Simulated Space Environmental Effects on Thin Film Solar Array Components

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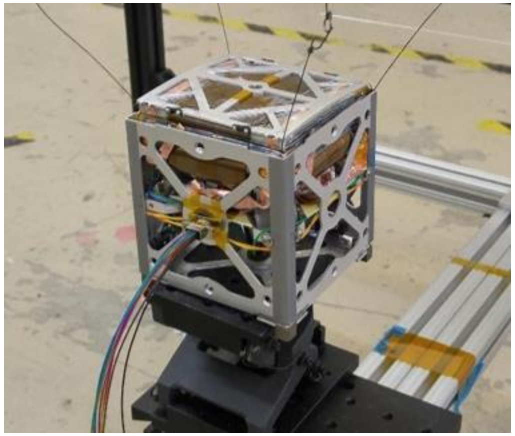
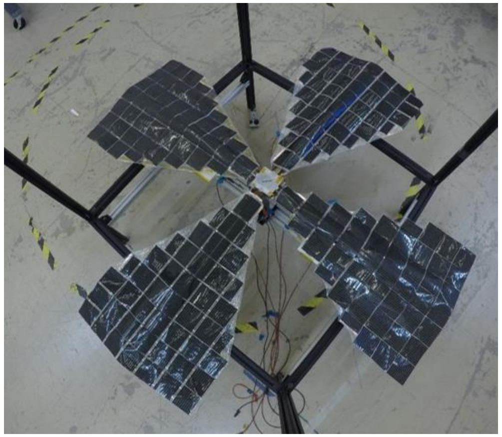
Simulated Space Environmental Effects on Thin Film Solar Array Components

- **Background**
- **Solar Array Materials**
- **Simulated Space Environment Exposures**
  - **Atomic Oxygen**
  - **Ultraviolet Radiation**
  - **Electron Radiation**
  - **Proton Radiation**
  - **Thermal Cycling**
- **Summary**

Simulated Space Environmental Effects on Thin Film Solar Array Components

- **Lightweight Integrated Solar Array and Transceiver (LISA-T)**
  - **Deployable solar array**
  - **Can provide over a hundred watts of power yet stow into less than a standard one-unit (1U) CubeSat, or a volume of less than 4 inches x 4 inches x 4 inches**
  - **Flexible solar cells do not allow for standard coverglass protection from the space environment**
  - **Candidate solar cells and protective thin films tested in space environment simulations**





Simulated Space Environmental Effects on Thin Film Solar Array Components

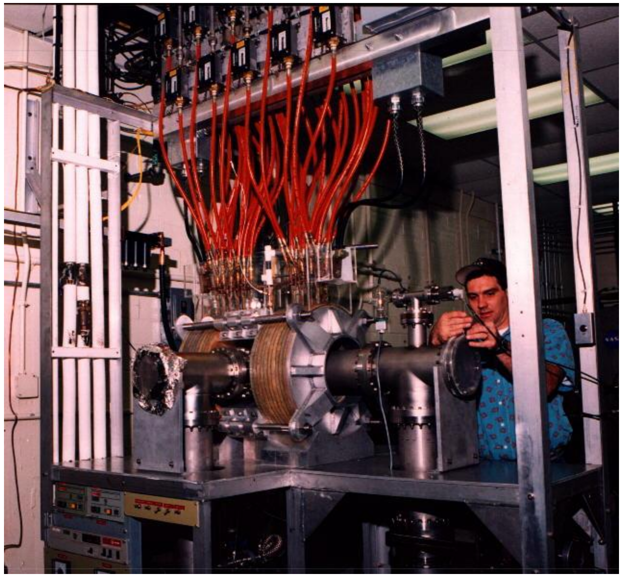
- **Solar Cells**
  - **Inverted metamorphic multi-junction (IMM)**
    - **High performance, higher cost, modestly lightweight, extremely thin**
  - **Copper indium gallium (di)selenide (CIGS)**
    - **Low cost, lower efficiency**
    - **Less than half the weight of the IMM cell but twice the thickness**
  - **Single junction GaAs cells**
    - **Medium option in cost and efficiency**
- **Solar cell performance evaluated by power curves, optical properties, mass loss**

