EpiNex®: Ultra Thin Epitaxial Wafers for Radiation Resilient PV Cells for Space

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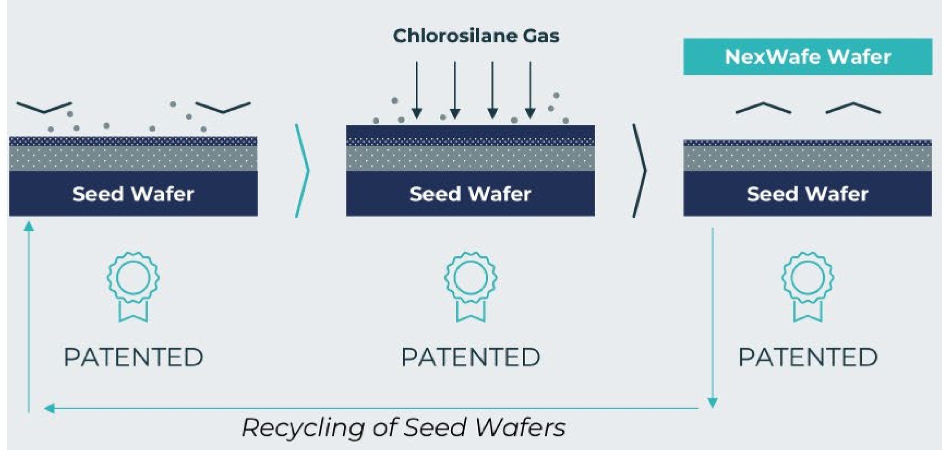
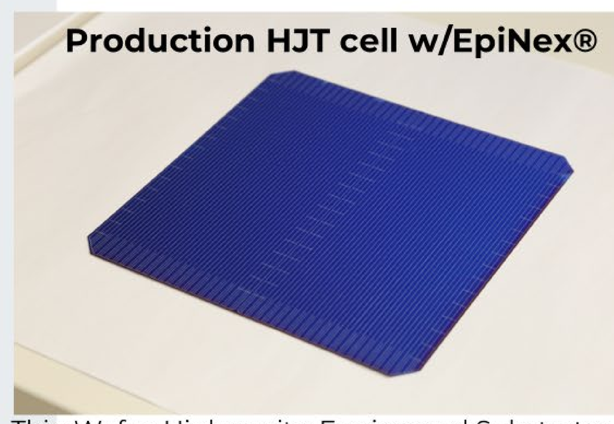
NEXWAFE

- ***Conventional CZ wafers enable current PERC-based LEO systems.***
- ***Next-generation space PV require lower mass, less shielding, higher power density and radiation resilience***
- ***EpiNex® enables ultra-thin wafers with engineered junctions leading to improved end of life performance***

EpiNex® Manufacturing Enables Engineered Ultra-Thin Wafer Profiles for Space Applications





