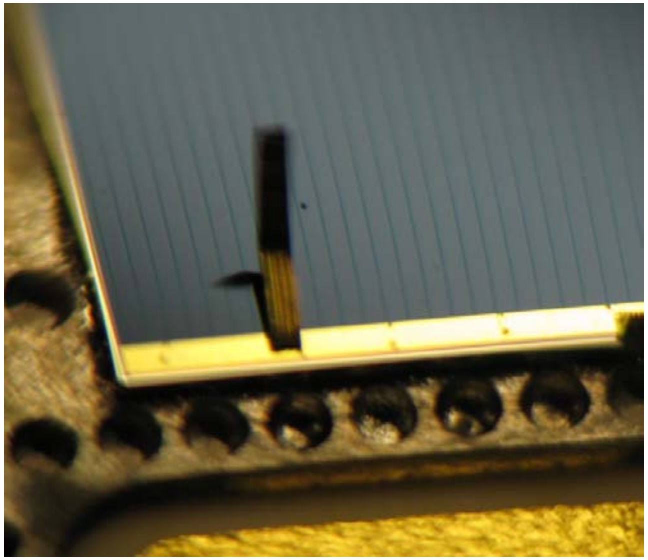
# Qualification plan draws from IEC 62108 and various military standards

| | | | |
|---|---|---|---|
| 1 | Thermal Aging for Intermetallics | 300ºC | Pass |
| 2 | Powered Thermal Cycling | -40 to 110ºC | TBD |
| | Stud Pull | | TBD |
| 3 | Humidity Freeze | -40 to 110ºC pre-condition<br>-40ºC to 85ºC test | Pass |
| | Stud Pull | | TBD |
| 4 | Damp Heat | 85ºC | Pass |
| 5 | Mechanical Shock | 30" drop | Pass |
| | Vibration | random vibration | Pass |
| | Liquid-Liquid Thermal Shock | -55 to 125ºC | Pass |
| 6 | ESD Damage Threshold | 8kV | TBD |

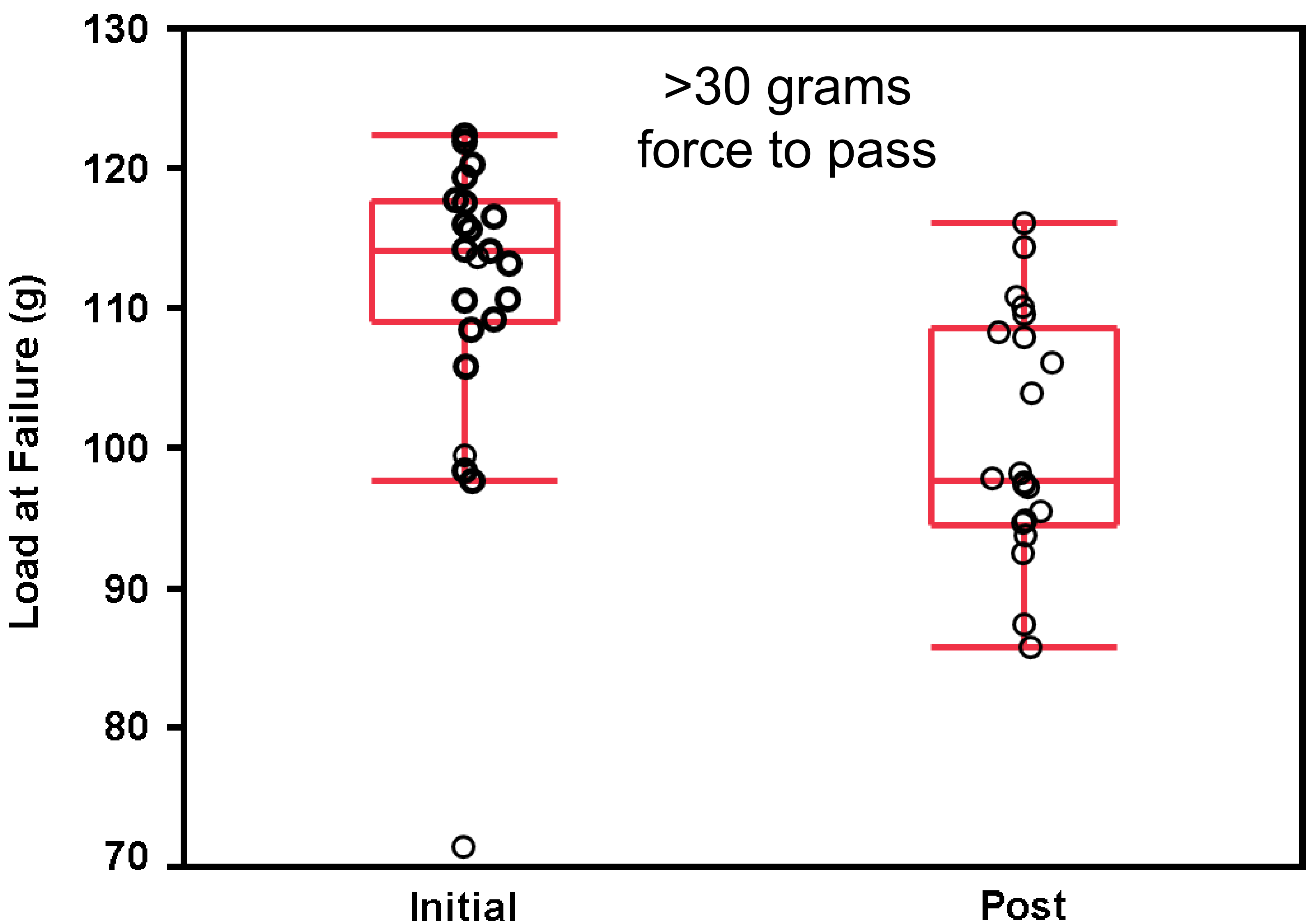
# Thermal aging does not result in intermetallic phases and ribbons fail first



