N85-32433

EXCIMER LASER ANNEALING FOR FABRICATION OF LOW-COST SOLAR CELLS

SPIRE CORP.

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Program Goal

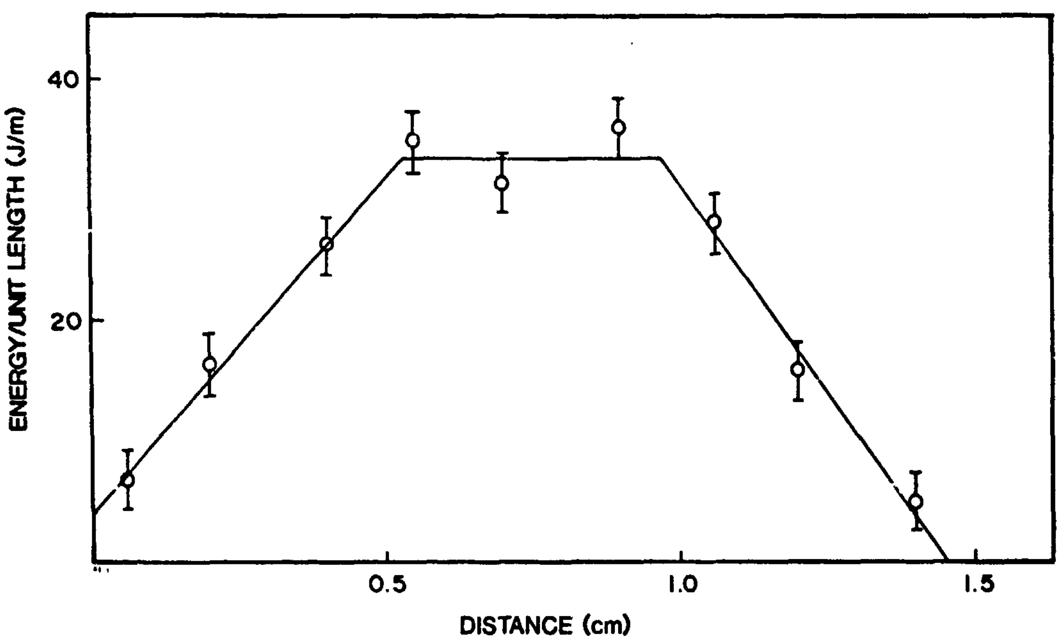
TO DETERMINE IF PULSED EXCIMER LASER ANNEALING (PELA) IS COST EFFECTIVE COMPARED TO BASELINE PROCESS.