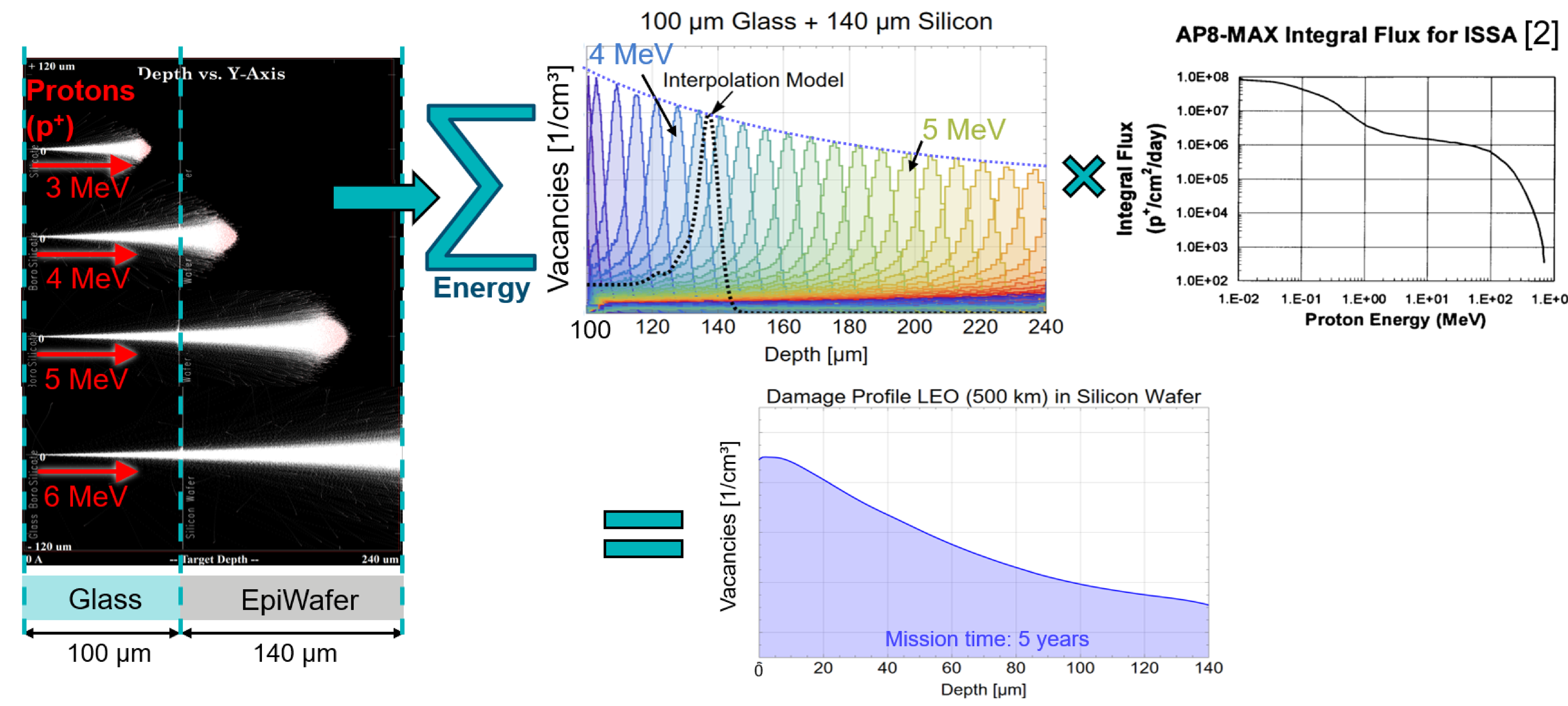
Thin Wafer, High purity, Engineered Substrates

Epitaxial growth enables ultra-thin, ultra-low-oxygen wafers with controlled doping gradients unlocking radiation-optimized designs and higher power density (W/kg)

1) Versus traditional Cz process 2) Compared to manufacturing of Cz wafers in China

LEO Radiation Profiles Enable Engineered Wafer Design

SRIM [1] Particle Simulation of Radiation Damage



Depth-dependent radiation damage enables engineered bulk fields aligned to damage profile

EpiNex Unlocks Junction Architectures Cz Cannot Enable

CZ Wafer

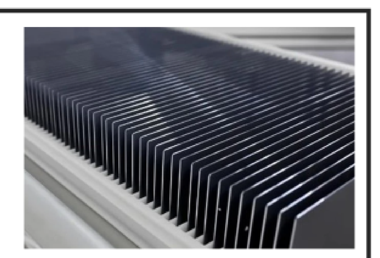
Wire sawed from ingot

Limitations

- **Wafer thickness below <90 µm challenging**
- **Variability in resistivity along the ingot**
- **Oxygen Contamination**
  - Degraded thermal stability/efficiency
- **Wire saw micro scale grooves**
  - Not compatible with low cost Tandem cells
- **Doping profile through wafer CANNOT be controlled**