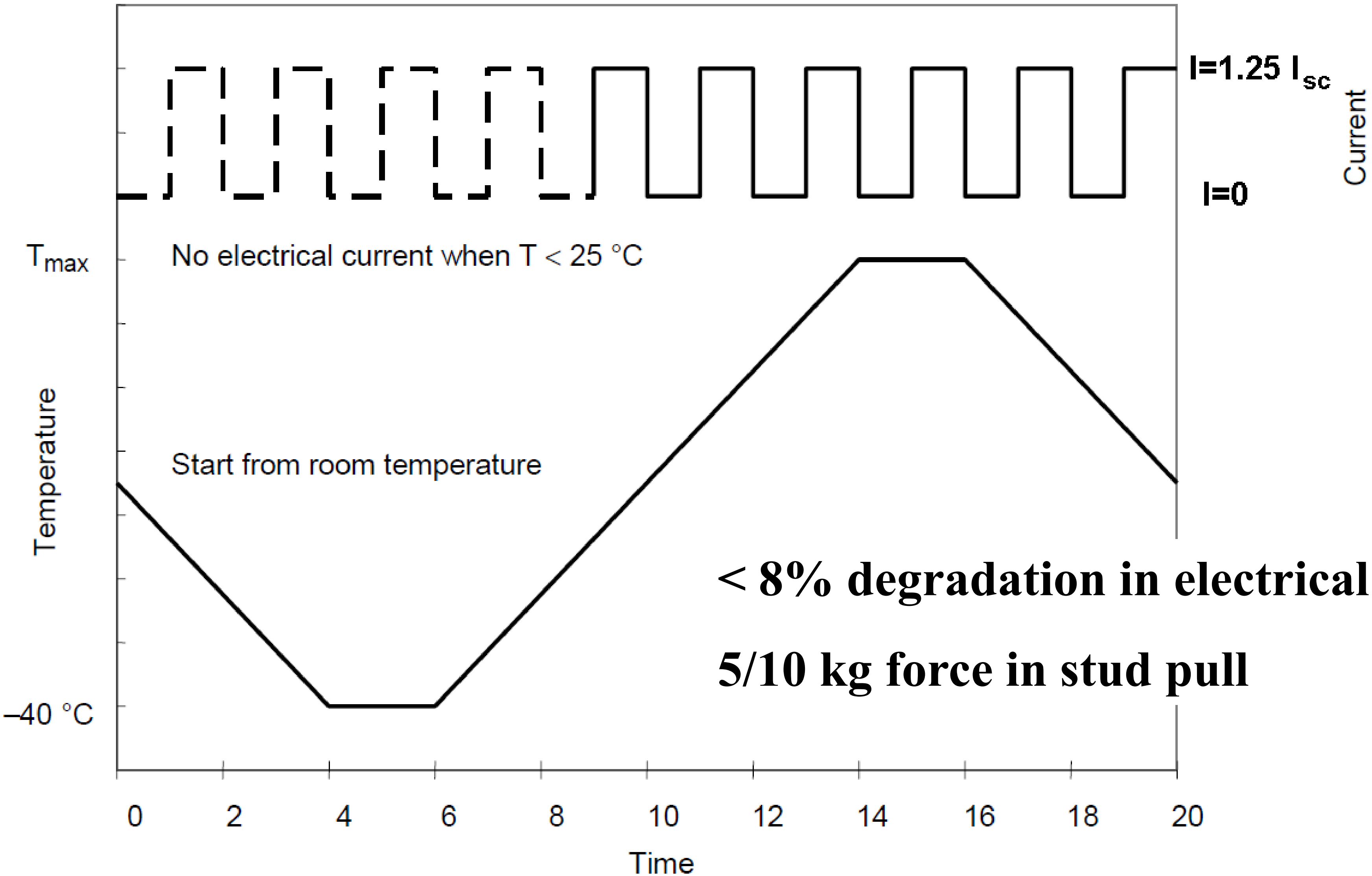

300ºC for 1h



# Thermal aging of ribbon bonds does not significantly reduce pull strength



