N86-29381

# EXCIMER LASER ANNEALING FOR FABRICATION OF LOW-COST SOLAR CELLS

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## Program Goal

TO DETERMINE IF PULSED EXCIMER LASER ANNEALING (PELA) IS COST EFFECTIVE COMPARED TO BASELINE PROCESS.

| BASELINE PROCESS | LASER PROCESS |
|---|---|
| CLEAN | CLEAN |
| DRY | DRY |
| DIFFUSE JUNCTION | ION IMPLANT |
| ALUMINUM BSF | LASER ANNEAL |
| CLEAN | |
| PRINT Ag BACK | PRINT Ag BACK |
| PRINT Ag FRONT | PRINT Ag FRONT |
| LASER CUT | LASER CUT |
| TEST AND SORT | TEST AND SORT |

## Objectives

- BUILD AN EXCIMER LASER PULSED ANNEAL APPARATUS
- DEVELOP ANNEAL PROCESSING FOR HIGH EFFICIENCY CELLS
- FABRICATE 300 SOLAR CELLS
- PERFORM ECONOMIC ANALYSIS

## Laser-Annealed AR-Coated Cells

| CELL | LOT | $\rho$ ($\Omega$ cm) | $V_{oc}$ (mV) | $J_{sc}$ (mA/cm$^2$) | FF (%) | Eff (%) |
|---|---|---|---|---|---|---|
| 4615-4d | SW-27 | 0.34 | 616 | 31.2 | 80.2 | 15.4 |
| 4615-8e | WA70055 | 0.31 | 614 | 31.7 | 79.9 | 15.6 |
| 4615-12d | WA70055 | 0.17 | 617 | 30.4 | 80.2 | 15.0 |
| 4615-16a | WA20820 | 0.34 | 616 | 31.2 | 80.0 | 15.4 |
| 4615-20b | WA20979 | 2.2 | 592 | 32.0 | 79.5 | 15.1 |

NOTES: INSOLATION WAS SIMULATED AM1, 100mW/cm$^2$. T=28°C. A=4cm$^2$.

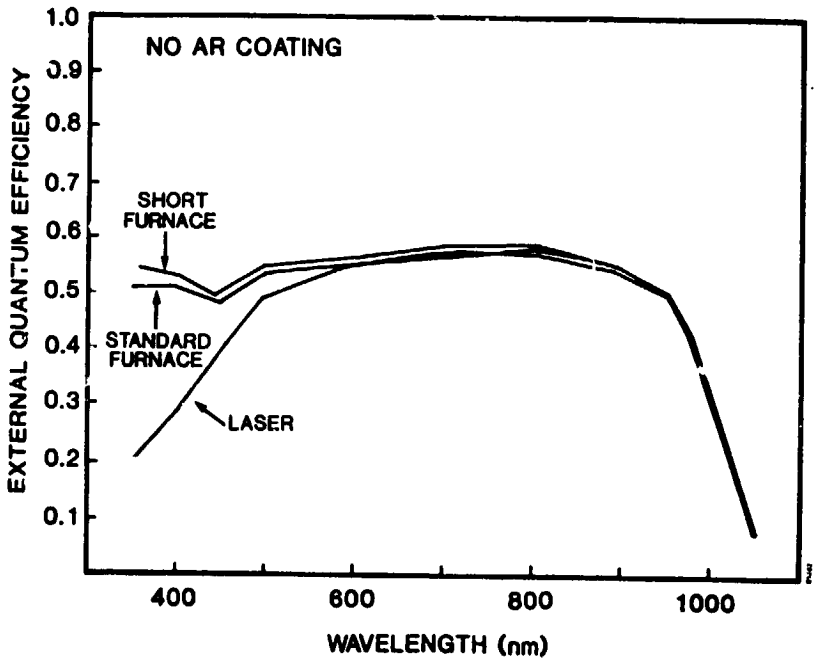
## Advantages and Disadvantages of Laser Annealing

- RAPID DRY PROCESSING
- NO HEATING OF THE WAFER
- TEXTURED WAFERS DIFFICULT TO ANNEAL
- NOT COMPATIBLE WITH $SiO_2$ PASSIVATION

## Best-Cell Comparison of Laser Annealing With Furnace Annealing (No AR Coatings)

| CELL | ANNEAL | $V_{oc}$ (mV) | $J_{sc}$ (mA/cm$^2$) | FF (%) | Eff (%) |
|---|---|---|---|---|---|
| 4615-4d | LASER | 607 | 22.6 | 79.5 | 10.9 |
| 4524-13e | SHORT FURNACE | 612 | 23.6 | 81.4 | 11.8 |
| 4524-9c | STANDARD FURNACE | 615 | 23.9 | 82.0 | 12.0 |