Simulated Space Environmental Effects on Thin Film Solar Array Components

- **Thin Films**
  - **CORIN**
  - **CORIN with cerium oxide**
  - **Optinox**
  - **Optinox with cerium oxide**
- **Applied to solar cells or exposed separately**
- **Performance evaluated by transmission measurements, mass loss**

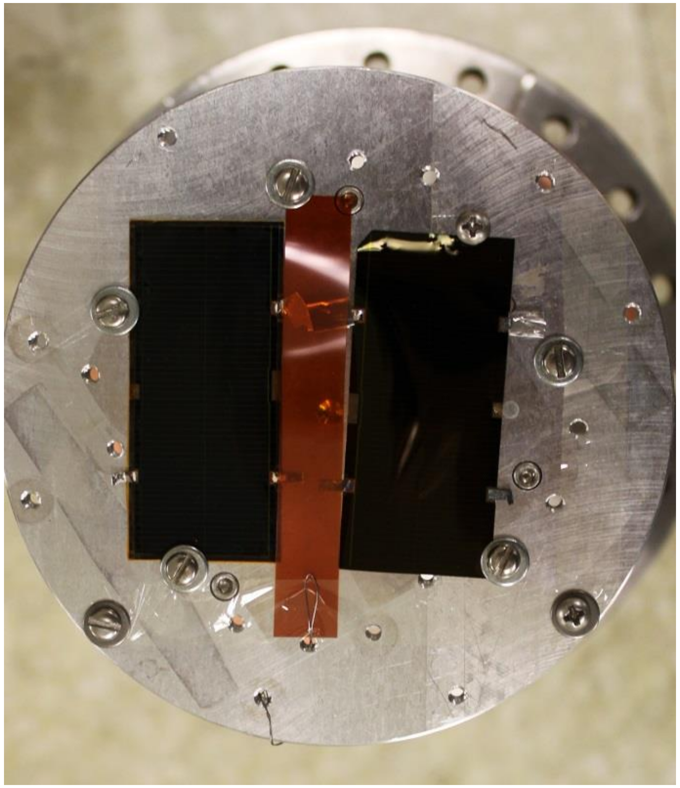
Simulated Space Environmental Effects on Thin Film Solar Array Components

- **Atomic Oxygen**
  - **Atomic Oxygen Beam Facility**
  - **5 eV neutral oxygen atoms with concurrent vacuum UV radiation**
  - **Iterations up to 2.5 x 10^{21} atoms/cm^2 fluence**
  - **One bare and one CORIN-coated IMM solar cell**
  - **All candidate thin films plus nitinol wire**



Simulated Space Environmental Effects on Thin Film Solar Array Components

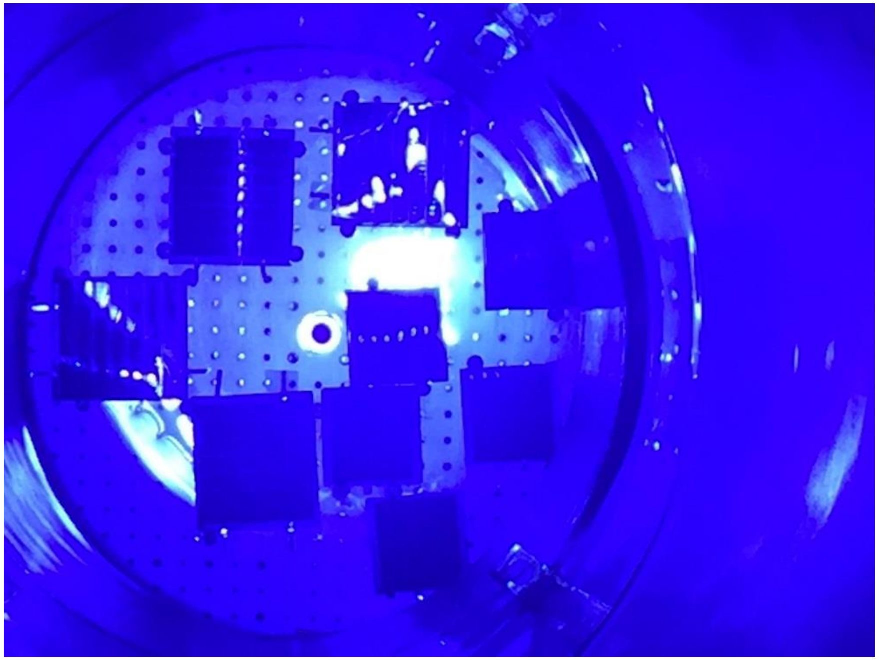
- **Atomic Oxygen Results**
  - **Bare Solar Cell**
    - **Mass loss of 1.3%**
    - **97.6% power retention**
  - **CORIN coated solar cell**
    - **Mass loss of 1.9%**
    - **103.6% power retention due to surface texturing and slight decrease in reflectance**