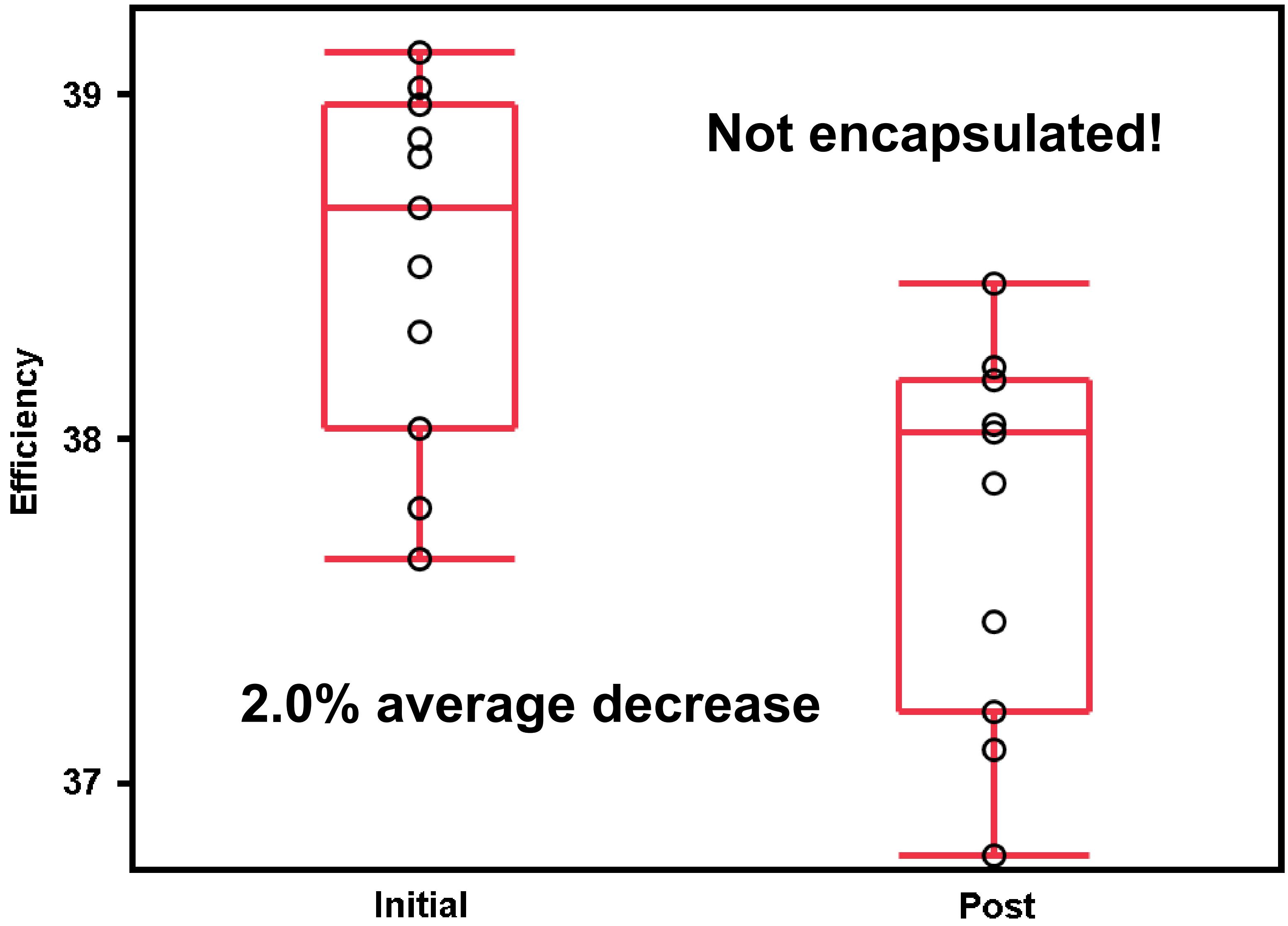
# Powered thermal cycling for electrical properties and stud pull for solder adhesion



