

N85-32426

# SIMULTANEOUS JUNCTION FORMATION

WESTINGHOUSE ELECTRIC CORP.

R.B. Campbell

## Contract Information

OBJECTIVE: INVESTIGATE HIGH-RISK; HIGH-PAYOFF IMPROVEMENTS  
TO WESTINGHOUSE BASELINE PROCESS SEQUENCE

TIME PERIOD: MARCH, 1984 - OCTOBER, 1984

## Contract Tasks

- EVALUATE FEASIBILITY OF SIMULTANEOUSLY FORMING BACK & FRONT JUNCTIONS OF SOLAR CELLS USING LIQUID DOPANTS ON DENDRITIC WEB SILICON
- COMPARE SIMULTANEOUS DIFFUSION TO SEQUENTIAL DIFFUSION
- TEST OF BELT FURNACE FOR DIFFUSION PROCESS

WHEN SHOWN FEASIBLE:

- DEVELOP PROCESS CONTROL PARAMETERS AND SENSITIVITIES
- PERFORM COST ANALYSES

## Potential Benefits

- FEWER PROCESSING STEPS
- LESS OPPORTUNITY FOR CONTAMINATION AND BREAKAGE DURING PROCESSING DUE TO HANDLING
- LESS COSTLY PROCESS

HOWEVER

- PROCESS WILL REQUIRE CAREFUL SELECTION OF DOPANTS, DIFFUSION MASKS, AND WEB CONDUCTIVITY TYPE

PRECEDING PAGE BLANK NOT FILMED

## PROCESS DEVELOPMENT

### Approaches

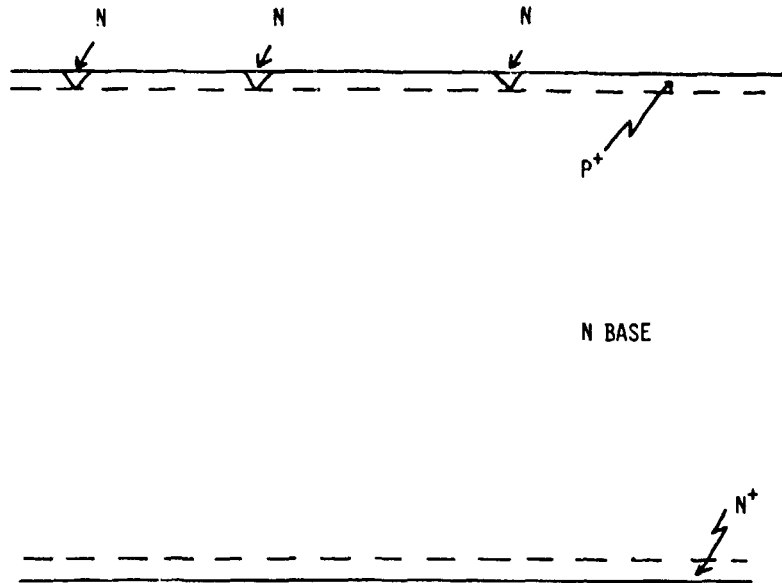
- DIFFUSION
  - N-TYPE DENDRITIC WEB
    - PHOSPHORUS OR ARSENIC FOR BACK N<sup>+</sup>N JUNCTION
    - BORON OR ALUMINUM FOR FRONT P<sup>+</sup>N JUNCTION
  - P-TYPE DENDRITIC WEB (LOW RESISTIVITY)
    - PHOSPHORUS FOR FRONT N<sup>+</sup>P JUNCTION
    - BORON OR ALUMINUM FOR BACK P<sup>+</sup>P JUNCTION
    - BACK SURFACE DAMAGE
- BASELINE PROCESS EXCEPT FOR DIFFUSION
- TEST OF VARIOUS VENDORS' DOPANTS AND DIFFUSION MASKS
- EXCIMER LASER DRIVE IN
  - PHOSPHORUS, BORON, AND ALUMINUM DOPANTS

