Solar Cell CIC Optimization and Factorization for CXBN-2

Lead Engineer:
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Dicing solar cells can be an effective method of optimizing surface area and packing factor on CubeSats, while providing the necessary wattage.

CXBN2’s solar panels will be tested to see if dicing solar cells and electrically connecting the string of diced cells in series will keep a positive power output for mission success.

Need to dice solar cells in order to achieve voltage matching for each string of cells.
Purpose of CIC Dicing

CIC- Solar Cell Interconnects Coverglass
This project will involve dicing the solar cell CIC to satisfy the small satellite system requirements while having the most effective surface area and providing the necessary wattage.
CXBN-2 Solar Cell System

Original Mission

• Double fold out solar panels have a double hinge system

Single Fold Out Design

• Payload power requirement is less, each payload reduced to ~1 watt each.
• Less Risk
• Less Expensive
Solar Cell

• Solar Cells are from Azur Space.

• Approximately 30% Triple Junction GaAs Solar Cell

• Type: TJ Solar Cell 3G30C - Advanced

• Equipped with an integrated bypass diode, which protects the adjacent cell in the string.
Before Dicing Full Cell Test

Azure Space Data

<table>
<thead>
<tr>
<th>Date</th>
<th>Isc mA</th>
<th>Voc V</th>
<th>Max Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell: 80361 1344 58</td>
<td>509.3</td>
<td>2.694</td>
<td>1372.0 mW</td>
</tr>
<tr>
<td>Cell: 80361 1344 60</td>
<td>512.5</td>
<td>2.713</td>
<td>1390.4 mW</td>
</tr>
</tbody>
</table>

Full Cell Data Before Dicing

<table>
<thead>
<tr>
<th>Date</th>
<th>Isc mA</th>
<th>Voc V</th>
<th>Max Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell: 80361 1344 58</td>
<td>489.5</td>
<td>2.46</td>
<td>1204.1 mW</td>
</tr>
<tr>
<td>Cell: 80361 1344 60</td>
<td>502.3</td>
<td>2.48</td>
<td>1245.7 mW</td>
</tr>
</tbody>
</table>

Scale Factor from Azure Space Data sheet to testing procedures by a factor of 1.05.
Solar Cell Dicing Process

Work was performed at University of Louisville Mico Nano Technology Center. Cutting the cells in two cuts and three pieces to test efficiency.

CubeSats need specific cuts for maximum surface area and to fit to design constraints.
After Dicing Dimensions

Fogged Region - 0.5mm²

Fogged Region - 0.5mm²

Fogged Region - 0.5mm²

Fogged Region - 0.5mm²
Solar Cell after dicing (backside)

Solar Cell diced and snapped for separation (front side)
# Testing after dicing

## Azure Space Solar Cell Testing

### Original Cell Data From Azure Space

<table>
<thead>
<tr>
<th>Cell: 80361 1344 58</th>
<th>Isc mA</th>
<th>Voc V</th>
<th>Max Power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>509.3</td>
<td>2.6</td>
<td>1372.0 mW</td>
</tr>
<tr>
<td>80361 1344 60</td>
<td>512.5</td>
<td>2.7</td>
<td>1390.4 mW</td>
</tr>
</tbody>
</table>

### Cut Cell Test Data (Measured)

<table>
<thead>
<tr>
<th>Cell: 80361 1344 58</th>
<th>Isc mA</th>
<th>Voc V</th>
<th>Max Power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>169.6</td>
<td>7.8</td>
<td>1323.4 mW</td>
</tr>
<tr>
<td>80361 1344 60</td>
<td>170.6</td>
<td>7.6</td>
<td>1297.0 mW</td>
</tr>
</tbody>
</table>
Dicing Issues

Cell Chipping and Fogging along cuts.

What caused the fogging and cracking?

Chipped Cell after dicing
Solar Cell Cuts with fogging
Possible Causes of fogging damage

- Speed rate of dicing saw.
- Vibrations from saw.
- Temperature increase.
- Water might not have been the best solution to dice with.

