RÉPUBLIQUE FRANÇAISE
*Liberté
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CNES CENTRE NATIONAL D'ÉTUDES SPATIALES

Solar activities @ CEA

- ❑ Innovation and competitivity
- ❑ **Reliable processes** from low maturity levels
- ❑ **Accelerate** technology transfer
- ❑ Support To PV Industry

22 000 sqm
120 M€ Equipment
≈500 employees
50 M€ Annual Budget
> 45 patents a year

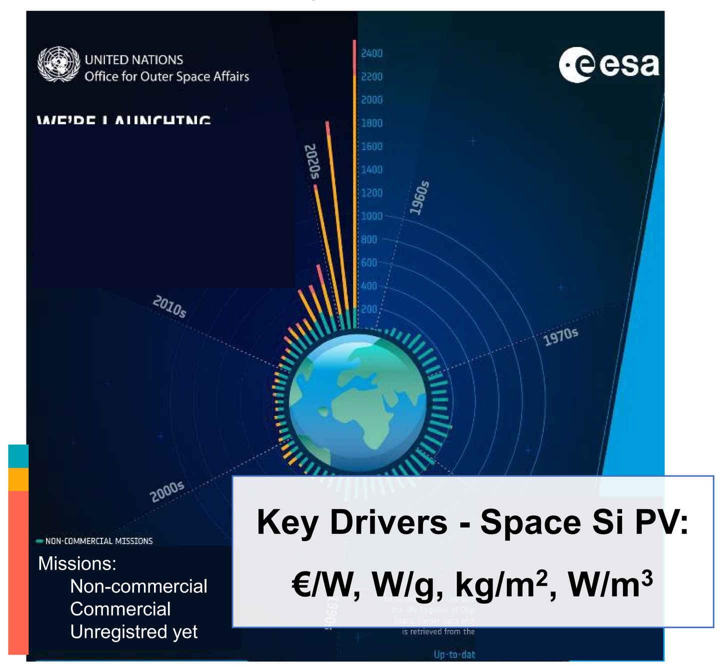
> 20 years!

Premium Photovoltaic Material, Cells and modules

Grid integration I Diagnosis & Data I Energy management systems I Storage

Context of PVA for space

- ❑ **III-V Reference:** > 30 % AM0 cells efficiency; PVA/ High stiffness/58 W/kg /8 kW/m3 /3-5 kg/m²
- ❑ **Harsh environmental constraints:**
  - Extreme temperature (-180°C, +120°C), thermal cycle (up to per day), vacuum, radiations (e-, p+, UV), ATOX, plasma, micro-meteoroids, AM0 spectrum, vibrations, ESD,



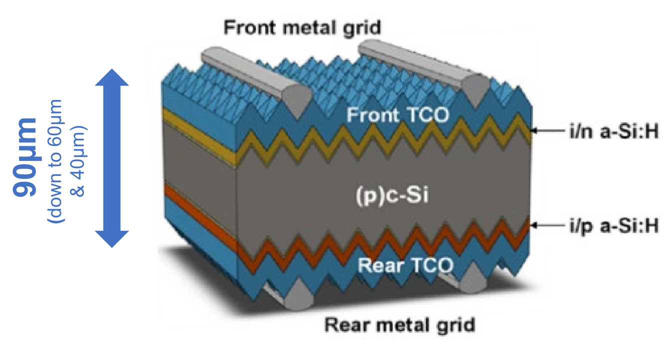
Silicon Approach Advantages

- ❑ Advanced **mature** terrestrial technologies
- ❑ **Cost effective** solution
- ❑ **Industrial capacity & Lead Time**
- ❑ **High performance** Opportunity with curing technologies (industrial mode)
- ❑ **100% French/ European Manufacturing** cells (from Material to cell)
- ❑ Managed **Secured** European Supply chain

Example of Silicon Heterojunction Solar Cell activities (SorSiHET Project*)

A key cell technology for space

Si materials & cell architecture choices for improved EOL performances



- ❑ **Radhard Si cells legacy**
  - p-Type doping
  - Front emitter architecture
  - Reduced absorber thickness
- ❑ **Symetric & low temp. Process**
  - Front emitter with p-Type Si (Ga doping)
  - Suitable for ultra-thin Si
- ❑ **New insights into the role of the Si material** properties on the radiation hardness of SHJ cells
- ❑ **European solar cells manufacturers**

- ❑ **Self-curing in Si**
  - Specific impurities help to promote displacement damages self-curing
  - Effect enhanced by light & temperature

✓ EOL/ > 17,6% efficiency after 1 MeV e- fluence = 1x1014 e-/cm² / fully certified

✓ Full phot-voltage self-curing demonstrated for SHJ @ 1 sun after 1000 hours even at low operational temperature (80°C/ 65°C)!

CERTIFIED

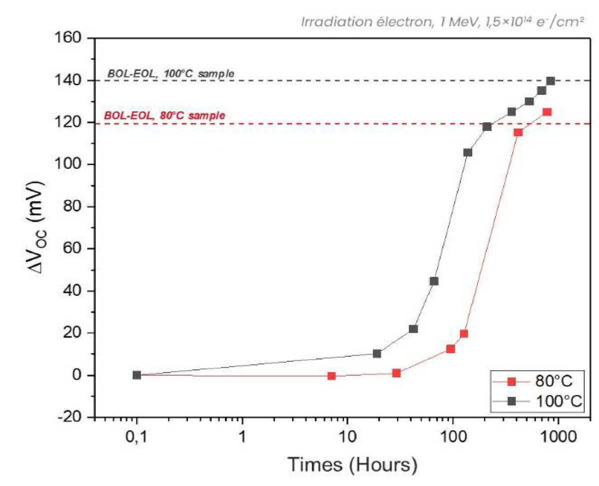


Fig 11. Particles irradiation damage self-curing at operating conditions [1].