EpiNex

Epitaxially grown



Advantages

Ultra Thin: Demonstrated to <60 µm

Precision doping within wafer and wafer to wafer

- Improved efficiency distribution

Ultra Low Oxygen: Improved thermal stability

Ultra Smooth surface

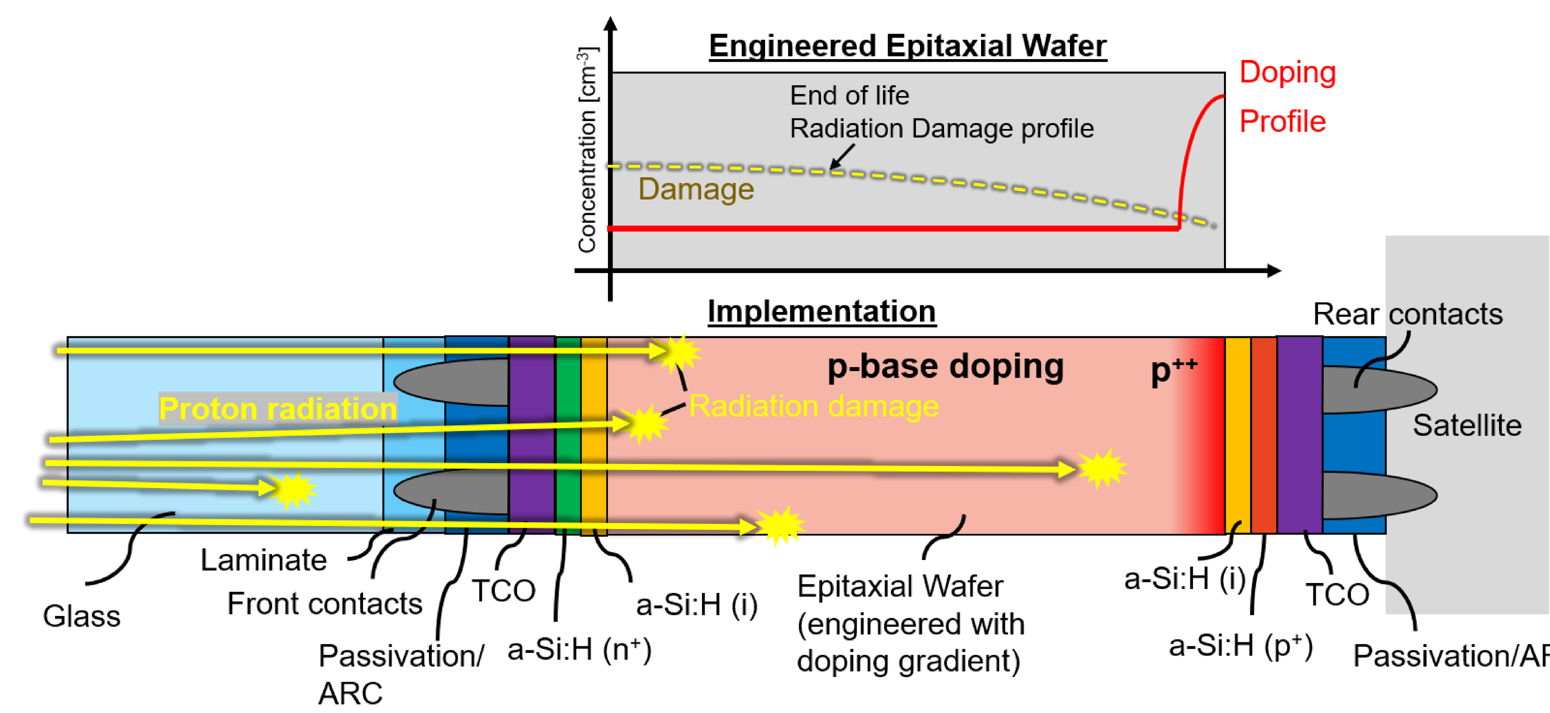
- Key for solution based Tandem Junctions

Graded Junction

- Improved efficiency & radiation resilience

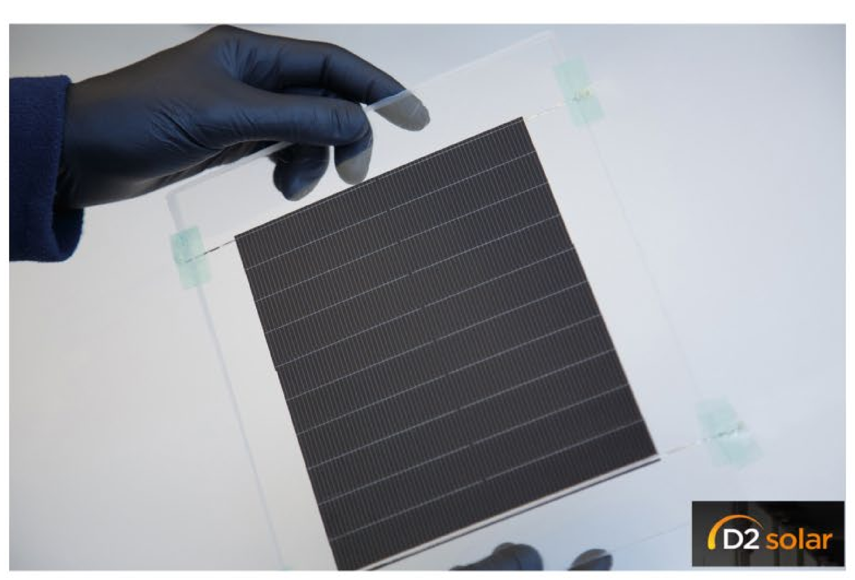
EpiNex enables Ultra thin, precision resistivity wafers with Junction Architectures not possible with CZ. Potential to Enable Efficiency gains and Radiation Resilience

