N87-16423

PROCESS RESEARCH OF NON-CZOCHRALSKI SILICON MATERIAL

WESTINGHOUSE ELECTRIC CORPORATION
ADVANCED ENERGY SYSTEMS DIVISION

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Contract Objectives

- INVESTIGATE SIMULTANEOUS DIFFUSION OF LIQUID PRECURSORS INTO DENDRITIC WEB SILICON TO FORM SOLAR CELL STRUCTURES

- INVESTIGATE PROCESS CONTROL PARAMETERS

- PERFORM COST ANALYSIS OF THE SIMULTANEOUS JUNCTION FORMATION PROCESS

Potential Benefits of Simultaneous Diffusion

- REDUCE NUMBER OF PROCESSING STEPS

- LESS COSTLY PROCESSING (CAPITAL EQUIPMENT, MATERIALS)

- MORE RAPID PROCESSING

- MORE UNIFORM CELL PARAMETERS

Simultaneous Junction Formation by Flash Diffusion

- NOVEL TECHNIQUE DEVELOPED TO ACHIEVE SIMULTANEOUS DIFFUSION WITHOUT CROSS-DOPING

- WEB STRIPS COATED WITH LIQUID PRECURSORS (B AND P DOPED) AND HEATED WITH A TUNGSTEN - HALOGEN LIGHT SOURCE.