Results are provided for 40x40 mm² cutted cell

1 MeV electron irradiations	V_{oc} [mV]	J_{sc} [mA.cm^{-2}]	FF [%]	eta [%]
BOL	740	46.0	73.4	18.3
EOL	562	45.1	74.1	13.8
After recovery	721	46.0	72.5	17.6
Tests conditions: 40x40 mm² laser cut, AM0 spectrum, light intensity=1367 W/m², cell temperature=25°C				

Example of PVA results (SPELL Project *)

- ❑ Build a predictive **thermomechanical model of interconnections**
- ❑ Develop adhesive electrical interconnection for 90µm & 60µm SHJ shingle PVA
- ❑ **Fabrication of Si PVA** with electrically conductive adhesive, **COTS component & processes**

Shingle SHJ PVA - APTC
3000 thermal cycles (TC) on 90 µm passed, towards 8000 APTC CT
> 10,000 TC for rigid configuration (130µm)

- ❑ Develop adhesive electrical interconnection for 90µm & 60µm SHJ shingle PVA
- ❑ Terrestrial ECA benchmarked & tested:
  - ✓ **Outgassing - ECSS-Q-ST-70-02C**
  - ✓ **Mechanical / adhesion study**

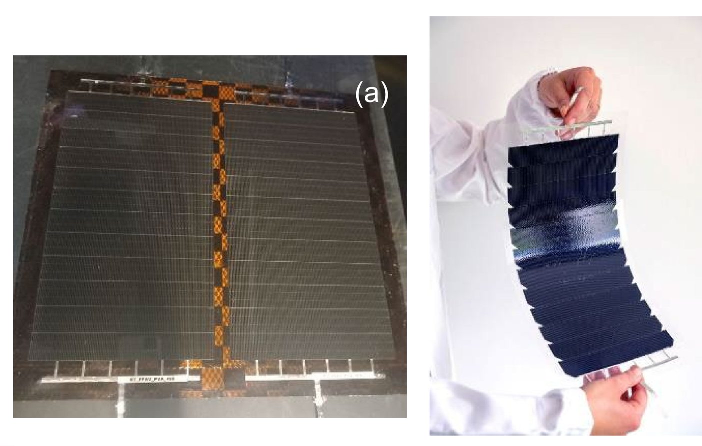


Fig 6. (a) 90 µm SHJ shingle PVA CRFP coupon; (b) 60 µm SHJ bifacial PVA [1,6].

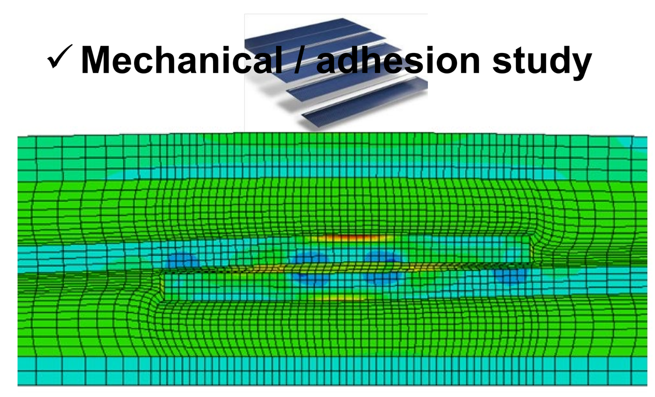


Fig 7. TCAD simulations for shingle interconnections.

Current Challenges & Perspectives

- ❑ **Silicon Solar Cell technologies**
  - ➢ Improvement of the EOL efficiency for LEO → mid term target at 19 % AM0 25°C (self resistant behavior)
  - ➢ Pre-industralization of a Silicon cell solution optimized for Space applications
- ❑ **Photovoltaic Array technologies**
  - ➢ Interconnection robustness versus thermal cycles (> 50 000) for LEO
  - ➢ Development of the PV expertise and tool boxes for PVA assessments
  - ➢ Understanding materials and system degradation mechanisms
  - ➢ Global system analysis trade-off
  - ➢ Pre-industralization of a Silicon PVA solution for Space applications

Présenté aux
RENCONTRES TECHNIQUES ET NUMERIQUES
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CNES team: DTN/TVO/3CE : Loris Ibarrart, Jean-Marc Belloir, DTN/QE/EC : Matthieu Fongral, D.Veyrie; DOA/NT : Christian DUPUY
CEA team: S.Harrison, N.Enjalbert; S.Dubois; W.Favre; C.Roux; C.Jamin; P.Voarino; R.Cariou; J.B.Charpentier; R.Feilleux; E.Voroshazi; M.Davenet

Examples de résultats solaires avec le support du CNES via son programme de R&T, puis dans le cadre de développement de technologie pour les projets Télécom (*programme PEGASE), pour permettre la création d'une filière industrielle européenne de cellules hétérojonction sur substrats minces (≤ 90 µm), efficaces pour des applications spatiales

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