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

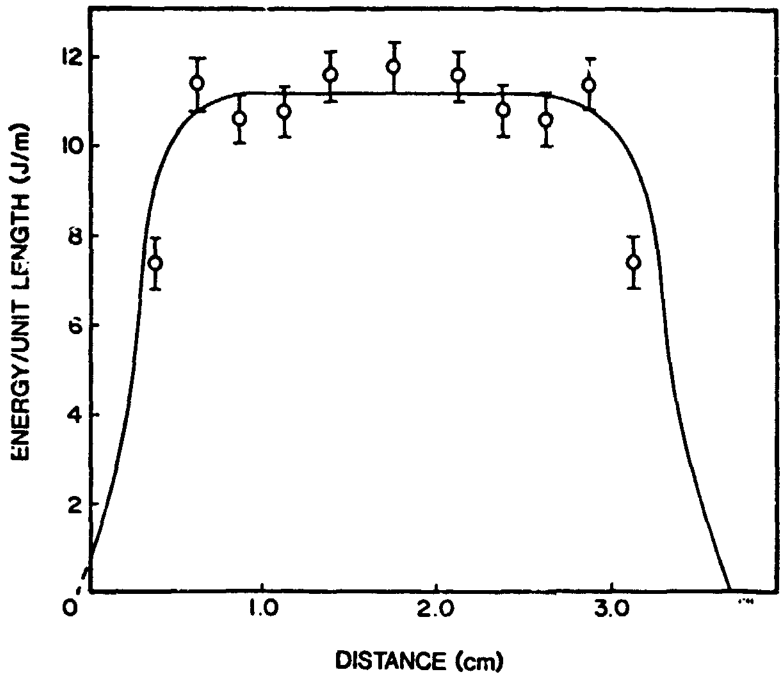
Objectives

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

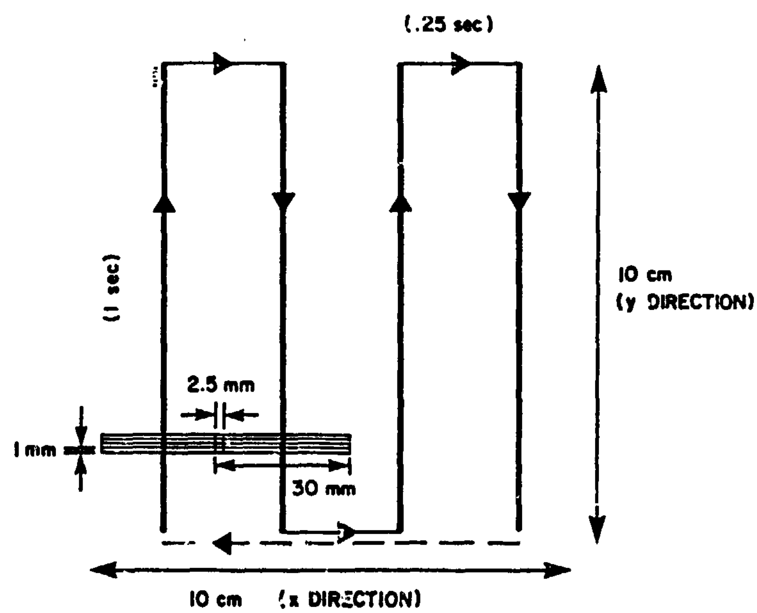
Fluence Measured Across Beam Width (at Lens)



Fluence Measured Across Beam Length (at Lens)



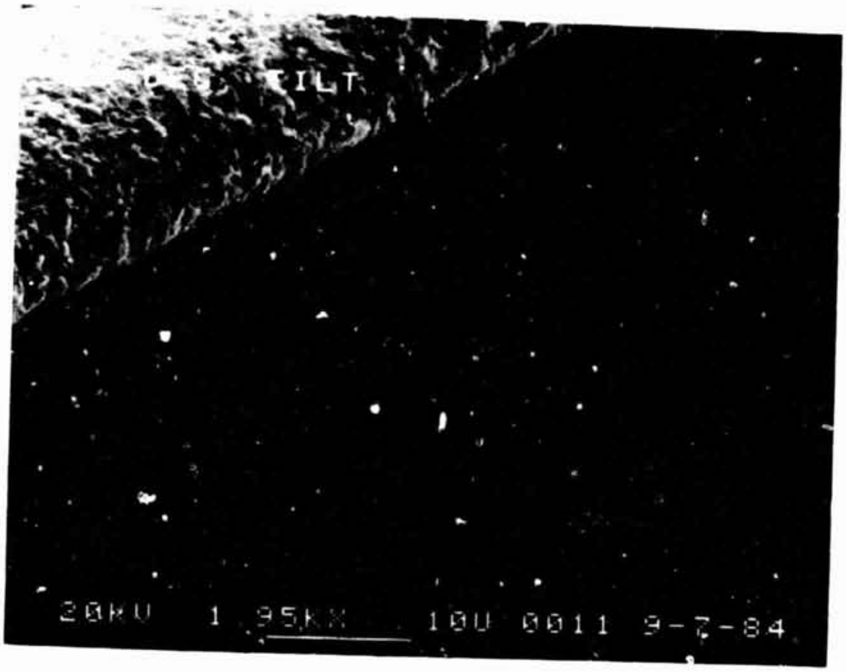
Scanning Pattern for Annealing a 100 cm^2 Wafer (Total Transit Time at 10 cm/s Is 5.5 Seconds)