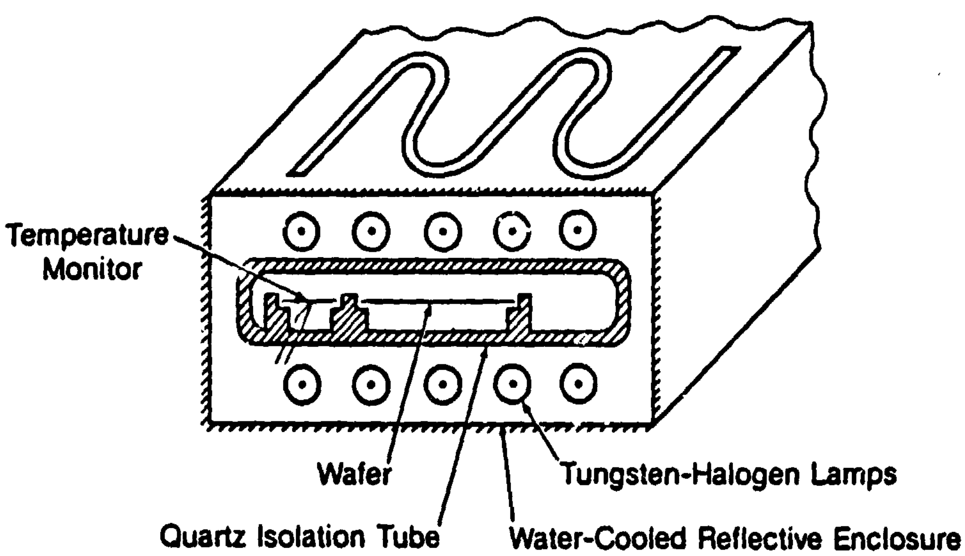
- NOMINAL TIMES - 10-20 SEC

  NOMINAL TEMPERATURE - 1050°C - 1150°C

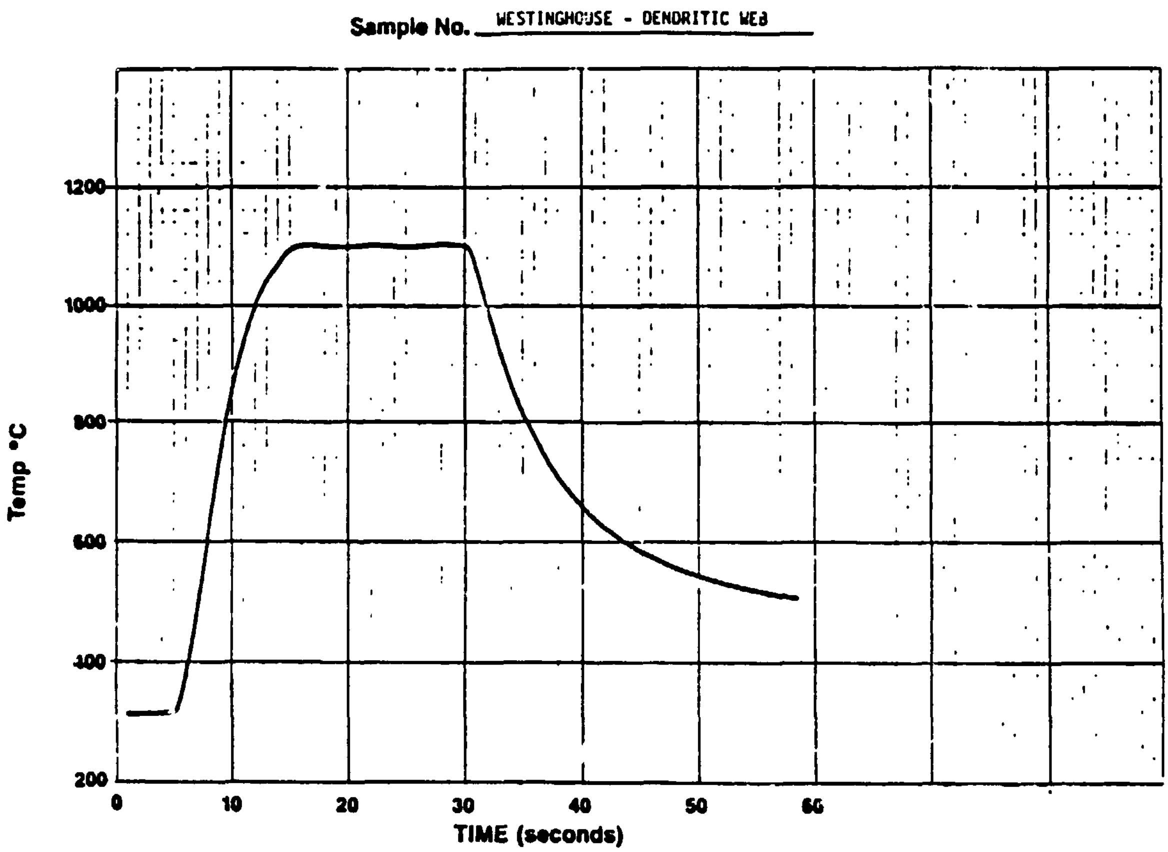
- N^+PP^+ AND P^+NN^+ CELLS FABRICATED

- NO CROSS CONTAMINATION NOTED

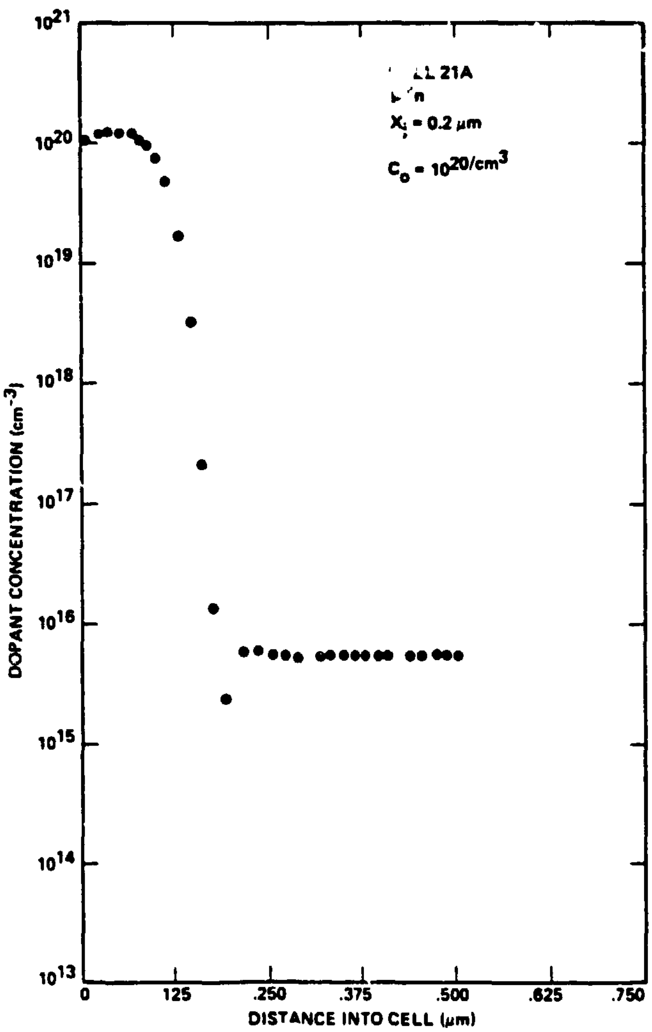
Heatpulse™ Annealing Chamber



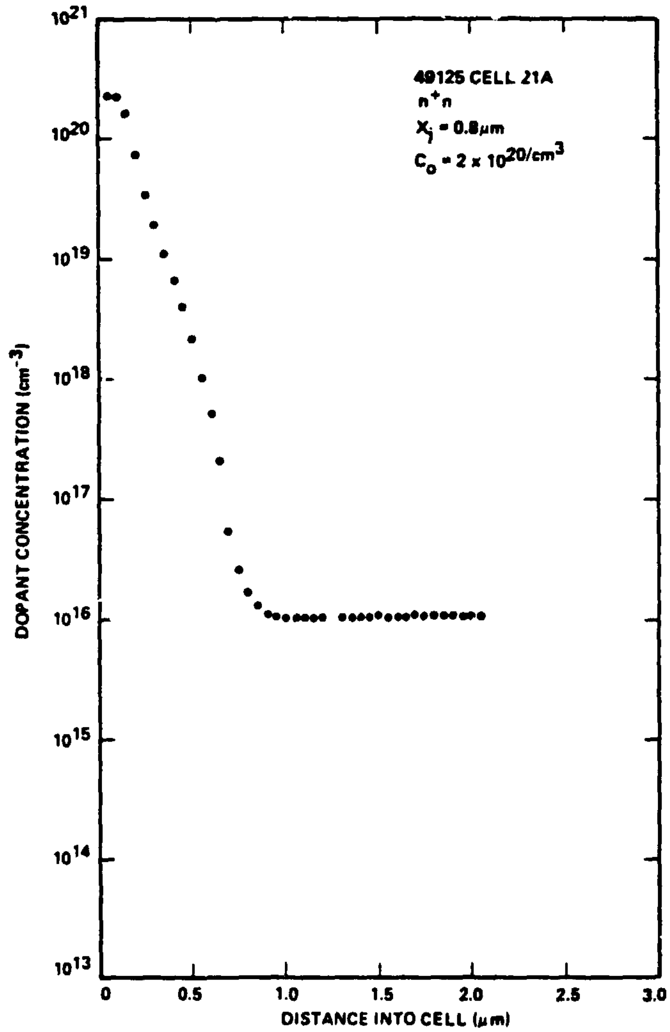
Heatpulse™ Temperature-Time Profile



Flash Diffusion: N-Type WEB Front Junction (Dopant Concentration Versus Distance into Cell)



Flash Diffusion: N-Type WEB Back Junction (Dopant Concentration Versus Distance into Cell)



Simultaneous Junction Form: ion by Flash Diffusion

OVERALL RESULTS

- SUITABLE JUNCTION DEPTHS ACHIEVED FOR N-TYPE DENDRITIC WEB

  P^+N - 0.15 μM TO 0.25 μM
  N^+N - 0.25 μM TO 0.80 μM

- FOR P-TYPE MATERIAL FRONT N^+P JUNCTION DEEFER THAN OPTIMUM TO ACHIEVE REQUIRED P^+P BSF

- ANNEALING OF DIFFUSED MATERIAL REQUIRED TO ACHIEVE HIGHEST EFFICIENCY - 750-800°C FOR 10 - 30 MIN

- EFFICIENCIES GREATER THAN 15.2% OBTAINED ON N-BASE CELLS - 24.5 CM^2 AREA

- P BASE CELLS GAVE MAXIMUM EFFICIENCY OF 12.5%

Flash Diffusion Verification

- 48 WEB STRIPS EACH OF:

0.4 ΩCM P TYPE	GROWTH RUN
6 ΩCM P TYPE	R499
0.2 ΩCM N TYPE	GROWTH RUN
2 ΩCM N TYPE	5332

  STRIPS 3 CM X 13 CM

- RUN R499 - 130 μM NOMINAL THICKNESS
  RUN 5332 - 100 μM NOMINAL THICKNESS

- COAT WITH LIQUID PRECURSORS (B & P DOPED)

- DIFFUSE AT 1100°C/10 SEC IN ARGON

- LESS THAN 1% OF STRIPS BROKEN DURING DIFFUSION

- ANNEAL AT TEMPERATURES 900°C TO 750°C AND TIMES 10 MIN. TO 60 MIN. (6 CONDITIONS)

- FINISH BASELINE PROCESS

Flash Diffusion Verification: Samples Diffused 1100°C/10 s Back Surface Reflector (No Passivation)

ANNEALING (TEMP. °C)	ANNEALING TIME (MIN)	CELL EFFICIENCY (%)			
		N BASE CELLS		P BASE CELLS	
		0.2 - 0.3 ΩCM	2 ΩCM	0.4 - 0.6 ΩCM	6-8 ΩCM
900	30	13.8	14.2	11.4	12.2
900	10	12.8	--	10.4	11.1
800	60	13.5	14.6	10.8	11.4
800	30	14.4	14.6	11.4	11.5
800	10	14.3	14.8	11.0	11.5
750	60	14.0	15.1	12.1	11.5

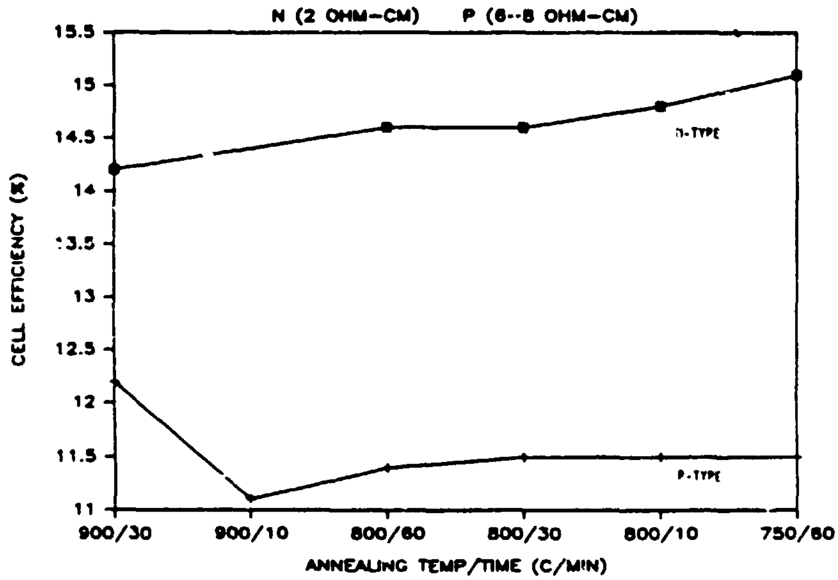
Diffusion Length in Flash-Diffused Cells

ANNEAL TEMP. (°C)	ANNEAL TIME (MIN)	DIFFUSION LENGTH (µM) BY SPV			
		P TYPE CELLS		N TYPE CELLS	
		0.2 ΩCM	6-8 ΩCM	0.2 ΩCM	2 ΩCM
900	30	--	55	---	160
900	10	--	25	125	185
800	60	--	92	--	145
800	30	--	75	---	168
800	10	--	75	---	130
750	60	65	--	---	165