### Results: n-Type Web

- LIQUID SOURCE - SEQUENTIAL DIFFUSION OF B (FRONT) AND P (BACK)  
PRODUCED CELLS WITH  $\eta_{AV} > 13\%$
- LIQUID SOURCE - SIMULTANEOUS DIFFUSION USING B & P PRODUCED JUNCTION  
DEPTHS OF 0.25  $\mu\text{m}$  ( $\text{P}^+\text{N}$ ) AND 0.6  $\mu\text{m}$  ( $\text{N}^+\text{N}$ )
- SUITABLE JUNCTIONS ALSO OBTAINED USING BORON (FRONT) AND ARSENIC  
(BACK)
- IN ANY EXPERIMENT WHERE TWO DOPANT SPECIES WERE PRESENT, CELL  
PROPERTIES WERE DEGRADED DUE TO CROSS DOPING OF THE FRONT JUNCTION
- CELL EFFICIENCIES VARIED FROM  $< 1\%$  TO 6-7% WITH A FEW CELLS  $> 10\%$
- CROSS DOPING ALSO OCCURRED WHEN  $\text{SiO}_2$  DIFFUSION MASKS (LIQUID OR  
THERMAL) WERE USED
- EFFECT ALSO OCCURRED AT LOWER DIFFUSION TEMPERATURES
- PROBLEM DUE TO HIGH MOBILITY OF P AT DIFFUSION TEMPERATURES  
REQUIRED
- EFFECT STUDIED USING DARK IV AND CONDUCTIVITY MEASUREMENTS

## PROCESS DEVELOPMENT

### Shorting Paths in Front $p^+n$ Junction Due to Contamination With Back-Surface Dopant



### Results: p-Type Web

- SHALLOW B-DOPED BSF DUE TO LOW TEMPERATURE DIFFUSION (REQUIRED FOR FRONT P-DOPED JUNCTION); HIGH RESISTIVE CONTACT PROBABLY SCHOTTKY BARRIER.  $\eta_{max} = 7\%$
- AL BSF ALSO GAVE HIGH RESISTANCE CONTACT WITH  $\eta_{max} = 8\%$
- CELLS OF  $>12\%$  EFFICIENCY FABRICATED USING PHOSPHORUS FRONT DOPING ONLY WITH THE BACK SURFACE DAMAGED (0.5  $\mu\text{cm}$  - 1.5  $\mu\text{cm}$ )
- NO NOTICEABLE CROSS DOPING IN CELLS

### Belt Furnace Test

- TEST CARRIED OUT AT RADIANT TECHNOLOGY CORPORATION
- PROPER TEMPERATURE AND TEMPERATURE GRADIENTS OBTAINED
- SUITABLE JUNCTION DEPTHS OBTAINED
- CELLS SHOWED EFFECT OF CROSS-DOPING

## Junction Formation Using an Excimer Laser

### APPROACH

HEAT SURFACES OF WEB WITH LASER TO DRIVE IN LIQUID DOPANTS

### CONDITIONS

WAVELENGTH - 3080 nm

POWER INPUT TO WEB 1 + 2 J/cm<sup>2</sup>

### EXPERIMENT

DRIVE IN B, P, AND AL INTO BOTH N-TYPE AND P-TYPE WEB

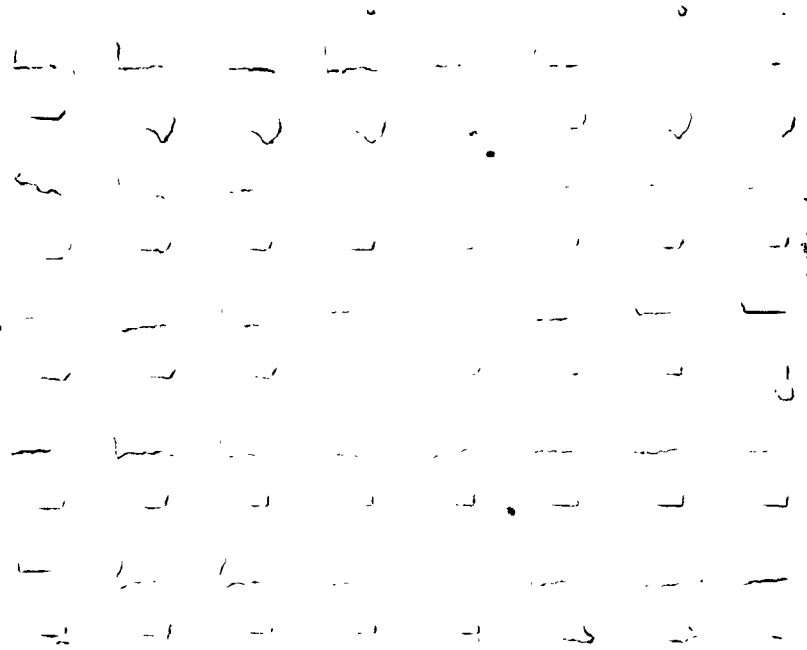
INITIAL STUDY CARRIED OUT AT MATHEMATICAL SCIENCES NORTHWEST, INC.