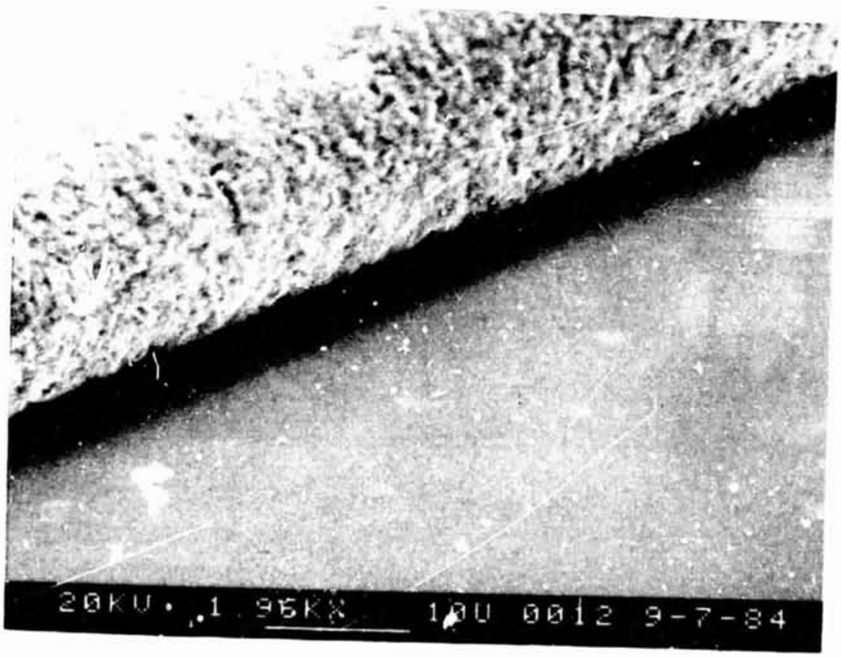
Implantation Parameters

	FRONT (TEXTURED)	FRONT (POLISHED)	BACK (EITHER)
ION	P^+	P^+	B^+
ENERGY	10 keV	10 keV	25 keV
DOSE	$4.3 \times 10^{15} cm^{-2}$	$2.5 \times 10^{15} cm^{-2}$	$5 \times 10^{15} cm^{-2}$

