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

Approaches

- DIFFUSION

  N-TYPE DENDRITIC WEB
  - PHOSPHORUS OR ARSENIC FOR BACK N^+N JUNCTION
  - BORON OR ALUMINUM FOR FRONT P^+N JUNCTION

  P-TYPE DENDRITIC WEB (LOW RESISTIVITY)
  - PHOSPHORUS FOR FRONT N^+P JUNCTION
  - BORON OR ALUMINUM FOR BACK P^+P JUNCTION
  - BACK SURFACE DAMAGE

- BASELINE PROCESS EXCEPT FOR DIFFUSION

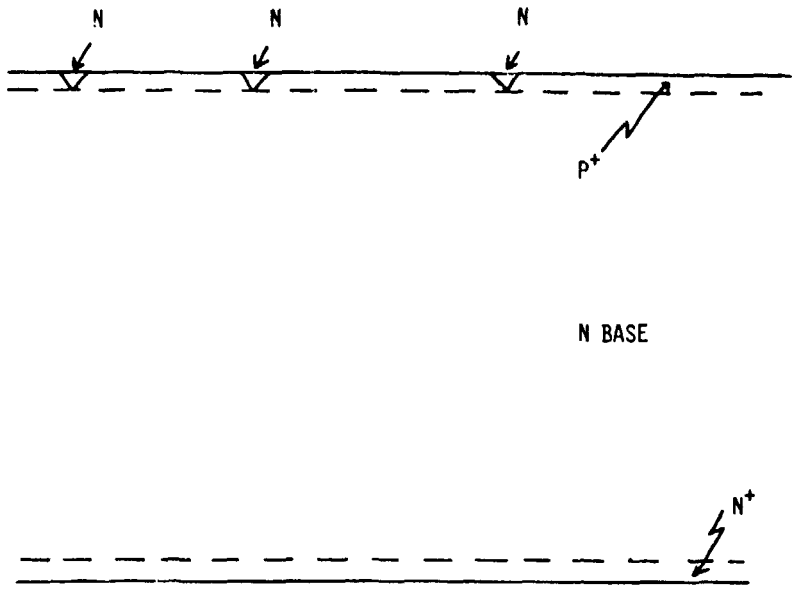
- TEST OF VARIOUS VENDORS' DOPANTS AND DIFFUSION MASKS

- 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 η_{AV} >13%
- LIQUID SOURCE - SIMULTANEOUS DIFFUSION USING B & P PRODUCED JUNCTION DEPTHS OF 0.25 μm (P^+N) AND 0.6 μm (N^+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 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

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. η_{max} = 7%
- AL BSF ALSO GAVE HIGH RESISTANCE CONTACT WITH η_{max} = 8%
- CELLS OF >12% EFFICIENCY FABRICATED USING PHOSPHORUS FRONT DOPING ONLY WITH THE BACK SURFACE DAMAGED (0.5 ncm - 1.5 ncm)
- 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^2