Sample 17B, p-Base Web, Phosphorus Emitter 1.15 J/cm<sup>2</sup>



## PROCESS DEVELOPMENT

### Sample 17B, p-Base Web, Boron BSF 1.15 J/cm<sup>2</sup>



### Results: Excimer Laser

- JUNCTION CHARACTERISTICS

N<sup>+</sup>N OR N<sup>+</sup>P (PHOS. DOPED)  $C_0 = 10^{19}/\text{cm}^2$   $X_j = 0.2 - 0.25 \mu\text{m}$

P<sup>+</sup>N OR P<sup>+</sup>P (B DOPED) ESSENTIALLY NO JUNCTION

P<sup>+</sup>P (AL DOPED) SHALLOW JUNCTION

- CELL PROPERTIES

P TYPE WEB,  $\eta_{\text{max}} = 9\%$  - DUE TO HIGH RESISTANCE BACK CONTACT (BOTH B & AL BSF)

N TYPE WEB,  $\eta_{\text{max}} < 1\%$  - POOR B DOPED EMITTER

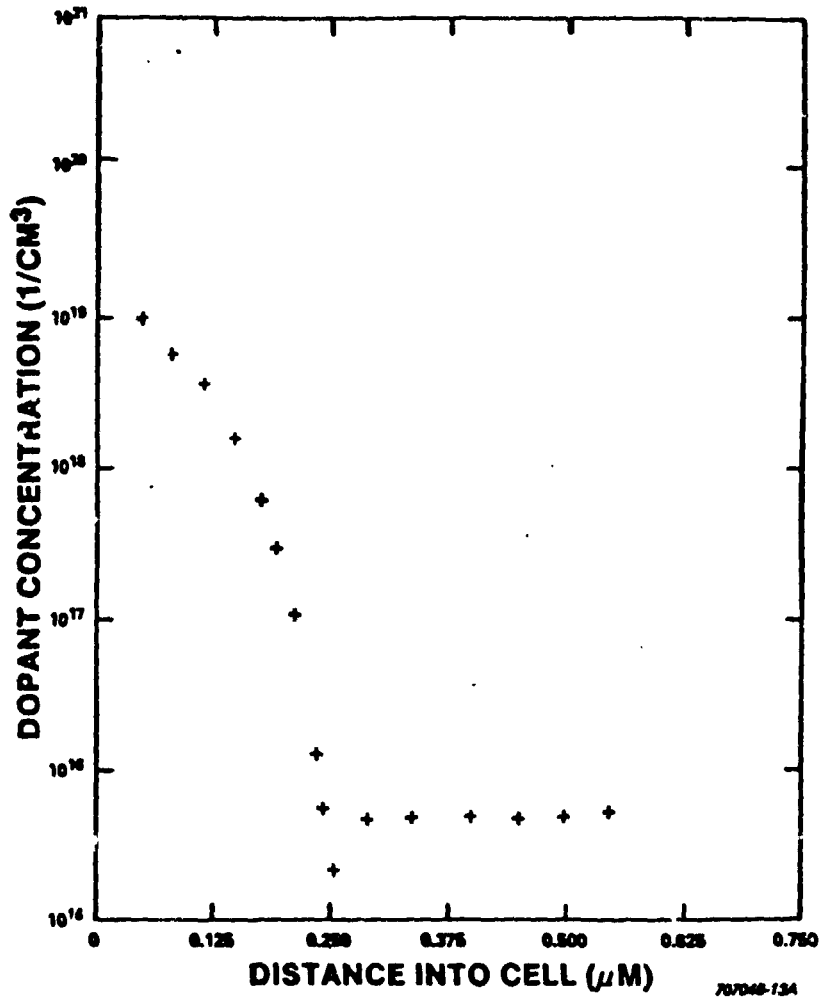
- LOW DIFFUSION CONSTANT OF BORON WILL REQUIRE HIGHER POWER INPUT

- NO CROSS CONTAMINATION NOTED

- CRYSTAL PAIRS PROCESSED BASELINE SEQUENCE -  $\hat{\eta} = 13.7\%$

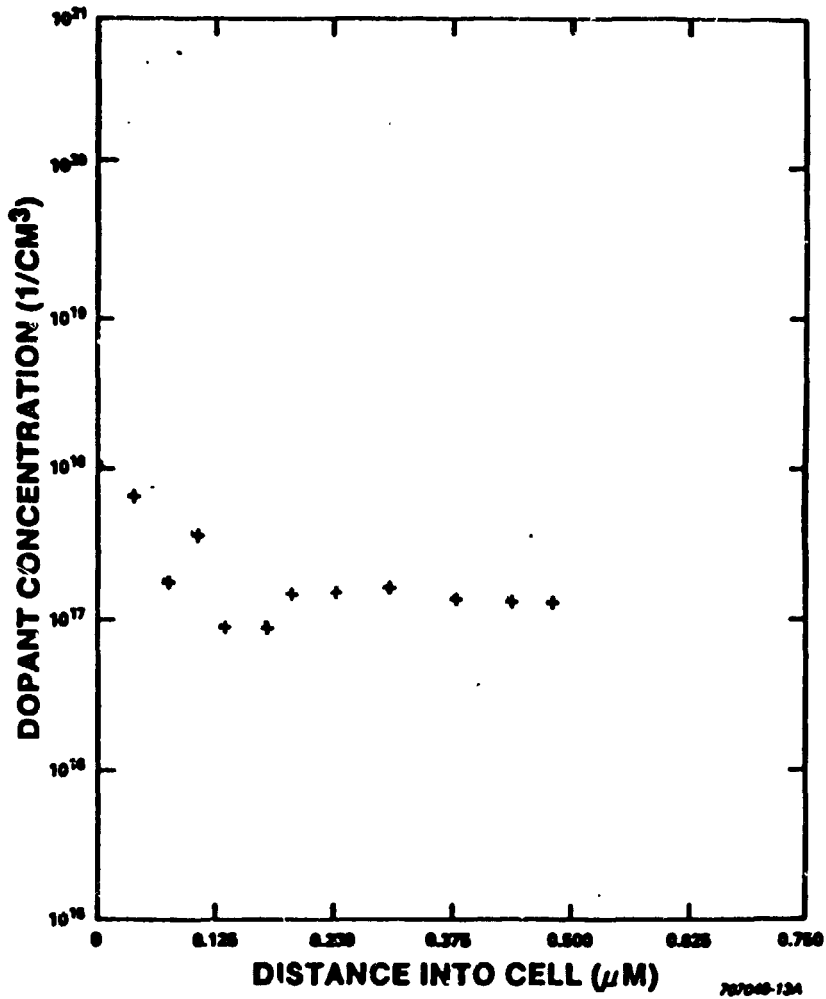
ORIGINAL FILE #  
OF POOR QUALITY

