N86-29384

PROCESS RESEARCH OF NON-Cz MATERIAL

WESTINGHOUSE ELECTRIC CORP.

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Contract Information

OBJECTIVE: INVESTIGATE HIGH-RISK, HIGH PAY-OFF IMPROVEMENTS TO WESTINGHOUSE BASELINE SEQUENCE

TIME PERIOD: JANUARY 1985 - AUGUST 1985

Contract Tasks

- INVESTIGATE EXCIMER LASER DRIVE OF LIQUID DOPANTS IN DENDRITIC WEB SILICON
- CONDUCT PROCESS SENSITIVITY STUDIES
- DEVELOP COST ANALYSIS (FORMAT A's)
- INVESTIGATE OTHER ADVANCED TECHNIQUES FOR JUNCTION FORMATION

Potential Benefits

- FEWER PROCESSING STEPS
- MORE RAPID PROCESSING
- LESS COSTLY PROCESSING
- MORE UNIFORM CELL PARAMETERS

C-6

PROCESS DEVELOPMENT

Junction Formation Using an Excimer Laser

APPROACH

HEAT SURFACES OF WEB WITH LASER TO DIFFUSE LIQUID DOPANTS

CONDITIONS

WAVELENGTH - 3080 nM

POWER INPUT TO WEB - 0.5 to 2.5 Joules/cm^2

EXPERIMENT

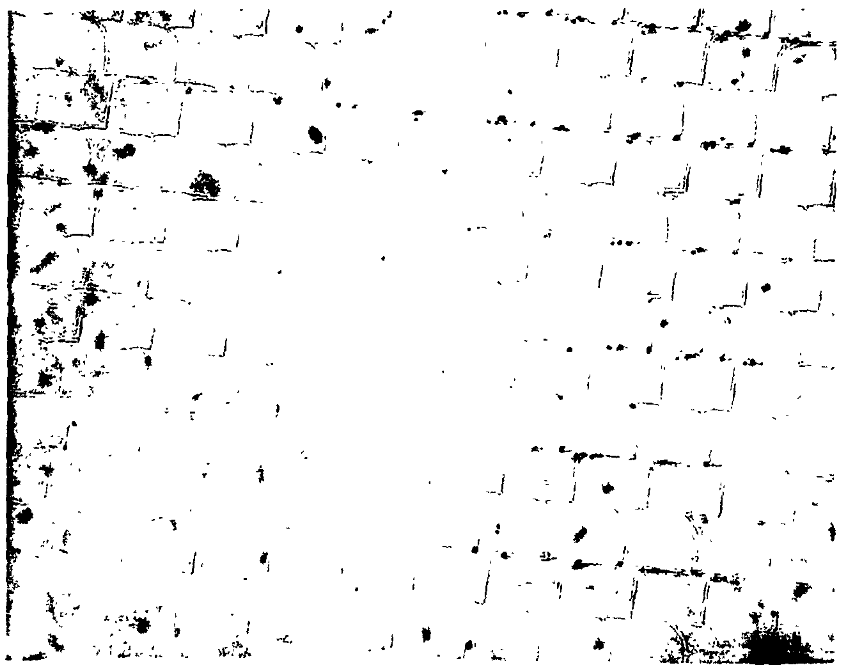
DRIVE B, P, AND AL INTO BOTH N-TYPE AND P-TYPE WEB

LASER PROCESSING CARRIED OUT AT SPECTRA TECHNOLOGY, BELLEVUE, WA,

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) ESSENTIALLY NO JUNCTION
- CELL PROPERTIES
  - P TYPE WEB, η_{max} = 9.6% - DUE TO HIGH RESISTANCE BACK CONTACT (BOTH B & AL BSF)
  - N TYPE WEB, η_{max} <1% - POOR B DOPED EMITTER
- ANNEALING UP TO 800°C IMPROVES CELL PROPERTIES
- NO CROSS-CONTAMINATION NOTED
- CRYSTAL PAIRS PROCESSED BASELINE SEQUENCE - $\hat{\eta}$ = 14% (TOTAL LIQUID SYSTEM)