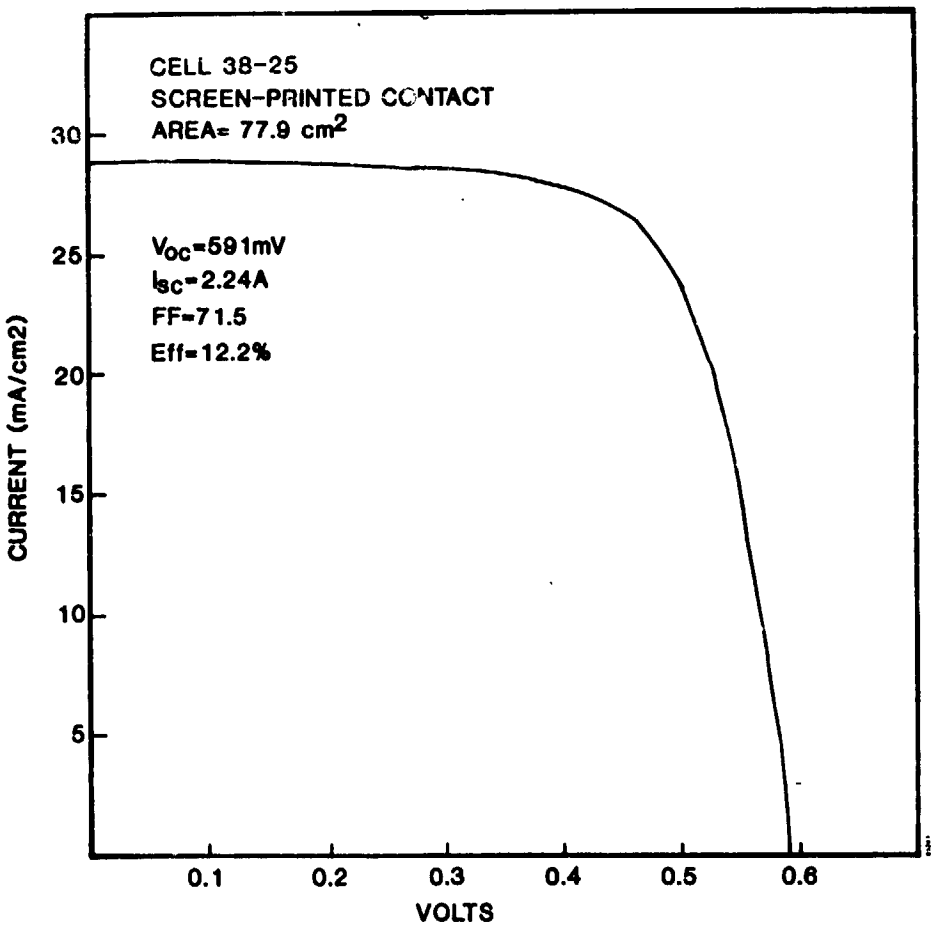
NOTES: INSOLATION WAS SIMULATED AM1. 100 mW/cm$^2$. T=28°C. A=4cm$^2$.



## Large-Area AR-Coated Solar Cells

| NO. OF CELLS | METALLIZATION | ANNEAL | $V_{OC}$ (mV) | $J_{SC}$ (mA/cm$^2$) | FF (%) | Eff (%) |
|---|---|---|---|---|---|---|
| 7 | PRINTED | LASER | 589 | 27.1 | 72.8 | 11.5 |
| 7 | PRINTED | FURNACE | 590 | 28.9 | 71.5 | 12.1 |
| 4 | EVAPORATED | LASER | 590 | 28.9 | 77.9 | 13.3 |
| 5 | EVAPORATED | FURNACE | 591 | 30.8 | 77.4 | 14.1 |

NOTES: AREA OF EVAPORATED CELLS IS 53cm$^2$.
AREA OF SCREEN-PRINTED CELLS IS 77.9cm$^2$.
INSOLATION WAS AM1,100mW/cm$^2$. T=28°C



## Excimer-Laser-Annealed Solar Cells

| CONTACT | NO. OF CELLS | $V_{oc}$ (mV) | $J_{sc}$ (mA/cm$^2$) | FF (%) | Eff (%) | Effx1.4 (%) |
|---|---|---|---|---|---|---|
| EVAPORATED (53cm$^2$) | 92 | 580 (3) | 21.2 (0.3) | 78.1 (0.6) | 9.6 (0.2) | 13.4 (0.3) |
| PRINTED (77.9cm$^2$) | 25 | 580 (2) | 19.9 (0.3) | 71.0 (2.0) | 8.2 (0.3) | 11.5 (0.4) |

NOTES: INSOLATION WAS AM1, 100mW/cm$^2$, T=28°C.

## Summary of Economic Analysis

| PROCESS | COST-PER-WAFER (1985$) |
|---|---|
| ION IMPLANT PHOSPHORUS (SPI-ION 1000) | 0.18 |
| TUBE FURNACE ANNEAL | 0.07 |
| BELT FURNACE ANNEAL | 0.035 |
| EXCIMER LASER | 0.05 |

1MW/SHIFT, 3 SHIFTS/DAY, 90% YIELD.

# Principal Findings

(1) EXCIMER LASER ANNEAL IS SATISFACTORY WHEN APPLIED TO POLISHED WAFERS. ANNEALING OF TEXTURED WAFERS REQUIRES FURTHER WORK.

(2) THE 50 WATT EXCIMER LASER IS CAPABLE OF HIGH THROUGHPUT PROCESSING.

(3) LASER UNIFORMITY IS SUFFICIENT.

(4) SCREEN-PRINTED CONTACTS CAN BE APPLIED TO EXCIMER-LASER-ANNEALED WAFERS.

(5) ANALYSIS INDICATES THAT THE LASER MUST PRODUCE BETTER CELLS THAN THE FURNACE TO BE ECONOMICALLY COMPETITIVE.