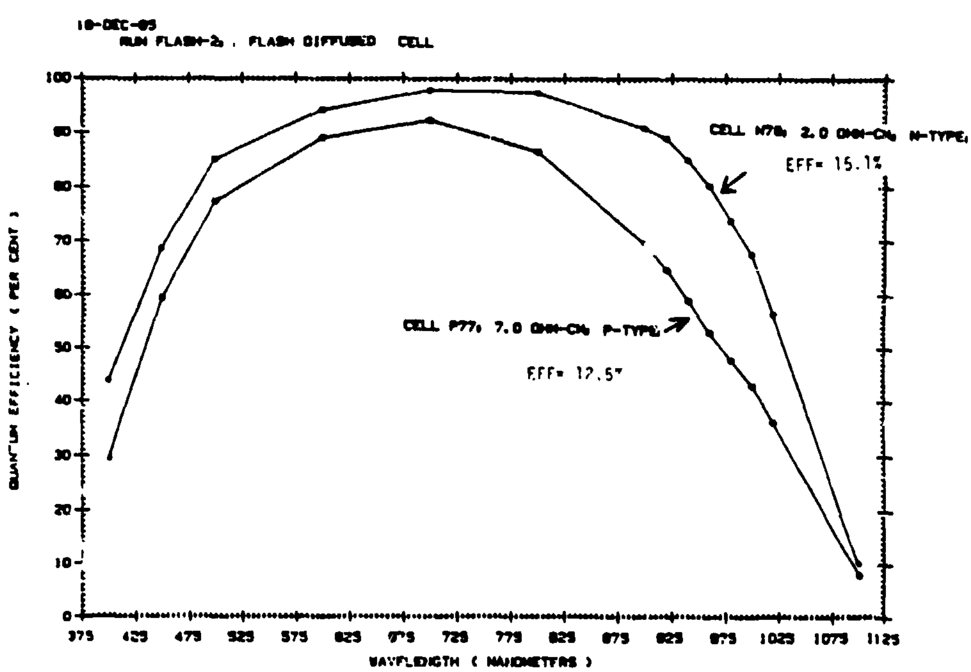
Representative Data from Selected Flash-Diffused Cells

Cell ID	Base Conductivity	Resistivity (Ω-cm)	Anneal Cycle (°C/min)	Eff. (%)	J_{01} (A/cm²)	J_{02} (A/cm²)	Ln (µm)
7N	N	0.32	900/30	13.4	4.1E-12	2.8E-4	--
10N	N	0.32	900/10	13.1	1.1E-12	1.8E-5	125
47N	N	2.0	900/30	14.2	1.2E-12	2.5E-5	170
58N	N	2.0	800/60	14.9	1.1E-12	2.8E-5	135
65N	N	2.0	800/30	14.7	1.2E-12	1.2E-6	168
79N	N	2.0	750/60	15.2	8.9E-13	7.1E-6	160
48P	P	9.0	900/30	12.5	3.3E-12	4.2E-8	50
57P	P	8.0	800/60	11.8	2.2E-12	9.8E-9	92
71P	P	8.0	800/30	12.2	3.7E-12	2.7E-8	70
77P	P	7.0	800/10	12.2	5.1E-[illegible]	6.0E-8	72

Flash Diffusion Results (Cell Efficiency Versus Annealing Temperature/Time)



Quantum Efficiency Plot



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Simultaneous Junction Formation by Flash Diffusion: Cost Analysis

- COMPARE SIMULTANEOUS JUNCTION FORMATION (FLASH DIFFUSION) WITH SEQUENTIAL DIFFUSION
- TWO PRODUCTION LEVELS CONSIDERED
  1 MW/YR - SEMI-AUTOMATED
  25 MW/YR - FULLY AUTOMATED
- COSTS CALCULATED IN 1985 $ FOR DIFFUSION PROCESS STEP
- FORMAT A'S PREPARED

Cost Analysis

ALL COSTS - 1985 $/WATT

PROCESS STEP COST (DIFFUSION)

PRODUCTION LEVEL (MW/YR)	SIMULTANEOUS - FLASH DIFFUSION	SEQUENTIAL DIFFUSION
1	0.57	0.92
25	0.072	0.134

Simultaneous Junction Formation by Flash Diffusion: Conclusions

CONCLUSIONS:

- SIMULTANEOUS JUNCTION FORMATION BY FLASH DIFFUSION VERIFIED
- NO CROSS-CONTAMINATION NOTED
- ANNEALING REQUIRED AFTER DIFFUSION TO ACHIEVE HIGHEST CELL EFFICIENCY
- TECHNIQUE IS COMPATIBLE WITH WESTINGHOUSE BASELINE PROCESS SEQUENCE
- N-BASE CELLS WITH EFFICIENCIES OF 15.2% FABRICATED USING FLASH DIFFUSION (AREA = 24.5 CM^2)
- COST ANALYSIS SHOWS SAVING OF 60 - 85% IN DIFFUSION PROCESS STEP