$n^+p$  Front Junction by Laser Drive-in



PROCESS DEVELOPMENT

p<sup>+</sup>p Back Junction by Laser Drive-in





## Conclusions

- SEQUENTIAL DIFFUSION OF N-TYPE WEB - USING LIQUID B & P SOURCES, CELLS WITH AVERAGE EFFICIENCIES >13% PRODUCED
- SIMULTANEOUS DIFFUSION - N TYPE WEB - WITH PRESENT DOPANTS AND DIFFUSION MASKS, A SUITABLE PROCESS HAS NOT BEEN DEFINED. PROBLEM DUE TO HIGH MOBILITY OF PHOSPHORUS AT TEMPERATURES REQUIRED FOR BORON DIFFUSION WHICH CAUSES FRONT JUNCTION CONTAMINATION.
- SIMULTANEOUS DIFFUSION - P TYPE WEB - AL BSF WITH PHOSPHORUS DOPED EMITTER GAVE BEST RESULTS. FURTHER STUDY REQUIRED TO OBTAIN LOW RESISTANCE BACK CONTACT AND OPERATIONAL BSF.
- EXCIMER LASER DRIVE IN
  - EXCELLENT PHOSPHORUS DOPED JUNCTIONS FABRICATED BOTH  $N^+P$  AND  $N^+N$
  - FURTHER STUDY REQUIRED TO PRODUCE BORON DOPED LAYERS FOR  $P^+N$  AND  $P^+P$  JUNCTIONS
  - NO CROSS-CONTAMINATION PROBLEM OBSERVED