Sample 18A, p-Base Web, Al BSF 1.5 J/cm^2



Sample 14B, p-Base Web, Boron BSF 2.0 J/cm^2

Summary of Data

PROCESS	AVG. EFF. (%)
1. WESTINGHOUSE BASELINE - DIFFUSION WITH TOTAL LIQUID SYSTEM (P100 & B150)	14.0
2. P100 FRONT JUNCTION - LASER DRIVL B150 BACK JUNCTION - DIFFUSED	13.2
3. P100 FRONT JUNCTION - DIFFUSED B150 BACK JUNCTION - LASER DRIVE	10.0
4. P100 FRONT JUNCTION - DIFFUSED B150 BACK JUNCTION - LASER DRIVE BACK SURFACE DAMAGED	11.0
5. P100 FRONT JUNCTION - LASER DRIVE B150 BACK JUNCTION - LASER DRIVE	8.6
6. P100 FRONT JUNCTION - LASER DRIVE B150 BACK JUNCTION - LASER DRIVE ANNEAL 700°C - 1 HR IN N_2	9.6

Dark I-V Data on Selected Cells

Process and Cell ID		Eff. (%)	Rs (Ωcm^2)	Rsh (K Ωcm^2)	J01 (A/cm^2)	J02 (A/cm^2)	Diffusion Length* (μm)
11-1	Total laser process + 700°C anneal	10.1	.68	22	4.7×10^{-11}	1.8×10^{-6}	26
12-2	Total laser process	8.1	.88	6	1.5×10^{-10}	6.4×10^{-6}	19
68-1	Laser drive front junction, diffused BSF	13.2	.68	1.0	1.3×10^{-11}	2.5×10^{-6}	36

Front Junction Dopant - P100

Back Junction Dopant - B150

*Ln measured by surface photovoltage technique.

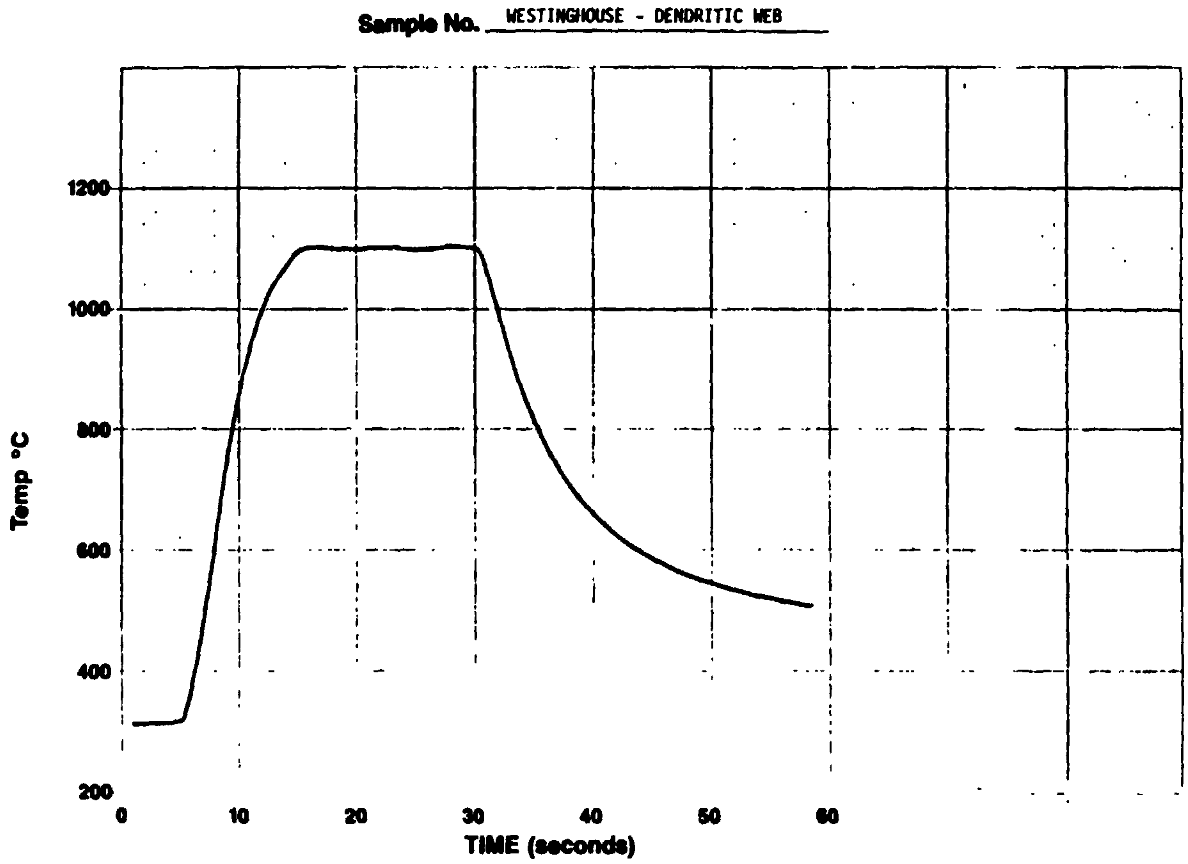
Conclusions: Excimer Laser Processing

- FRONT JUNCTION (PHOSPHORUS DIFFUSED) SATISFACTORY FOR SOLAR CELLS.
- BACK JUNCTION SHALLOW DUE TO SLIGHT PENETRATION OF BORON OR ALUMINUM. RESULTS IN HIGH SERIES RESISTANCE IN CELLS.
- FURTHER TESTS TO BE CARRIED OUT ON LOW RESISTIVITY MATERIAL.