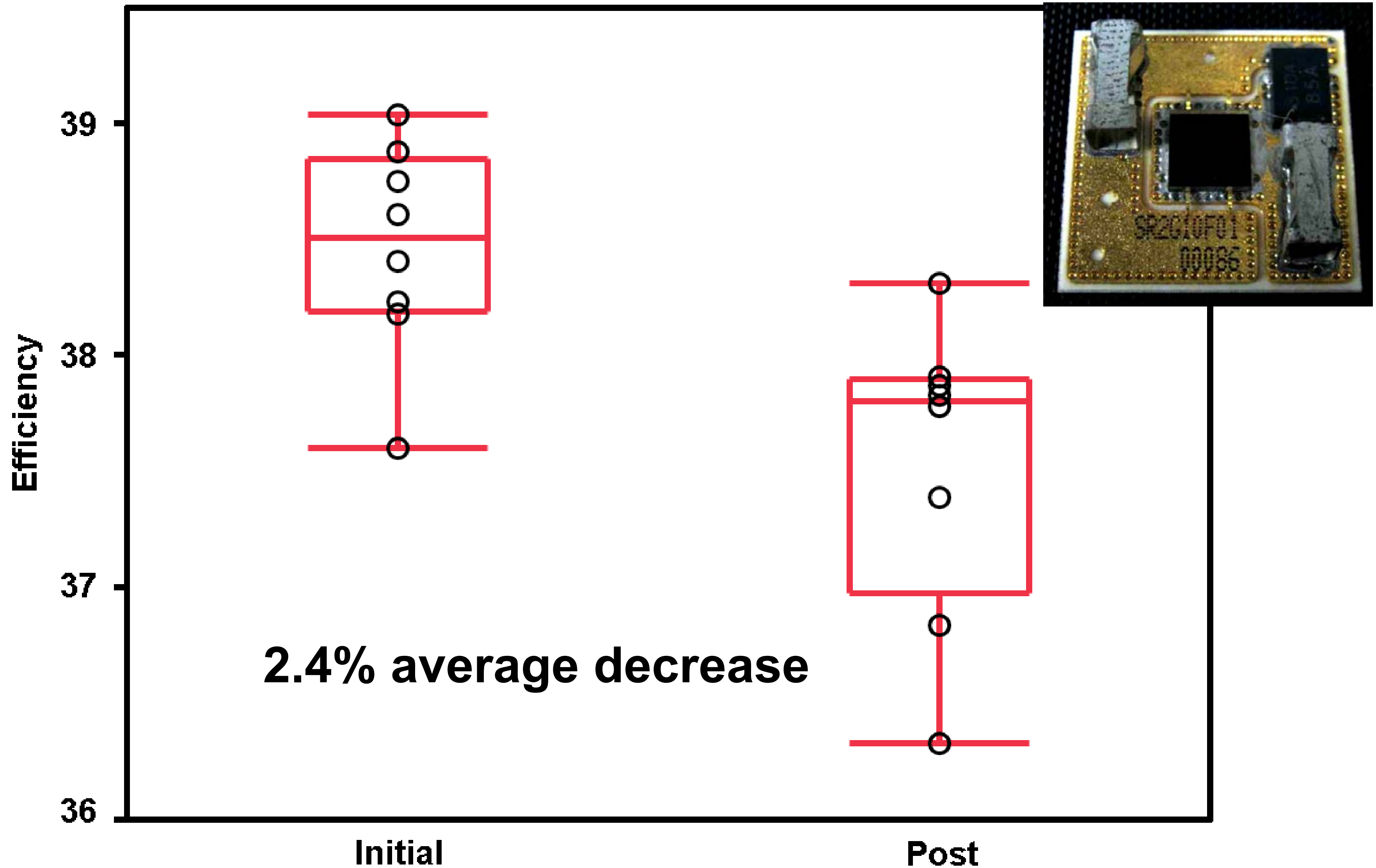

**< 8% degradation in electrical**

**5/10 kg force in stud pull**

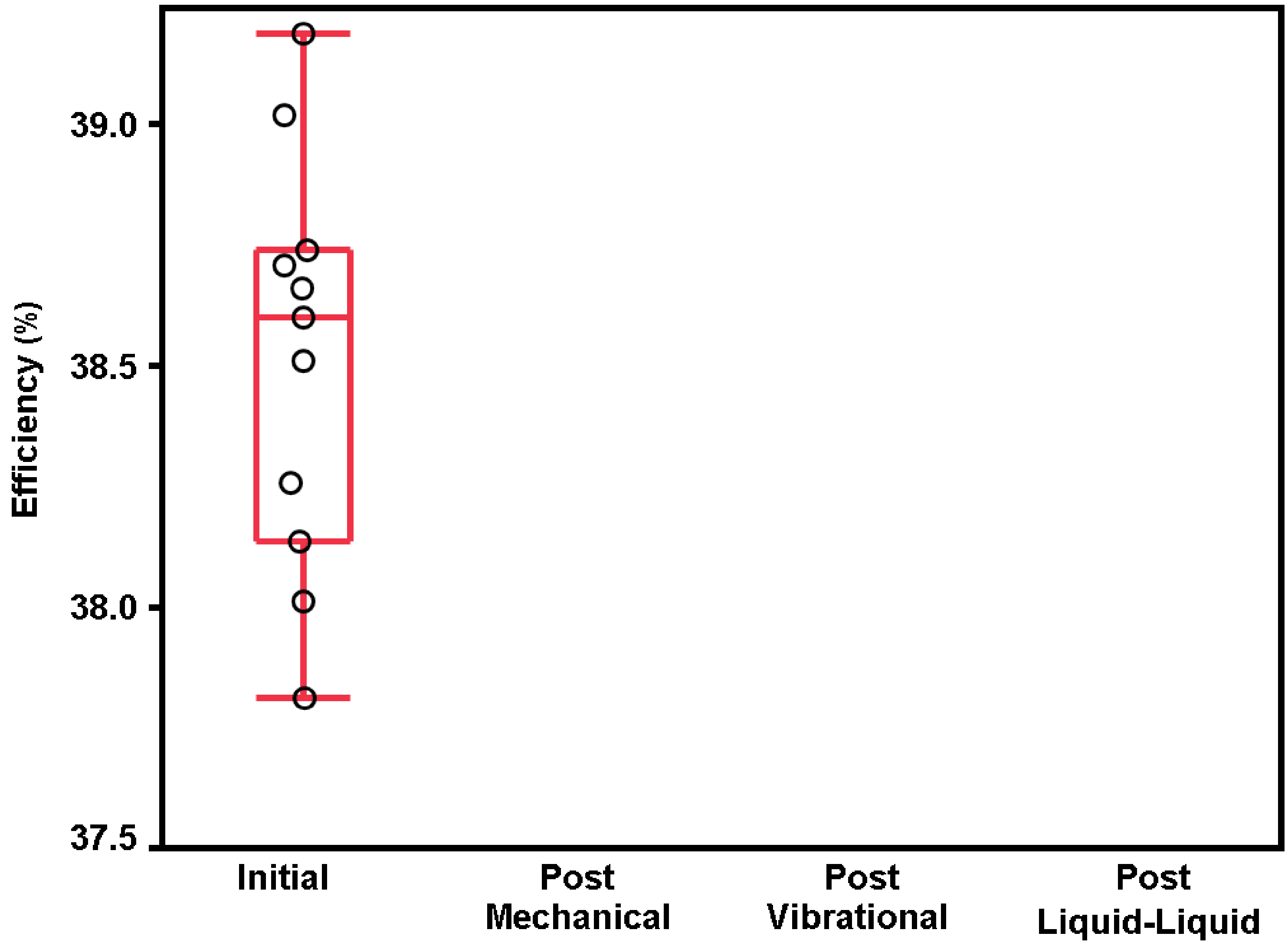
# Damp freeze impacts efficiency, but the decrease is less than 8%