Pulsed Excimer Laser Annealing Polished Surfaces

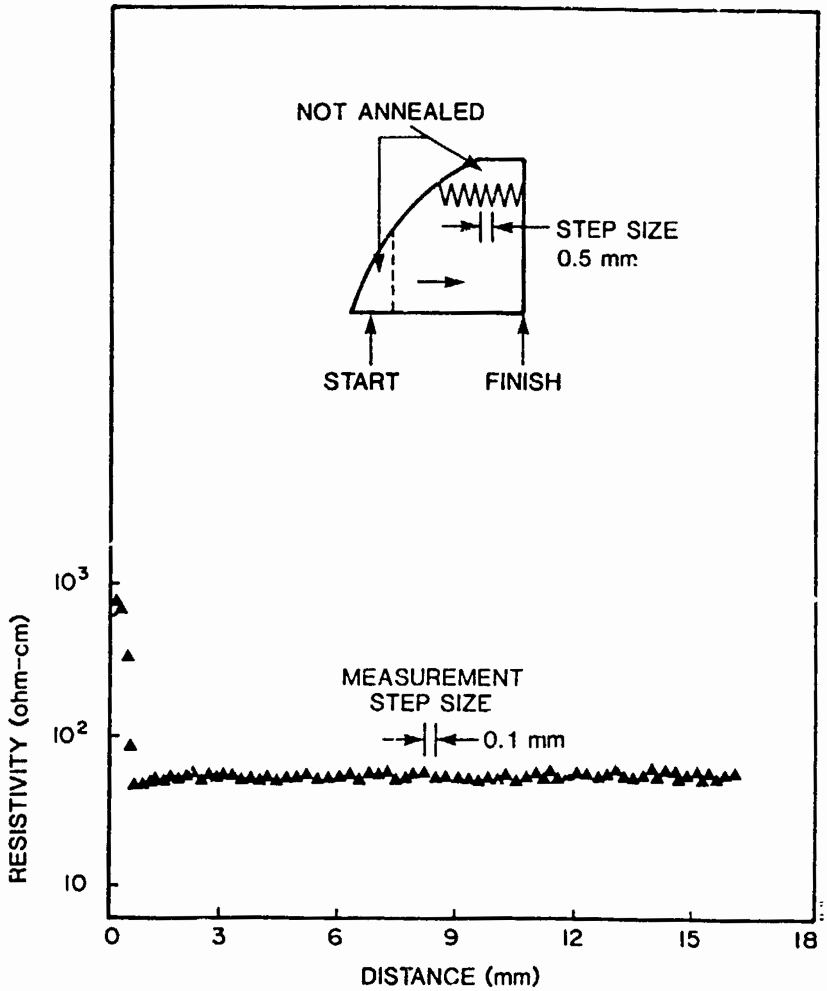


FURNACE ANNEAL

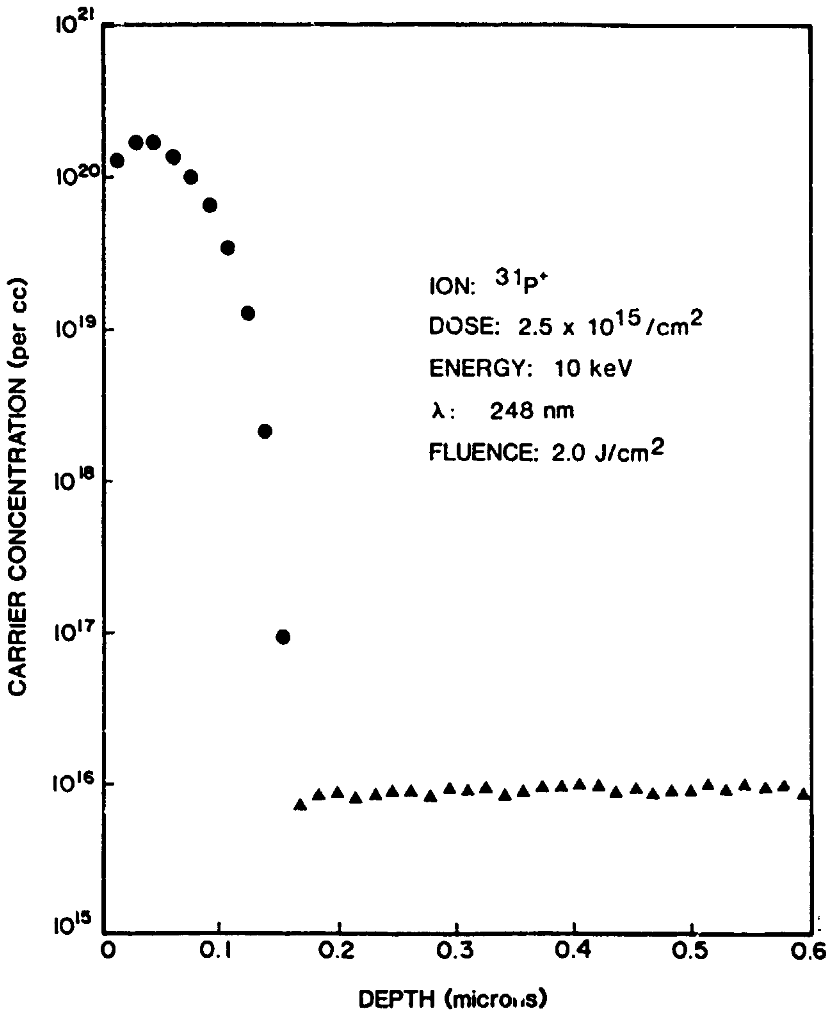


PELA

Sheet Resistance Uniformity of PELA Sample 4520-1b



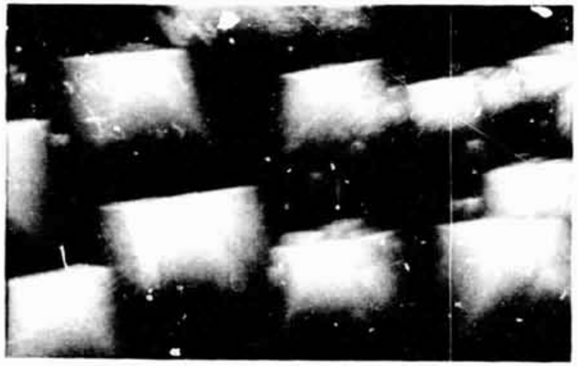
PELA Junction Depth Profile, Sample 4520-16



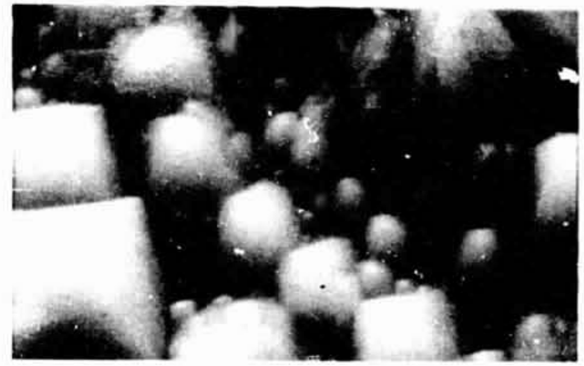
Efficiency vs Laser Fluence: Polished Wafers, No AR Coating

LOT	η (%)	FLUENCE (J/CM^2)	NO. OF PULSES
I	8.9	1.2	1-2
	8.4	1.8	1
$\lambda = 248$ nm	8.9	1.9	2-3
	9.1	2.0	1-2
	9.1	FURNACE CONTROL	
	7.3	0.8	1
II	8.1	1.0	4
	9.7	1.4	1
$\lambda = 308$ nm	10.5	1.8	1
	10.2	1.8	2-3
	7.5	FURNACE CONTROL (?)	

Melting of Texture-Etched Surfaces



NOT PULSED



1.4 J/cm^2 1 PULSE

2 PULSES

5 µm

>1.8 J/cm^2 2 PULSES

Efficiency vs Laser Fluence: Texture-Etched Wafers, No AR Coating

LOT	η (%)	FLUENCE (J/CM^2)	NO. OF PULSES
I	10.8	1.2	1-2
	10.5	1.8	1
λ =248 nm	8.2	1.8	2
	9.2	2.0	1-2
	12.9	FURNACE CONTROL	
	9.1	0.8	1
II	8.7	0.8	2
	9.1	0.8	4
λ=308 nm	11.8	1.0	4
	12.4	1.4	2
	8.8	1.8	2
	8.1	FURNACE CONTROL (?)	