- Will thermal bake and vacuum remove fogging?
• After cells are diced they underwent performance testing determining
• Power output and voltage max power, to Azure Space datasheet measured under AM0.
• Extrapolate Cut Cell Power Output @ AM0?
• Compare Efficiency of cells at max power.
Testing Model (Indoor and Outdoor)

**Conditions:**
Indoor under Halide and Flood lamps to simulate part of the visible light solar spectrum from 500nm-700nm. Humidity= 0%  Room Temp= 20°C

**Outside:** AM1.0-1.2;
Sunny (No Clouds)
Region Forecast- 26.6 - 31.6°C
Temp. Measured- 31.1°C
Humidity 88%
Wind @ 2MPH (TWC)
Time: 12:51 AM - 1:51 PM

Cells were placed onto 3D printed plates
Testing Performance after dicing at MSU

Solar Light Table- Uncalibrated but simulates solar spectrum inside.

AM0
The spectrum outside the atmosphere, approximated by the 5,800 K black body, is referred to as "AM0", meaning "zero atmospheres". Solar cells used for space power applications, like those on communications satellites are generally characterized using AM0.

AM1
The spectrum after travelling through the atmosphere to sea level with the sun directly overhead is referred to, by definition, as "AM1". This means "one atmosphere". AM1 (z=0°) to AM1.1 (z=25°) is a useful range for estimating performance of solar cells in equatorial and tropical regions.
Testing Block Diagram

Indoor Solar Table

- Halide & Flood Lamp
- Solar Cell
- LOAD (PV8500) (B1500A)
- Data Output to Computer

Outside testing

- Sun
- Solar Cell
- Digital Multi-meter (DMM) Voltage and Current Readings
Power Output Results (AM1)

Full Cell Test 1
(2.2v, 0.837W)

Cut Cell Test Max Power Point-(6.78v, 0.732W)

Cut AM0 = (Cut AM1.5) * ((Full AM0) / (Full AM1))
Cut AM0 = (0.837W)(1.205W)/(0.812W)
Cut AM0 = 1.086W

Full Cell Test 2-
(2.22v, 0.787 W)
Thermal Vacuum Residual Gas Analysis Testing

Thermal Vacuum RGA test to determine the effect of the space environment on fogged regions on diced cells.

Start = Saturday, June 04, 2016
4:46:40 PM:000
Span = 4 Day(s) 20 Hour(s) 33 Min(s) 20 Sec(s)

Three Thermocouples (TC)
TC1– Between Aluminum plate and kapton Tape.
TC2- Cell #60 (Top Row)-Left Cut
TC3- Cell #58 (Bottom Row)-Right Cut

Other Measurements
Platen Temperature
Oven Temperature- 21.85°C - 80°C
Pressure– 9.3x10⁻⁷ Torr
# Test Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oven Max</td>
<td>63.6 °C</td>
</tr>
<tr>
<td>TC1 Max</td>
<td>100.8 °C</td>
</tr>
<tr>
<td>TC2 Max</td>
<td>98.6 °C</td>
</tr>
<tr>
<td>TC3 Max</td>
<td>101.8 °C</td>
</tr>
<tr>
<td>Platen Max</td>
<td>92.3 °C</td>
</tr>
<tr>
<td>Pressure</td>
<td>9.98E-07 Torr</td>
</tr>
</tbody>
</table>
Post TVAC Fogging Inspection
Cut Cell

Left Cut
Left Center
Right Center
Right Cut
Full Cell vs Cut Cell CXBN2 Mission Requirements

- Full Cell is 29% efficient.
- Cut cell with no damage is 29% efficient.
- Cut cell at AM1.5 is ~28% due to fogging.
- Would have to connect two cells that are diced in series with fold out panel to keep solar array at max power output and solar efficiency.

Cut cells will provide more voltage at Vmp (Voltage Max Power) AM0 compared to full cell.
Conclusions

Dicing method is successful as long as the cut rate stays below 0.5mm/s.

Cut cells that are not damaged from dicing will keep the same efficiency and provide the mission requirements needed.

Fogging of cells is permanent damage, proof after environmental testing.
Questions/Comments