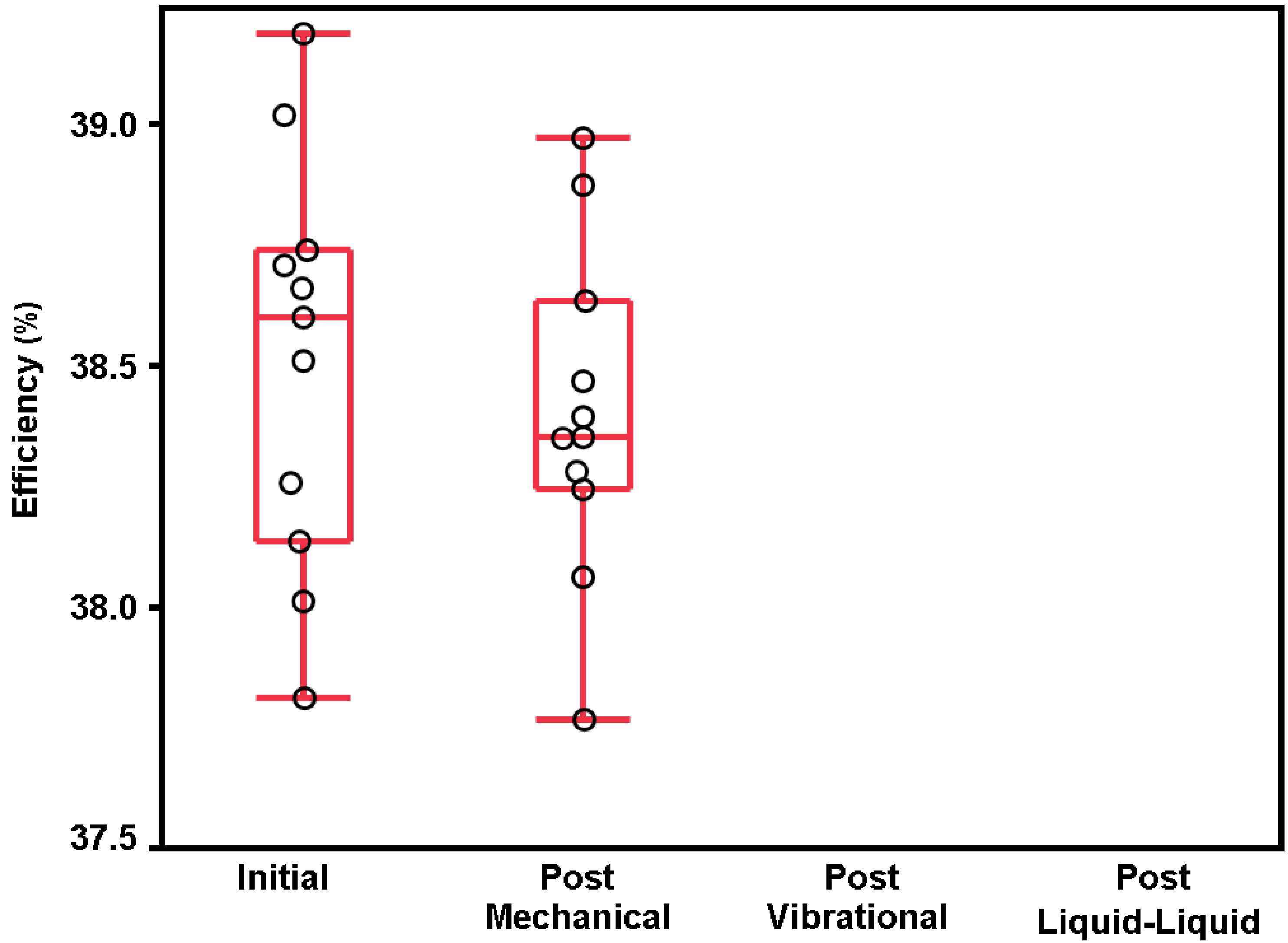
# Damp heat impacts efficiency, but the decrease is less than 8%



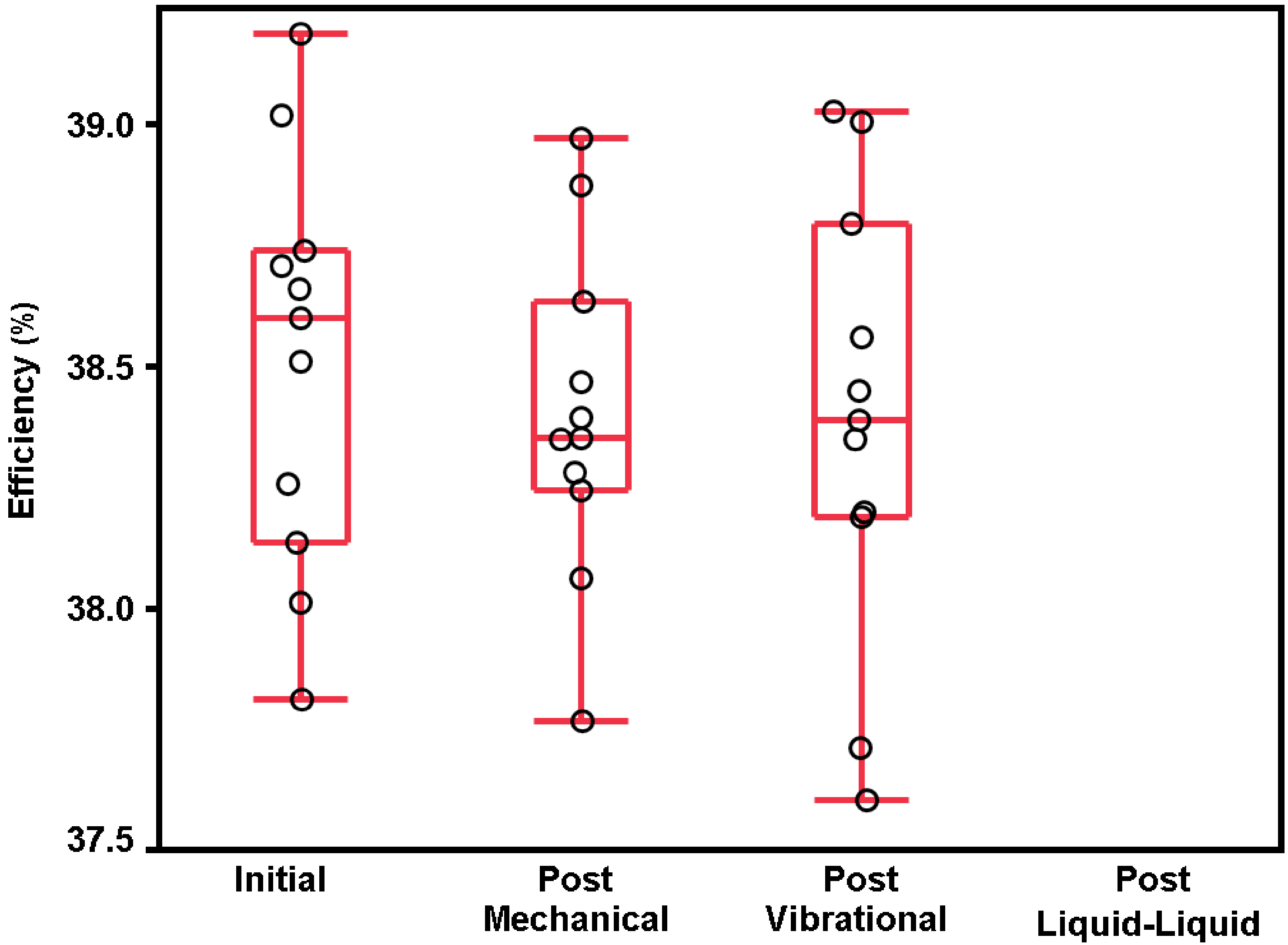
# Initial efficiency whisker plot showing an average efficiency between 38% and 39%