Best Cell to Date

IMPLANT: $^{31}P^{+}$ 2.5 x 10^{15} ions/cm^2 10 keV

ANNEAL: XeCl LASER, 1.8 J/cm^2 1 pulse
minimum overlap

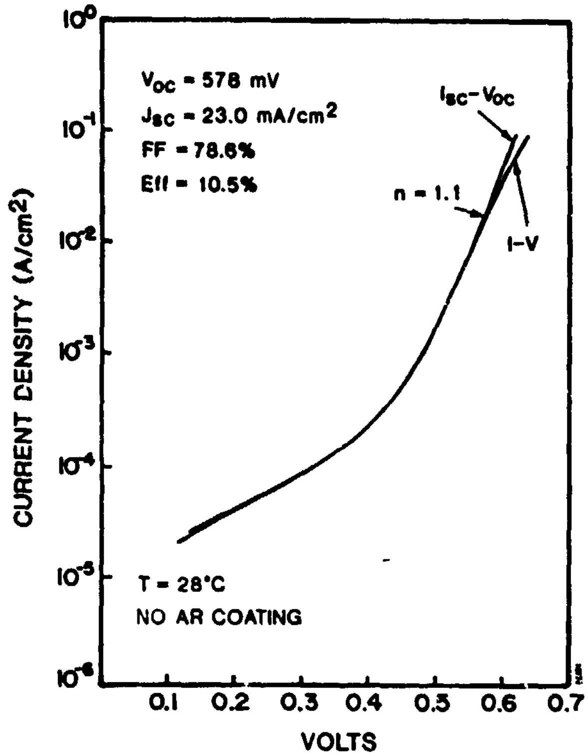
V_{OC} = 578 mV

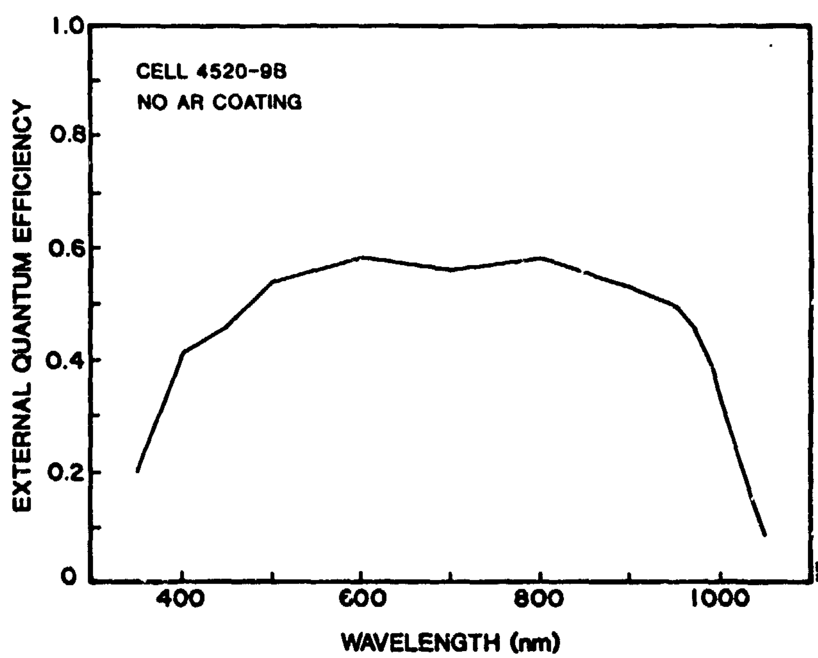
J_{SC} = 23.0 mA/cm^2

FF = 78.6%

EFF = 10.5%

WITH AN AR COATING, EFFICIENCY WOULD BE ABOUT 15%


V_{oc} = 578 mV
J_{sc} = 23.0 mA/cm^2
FF = 78.6%
Eff = 10.5%
I_{sc}-V_{oc}
n = 1.1
I-V
T = 28°C
NO AR COATING
CURRENT DENSITY (A/cm^2)
VOLTS
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.1 0.2 0.3 0.4 0.5 0.6 0.7


CELL 4520-9B
NO AR COATING
EXTERNAL QUANTUM EFFICIENCY
WAVELENGTH (nm)
1.0
0.8
0.6
0.4
0.2
0
400 600 800 1000

Can the Laser Deliver Enough Power to Rapidly Anneal a Large Wafer?

THE 50 WATT LASER ANNEALED A 4" ROUND POLISHED WAFER, A 4" ROUND TEXTURED WAFER, AND A 10 cm x 10 cm SILSO WAFER, EACH IN UNDER 10 SEC.