Junction Formation Using a Directed Heat Source

- WEB STRIPS COATED WITH LIQUID DOPANTS (BOTH SIDES) AND HEATED IN A TUNGSTEN-HALOGEN FLASH LAMP
- NOMINAL TIME - 15 SEC.
  NOMINAL TEMPERATURE - 1100^{o}C
- JUNCTIONS FORMED SIMULTANEOUSLY ON BOTH SIDES OF WEB STRIP
- $N^{+}PP^{+}$ AND $P^{+}NN^{+}$ CELLS FABRICATED
- NO CROSS-CONTAMINATION NOTED
- WORK CARRIED OUT COURTESY OF AG ASSOCIATES, PALO ALTO, CA

Heat Pulse Temperature-Time Profile



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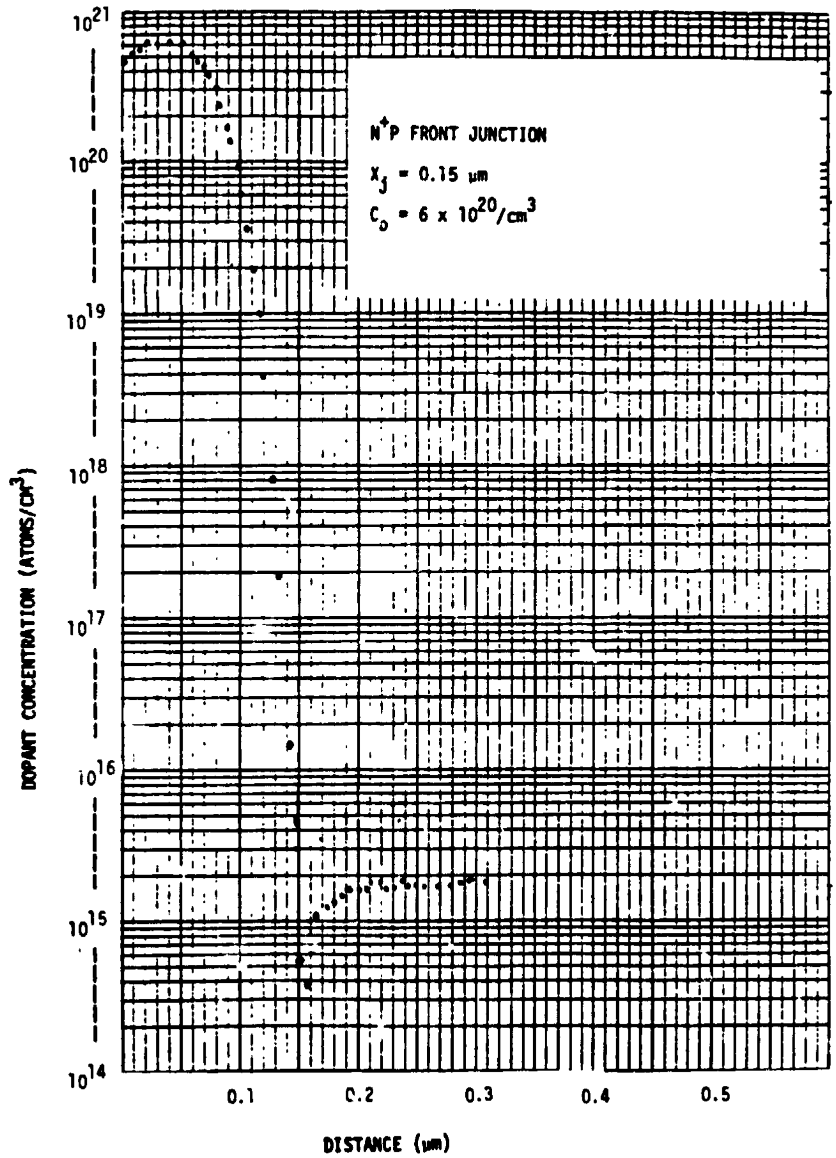
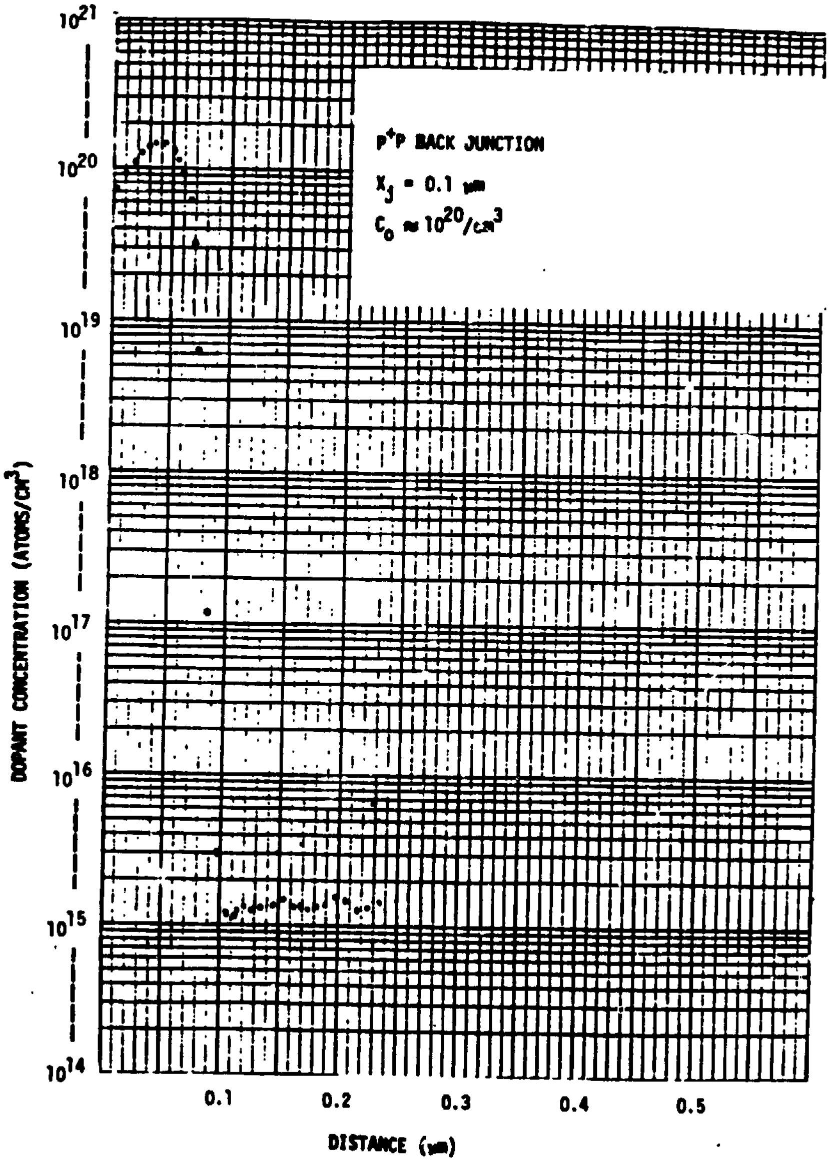
Heat Pulse Simultaneous Junction Formation