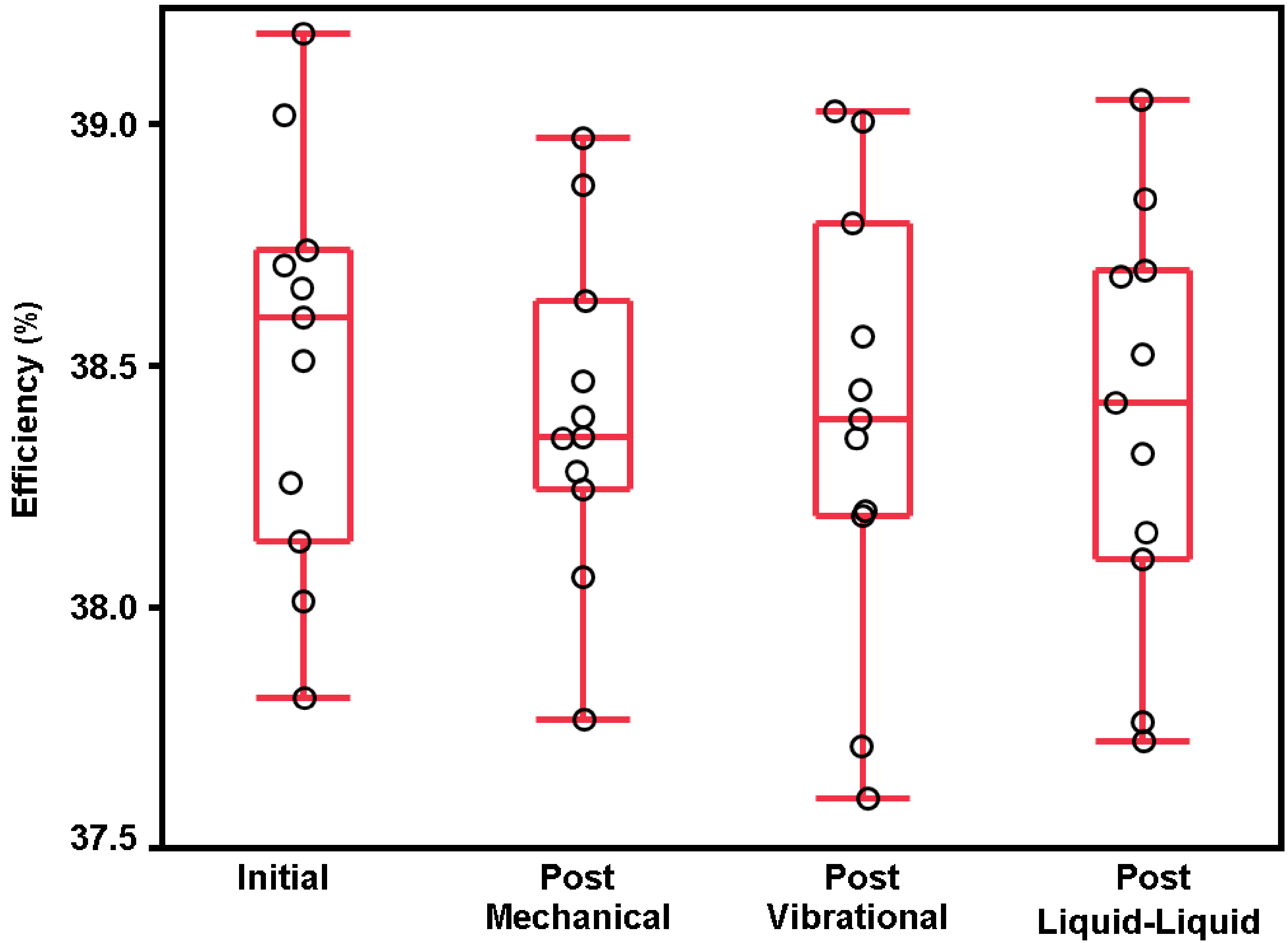
# Efficiency whisker plot after mechanical stress showing no difference after the test