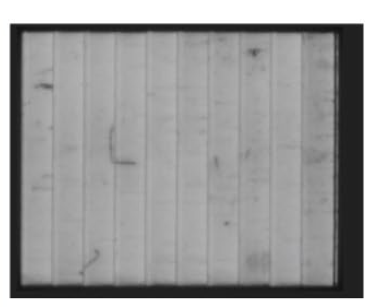
p-type HJT (Front Side Emitter) with Engineered Junction



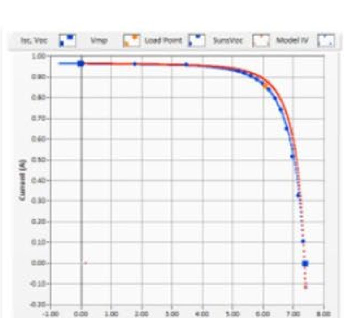
Engineered doping gradient reduces recombination in radiation-damaged regions

Ultra-thin EpiNex (70 µm) HJT Shingled Mini-Module





EL Test shows good Structural integrity



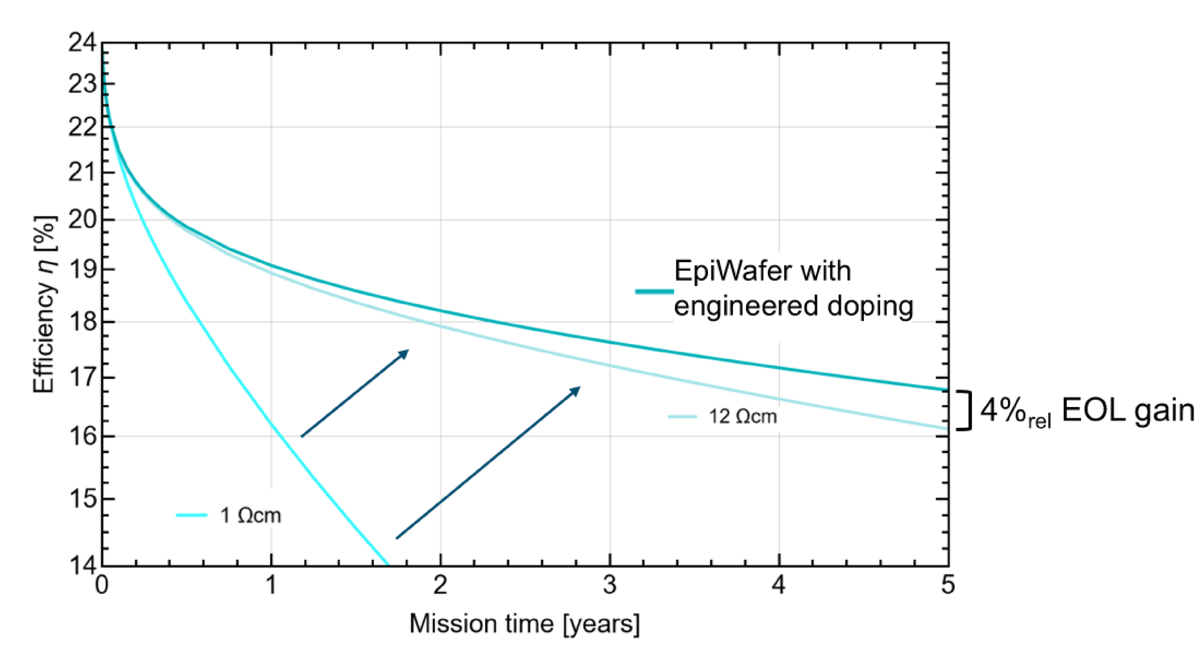
Module Efficiency ~20%

LEO requirement >200 W/kg. EpiNex p-HJT mini module shows 230 W/kg
Roadmap to >300 W/kg for LEO with p-EpiNex HJT 70 µm

EpiNex LEO mini HJT Module Demonstrated 230W/Kg Performance

EpiNex® Improves End-of-Life Efficiency (~14% Relative Gain)

Modeling of the EpiNex junction engineering has potential to improve radiation resilience



Engineered wafers will significantly improve 5-year end-of-life efficiency

[1]: Ziegler *et al.*, Nucl. Instrum. Methods B 268, 1818 (2010).
[2]: Marshall, P. W., & Marshall, C. J. (1999). *Proton effects and test issues for satellite designers* (NSREC Short Course, Section IV). NASA Technical Reports Server. NTRS ID 19990110691.