Laser Parameters

GAS	Kr, F_2, and Ne
WAVELENGTH	248 nm
POWER	50 watts
REP. RATE	160 Hz
PULSE WIDTH	20 nanoseconds

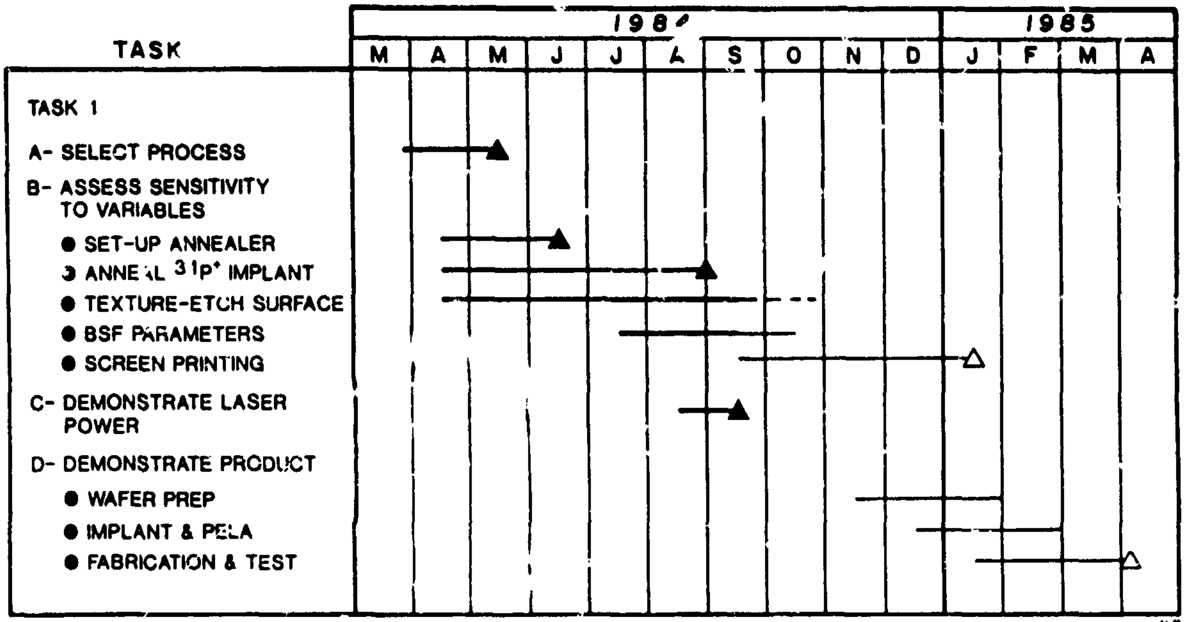
Anneal Parameters

FLUENCE	~1.4 J/cm^2 at sample
SPOT SIZE	~0.7 mm x 25 mm
TABLE SPEED	10 cm/sec.

Summary of Process Variables

- LASER POWER OF 2 J/cm^2 IS REQUIRED FO[illegible]ED WAFERS, LESS FOR TEXTURED WAFERS.
- WAVELENGTH (KrF v[illegible] XeCl) IS NOT IMPORT[illegible]
- BEAM UNIFORMITY MUST BE BETTER THAN 5% BUT NOT NEE[illegible] NOT BE BETTER THAN 2%.
- DUST IS NOT TOO IMPORTANT.
- UNANNEALED AREAS REDUCE Jsc BUT DO NOT SHUNT JUNCTION.
- OVERLAP IS IMPORTANT FOR TEXTURED WAFERS.

Program Schedule



Summary

- AN EXCIMER LASER ANNEALER HAS BEEN BUILT AND TESTED.
- SOLAR CELL EFFICIENCY, WITHOUT AR, OF UP TO 10.5% HAS BEEN ACHIEVED (~15% WITH AR).
- REQUIRED THROUGHPUT FOR ECONOMICAL OPERATION APPEARS FEASIBLE AT THIS TIME.