# Efficiency whisker plot after vibrational stress showing no difference after the test



# Efficiency whisker plot after liquid-liquid shock showing no difference after the test



# Electrostatic discharge damage threshold

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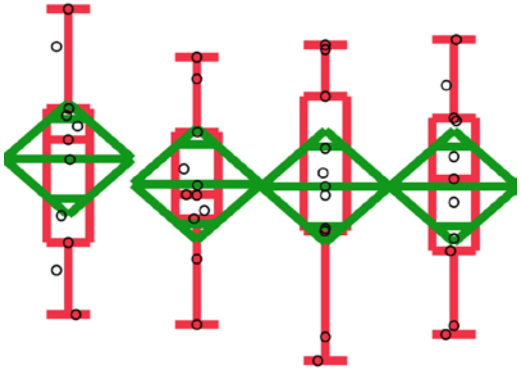
I-V measurements

ESD followed by I-V in increments

leakage current < 8 mA at 2.2 V

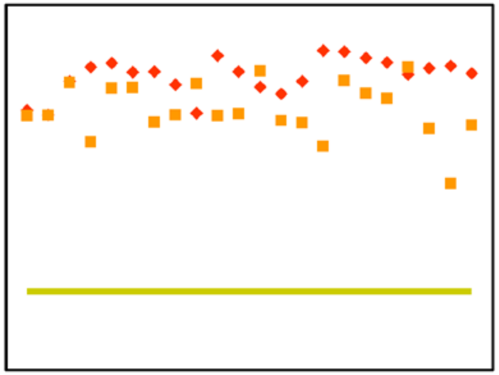
similar parts to 4kV have shown
<1 mA at 2.2 V

# The 5.5 x 5.5 mm sub-assembly is a robust product against strife testing



**Thermal and mechanical shock have no effect on efficiency**

**Thermal aging does not compromise ribbon bond strength**



**Humidity with temperature impacts performance, but within acceptable limits**

# Effect of soiling on PV performance

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## Air Force test location in Maui (leeward side)

# Panels near the ground were untouched elevated panels cleaned weekly

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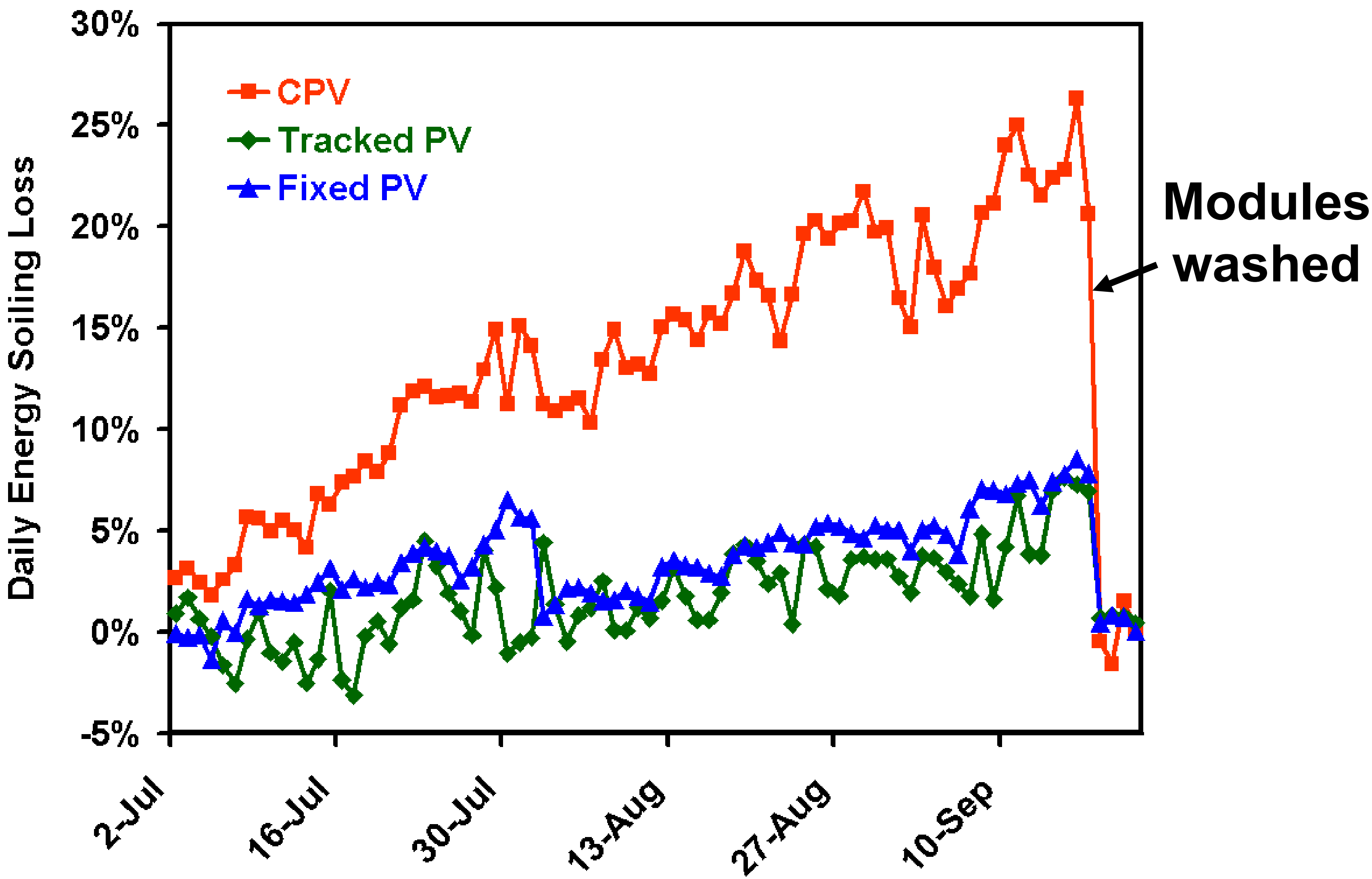
# CPV soiling performance evaluation criteria