Heat Pulse Simultaneous Junction Formation



Simultaneous Junction Formation Using Heat Pulse: Representative Data

CELL ID	COND. TYPE	Res (Ωcm)	Voc(V)	Jsc $\left(\frac{mA}{cm^2}\right)$	FF	EFF.	COMMENTS
8A	P	4	.497	23.8	.76	9.0	AS DIFFUSED
8B	P	4	.541	29.1	.78	12.3	800°C ANNEAL
6A	N	1	.556	24.9	.78	10.8	AS DIFFUSED
6B	N	1	.578	30.5	.75	13.2	800°C ANNEAL
7A	N	1	.561	26.6	.79	11.8	AS DIFFUSED
7B	N	1	.601	32.9	.77	15.0	800°C ANNEAL

Dark I-V Data

SAMPLE	TREATMENT	J_{02} $\left(\frac{A}{cm^2}\right)$	Ln (μm)
7A	AS TREATED	6.6×10^{-12}	63
7B	ANNEALED 800°C	1.4×10^{-12}	320

N-TYPE SAMPLES FROM SAME WEB CRYSTAL

Conclusions: Directed Heat-Source Junction Formation

- SIMULTANEOUS DIFFUSION POSSIBLE WITHOUT CROSS-CONTAMINATION
- ANNEALING REQUIRED AFTER JUNCTION FORMATION TO ACHIEVE HIGHEST EFFICIENCY
- A DETAILED STUDY REQUIRED TO OPTIMIZE HEAT PULSE PARAMETERS (TIME/TEMP/COOLING RATE)