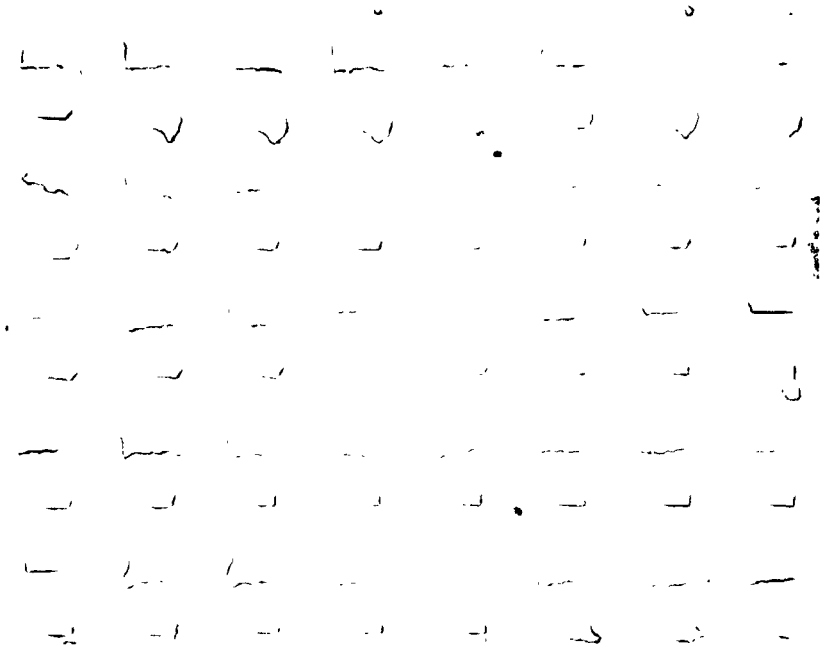
EXPERIMENT

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^2

Sample 17B, p-Base Web, Boron BSF 1.15 J/cm^2



Results: Excimer Laser

- JUNCTION CHARACTERISTICS

  N^+N OR N^+P (PHOS. DOPED) $Co = 10^{19}/cm^2$ $X_j = 0.2 - 0.25$ μm

  P^+N OR P^+P (B DOPED) ESSENTIALLY NO JUNCTION

  P^+P (AL DOPED) SHALLOW JUNCTION

- CELL PROPERTIES

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

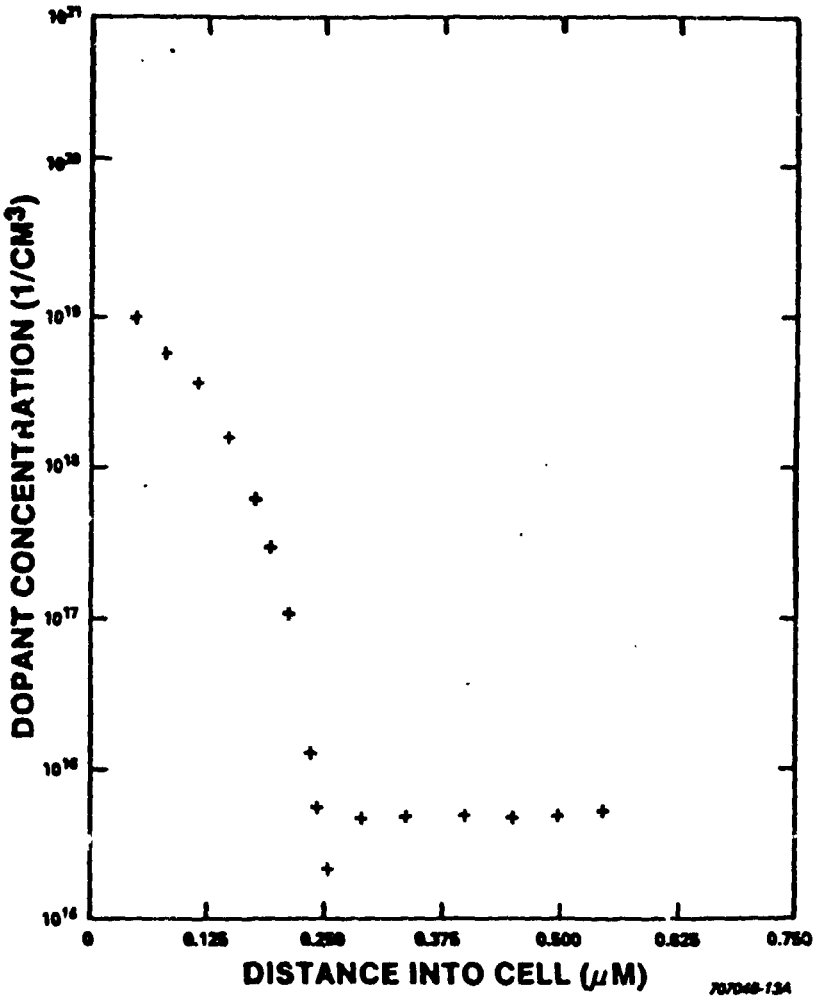
  N TYPE WEB, η_{max} <1% - POOR B DOPED EMITTER

- LOW DIFFUSION CONSTANT OF BORON WILL REQUIRE HIGHER POWER INPUT

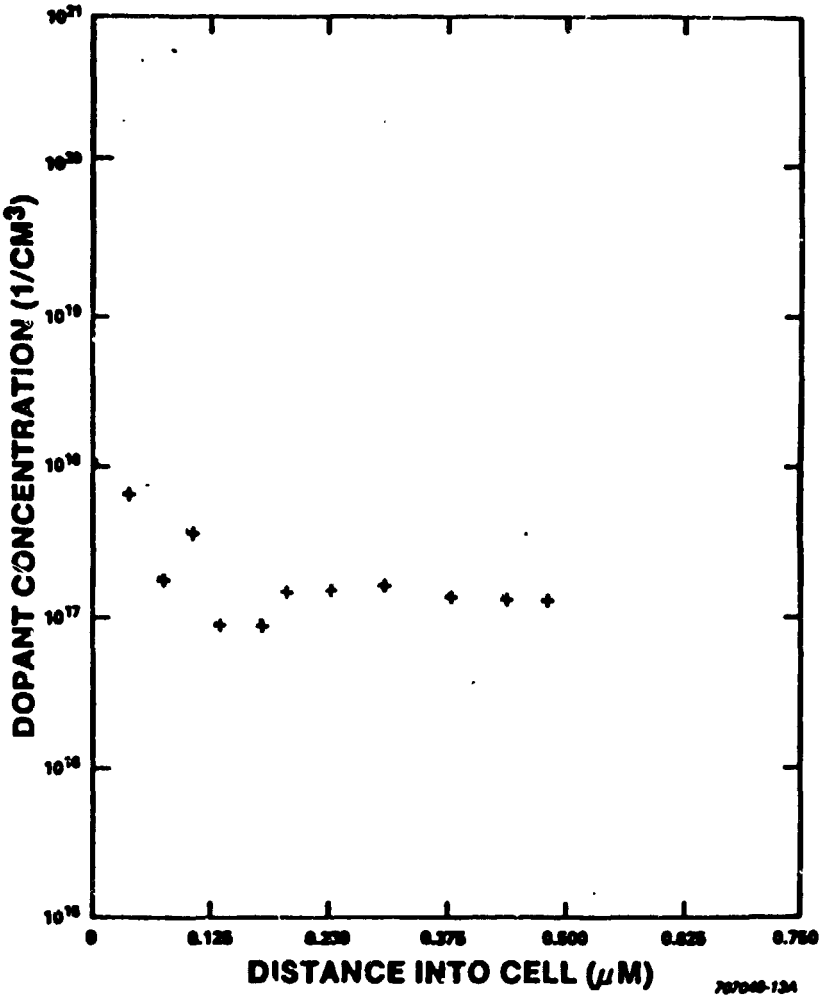
- NO CROSS CONTAMINATION NOTED

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

n^+p Front Junction by Laser Drive-in



p^+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