Soiling loss calculated using the following

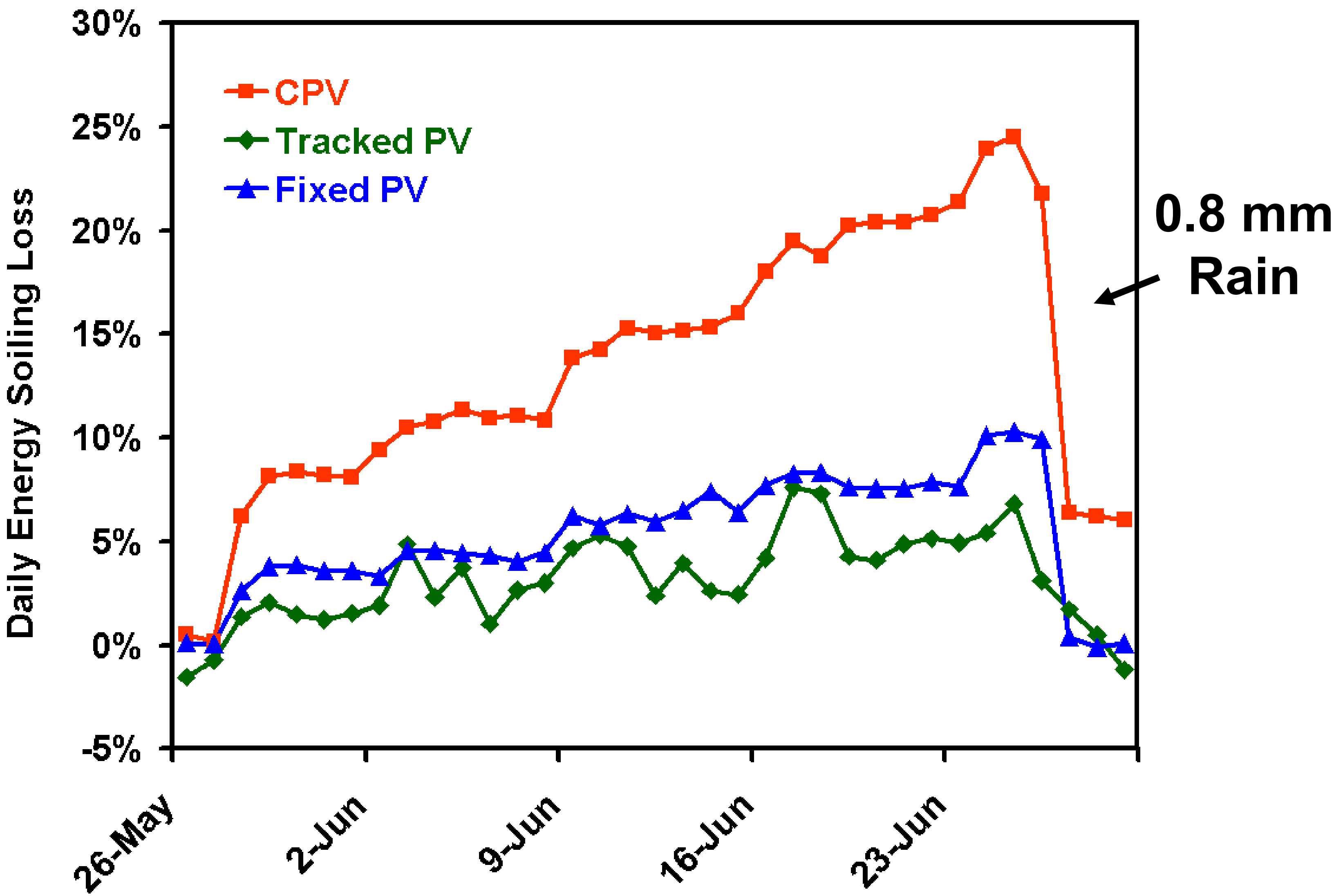
$$SL = \frac{E_{clean} - E_{dirty}}{E_{clean}}$$

Dirt accumulates at high rates in this environment

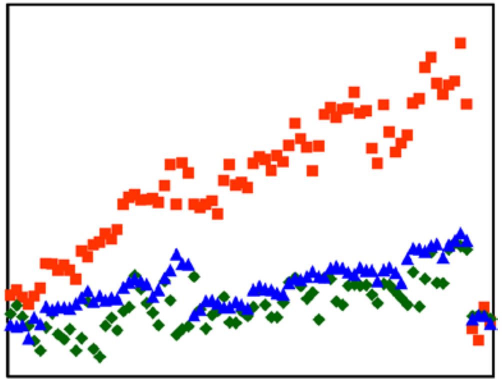
# Dirt accumulation on CPV has a strong impact on electrical performance



# Dirt accumulation may be easily removed by small (0.8 mm) rain events



# Clean lenses are crucial for efficient CPV power generation



**The data show what we knew: Dirt accumulation affects efficiency**

**Washing and rain events restore performance to as-installed**

**Soiling effects and mitigation measures will be site and season dependent**