  - **Optinox film heavily eroded**
  - **CORIN formed self-passivating layer in AO**
  - **Nitinol wire had slight mass loss, no performance changes**

Simulated Space Environmental Effects on Thin Film Solar Array Components

- **Ultraviolet Radiation**
  - **Solar Simulator with xenon arc lamp**
  - **IMM and CIGS cells**
    - **Bare**
    - **Coated with Optinox**
    - **Coated with CORIN**
    - **Coated with CORIN with cerium oxide**
  - **Iterations up to 2,000 equivalent sun hours**



Simulated Space Environmental Effects on Thin Film Solar Array Components

- **Ultraviolet Radiation Results**
  - **Bare IMM**
    - **98.5% power retention**
  - **Coated IMM**
    - **80.8% power retention for CORIN, slightly better with addition of ceria**
    - **85.5% power retention for Optinox**
  - **Bare CIGS**
    - **Degraded open circuit voltage, 70% power retention at best**
  - **Coated CIGS**
    - **86.5% power retention for CORIN, 91.6% with addition of ceria**
    - **73.4% power retention for Optinox**

Simulated Space Environmental Effects on Thin Film Solar Array Components

- **Electron Radiation**
  - **Combined Environmental Effects Facility with Pelletron accelerator**
  - **1 MeV electrons**
  - **IMM, CIGS, and single junction GaAs cells**
    - **Bare**
    - **Coated with Optinox**
    - **Coated with CORIN**
    - **Coated with CORIN with cerium oxide**
  - **CORIN and CORIN with ceria thin films also exposed**
  - **Iterations from 3 x 10^{13} up to 5 x 10^{15} e-/cm^2**

Simulated Space Environmental Effects on Thin Film Solar Array Components

- **Electron Radiation Results**
  - **Coatings had little effect on solar cell durability**
  - **IMM**
    - **Slightly degraded after 1 x 10^{14} e-/cm^2**
  - **CIGS**
    - **Maintained power retention through all exposures**
  - **Bare single junction GaAs**
    - **Significant degradation**
  - **No significant change in transmission for either type of film**

Simulated Space Environmental Effects on Thin Film Solar Array Components

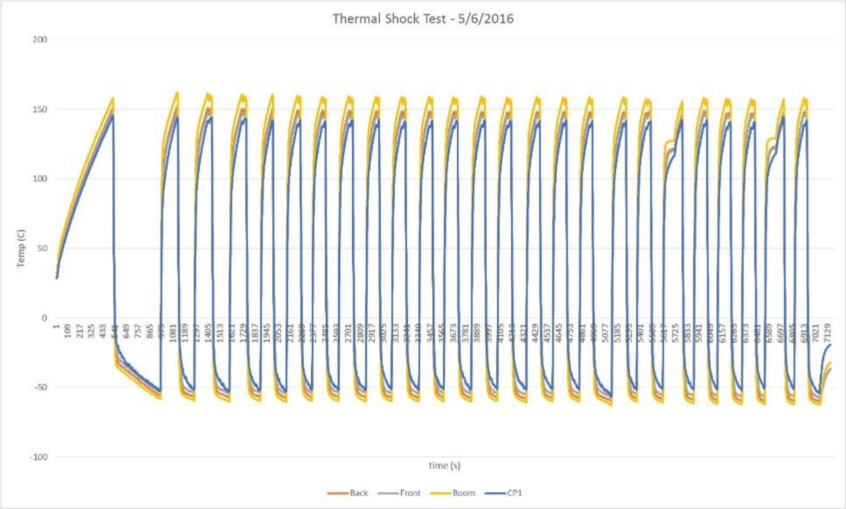
- **Proton Radiation**
  - **Combined Environmental Effects Facility with Pelletron accelerator**
  - **IMM and CIGS cells**
    - **Bare**
    - **Coated with Optinox (IMM only)**
    - **Coated with CORIN**
    - **Coated with CORIN with cerium oxide**
  - **50 keV iterations from 7 x 10^{10} up to 1 x 10^{15} p+/cm^2**
  - **100 keV, 500 keV, 700 keV 1 x 10^{13} p+/cm^2**

