SOLAR DEVICE STUDIO / PUBLIC EVIDENCE

# Laboratory validation request

Matched three-arm silicon HBC split-lot experiment for a frozen 75 um research design projection.

## Purpose

We are seeking a fabrication and measurement partner to test a frozen three-arm design. Arm A reproduces the 175 um baseline process, Arm B applies the published roadmap stack at 175 um, and Arm C applies the same roadmap stack at 75 um. The headline gate compares C with A; the B-to-C comparison separately isolates the thinning increment. The candidate was frozen before measurement and will not be tuned to the resulting data.

| A | B | C | >= 10 |
|---|---|---|---|
| 175 um BASELINE PROCESS | 175 um ROADMAP STACK | 75 um ROADMAP CANDIDATE | CELLS PER ARM PER LOT |

### Experimental design

- Use the same feedstock family and preserve the measured resistivity distribution across all three arms.
- Arm A reproduces the published baseline process as closely as the participating line permits.
- Arms B and C use the same roadmap surface preparation, passivation, selective contacts, rear pattern, metallization, anneals, edge treatment, antireflection stack, and rear reflector.
- Thickness is the only intentional difference between Arm B and Arm C.
- Randomize wafer assignment within each lot and retain every processed cell in the outcome table.
- Use stable lot_id, wafer_id, cell_id, and arm identifiers in every raw and processed file.

### Minimum useful campaign

One three-cell set can test data plumbing but cannot establish robustness. The preferred campaign is at least three independent process lots with ten completed cells per arm per lot. Report breakage and process failures as outcomes rather than removing them.

**The lab measures the design. It does not fit or revise the model.**

# Required measurements

Provide instrument-native numerical files wherever possible. Do not submit graph images as the only numerical record.

## 1. Geometry and identity

Measured wafer and finished-cell thickness, total and active area, bow/warp, breakage, lot and cell identity, and complete process metadata.

## 2. Optical response

Total and diffuse reflectance plus EQE on the same cells, ideally 300-1200 nm at 5 nm spacing or finer, with uncertainty and calibration identifiers.

## 3. Light J-V

Raw voltage and current-density points at 25 C under calibrated AM1.5G, 1000 W/m2; scan direction/rate, aperture, Voc, Jsc, fill factor, and PCE.

## 4. Recombination

Lifetime versus injection, Suns-Voc, and dark J-V on identified cells or traceable companion samples; include stated extraction methods.

## 5. Contacts

Area-normalized series and contact resistance, extraction method, grid geometry, metal coverage, and raw curves or maps.

## 6. Material state

Direct resistivity or doping measurement, conductivity type, wafer orientation, feedstock class, and measurement depth/location.

## 7. Traceability

Instrument models, calibration IDs and dates, timestamps, operators, units, uncertainty budgets, and SHA-256 for every delivered file.

## Required comparisons

- Arm C versus Arm A tests the complete candidate's headline relative-gain gate.
- Arm B versus Arm A measures the contribution of the published roadmap stack.
- Arm C versus Arm B isolates the thin-wafer increment and its optical-current tradeoff.
- Long-wavelength EQE, lifetime, recombination, yield, breakage, and bow/warp are compared by arm within each lot.

# Freeze, score, and falsify

Before outcomes are opened, both parties freeze the design receipt, file schema, cell identities, exclusions, and analysis plan. The model is run once on the complete packet. Missing or failed cells remain visible. Any later model improvement is a new version and must be tested on new held-out data.

## Predeclared decision gates

| Gate | Pass condition |
|---|---|
| Primary design gain | Mean Arm C PCE is at least 5% higher relative to Arm A, with the uncertainty analysis reported. |
| Thinning increment | Arm C improves on Arm B while the optical and electrical measurements account for the thickness-only tradeoff. |
| Optical retention | Measured EQE-integrated current supports the required long-wavelength retention; raw spectra and uncertainty remain public to reviewers. |
| Electrical mechanism | Lifetime, recombination, and voltage measurements are directionally consistent with the proposed thin-wafer benefit. |
| Manufacturing viability | Breakage, bow/warp, and completed-cell yield are reported for all three arms; no silent survivor-only analysis. |
| Traceability | All reported results resolve to cell IDs, raw files, calibration records, units, and checksums. |

## Delivery package

- One immutable manifest linking every lot, wafer, cell, sample, measurement, and method.
- Raw reflectance, EQE, light J-V, dark J-V or Suns-Voc, lifetime, and resistance files.
- Cell metadata, process deviations, yield and breakage table, calibration records, uncertainty note, and SHA-256 list.
- Preferred package name: LABNAME_HBC_THREE_ARM_SPLITLOT_V1_YYYYMMDD.zip

## Current projection supplied to the lab

Frozen midpoint projection: 42.652 mA/cm2 Jsc, 0.7873 V Voc, 0.8492 fill factor, and 28.513% PCE for the 75 um candidate. This is an unbuilt research prediction and is included so the test is fully preregistered.

## Contact request

Please respond to contact@fluxmateria.com with available HBC process capability, minimum wafer thickness, measurement coverage, expected uncertainties, lot and cell capacity, schedule, cost, data-use terms, and any required confidentiality conditions. Project website: https://fluxmateria.com

Primary device source: https://doi.org/10.1038/s41467-024-53275-5

Thin-wafer precedent: https://doi.org/10.1038/s41586-023-06948-y