Simulated Space Environmental Effects on Thin Film Solar Array Components

- **Proton Radiation Results**
  - **IMM**
    - **Bare cells degraded after 1 x 10^{12} p+/cm^2 at 50 keV**
    - **Coated cells started degrading at 1 x 10^{15} p+/cm^2 at 50 keV**
    - **Coated cells maintained power retention through higher energy exposures**
  - **CIGS**
    - **Bare cells degraded with 50 keV exposure**
    - **Coated cells maintained power retention through all exposures**

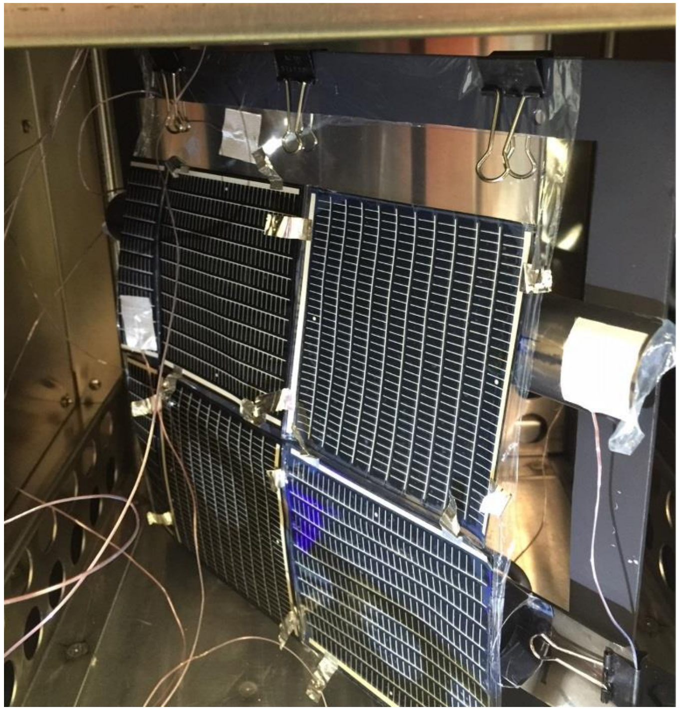
Simulated Space Environmental Effects on Thin Film Solar Array Components

- **Thermal Cycling**
  - **Associate Engineering rapid thermal shock chamber**
  - **IMM cells**
    - **Bare**
    - **Coated with CORIN**
  - **CIGS cells**
    - **Bare**
    - **Coated with CORIN**
    - **Coated with CORIN plus anti-reflectance**
  - **CIGS and IMM sub-coupons with solar array boom elements were cycled at least 35 times and in some cases up to 100 times.**
  - **Temperatures from -55 to +125 °C**



Simulated Space Environmental Effects on Thin Film Solar Array Components

- **Thermal Cycling Results**
  - **IMM**
    - **Some delamination of coating**
  - **CIGS**
    - **CORIN-coated cells performed well**
    - **AR coating delaminated**
    - **AR process has been improved but not yet tested**
  - **IMM and CIGS sub-coupons with boom elements**
    - **Both had one cell drop out for power loss**
    - **Test will be repeated to determine if power loss due to handling or thermal cycling**



- **Summary**
  - **CORIN and CORIN with cerium oxide show promise as protective coatings for both IMM and CIGS solar cells.**
  - **CORIN was particularly effective in protection from AO and proton radiation damage.**
  - **Optinox shows promise as a protective coating for the IMM solar cells outside of the AO environment.**

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