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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.

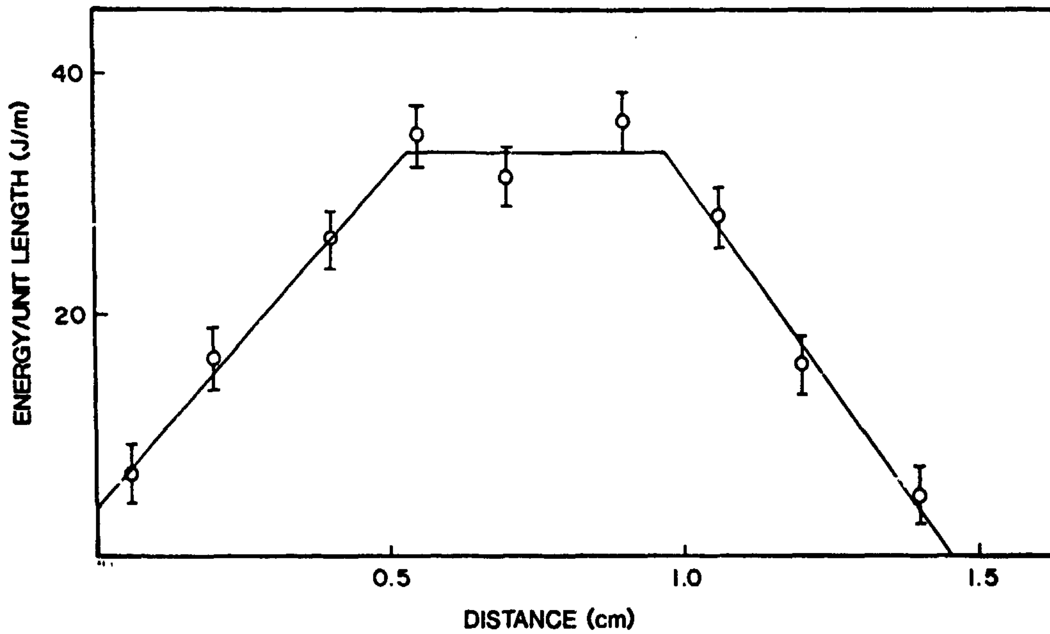
BASELINE PROCESS	LASER PROCESS
CLEAN	CLEAN
DRY	DRY
DIFFUSE JUNCTION } ALUMINUM BSF } CLEAN }	{ ION IMPLANT { LASER ANNEAL
PRINT Ag BACK	PRINT Ag BACK
PRINT Ag FRONT	PRINT Ag FRONT
LASER CUT	LASER CUT
TEST AND SORT	TEST AND SORT

PROCESS DEVELOPMENT

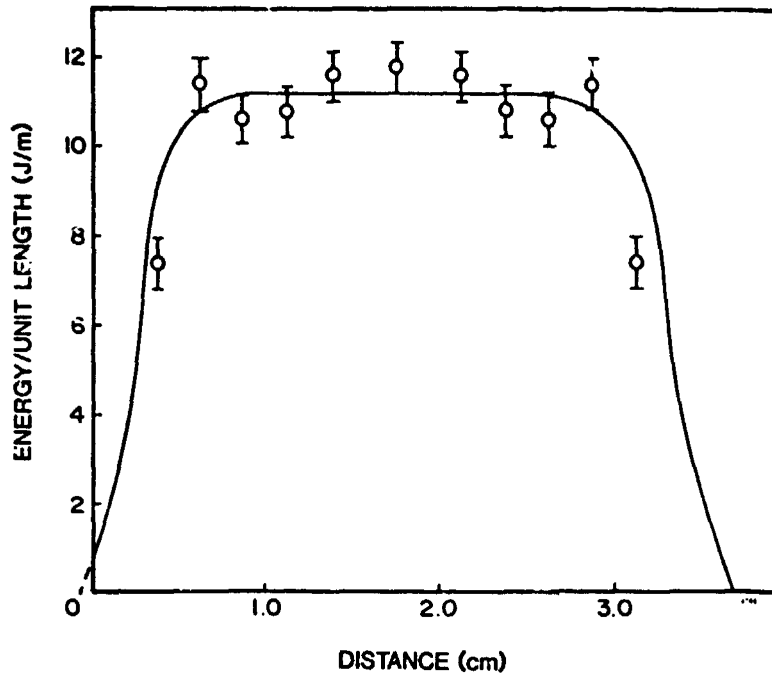
Objectives

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

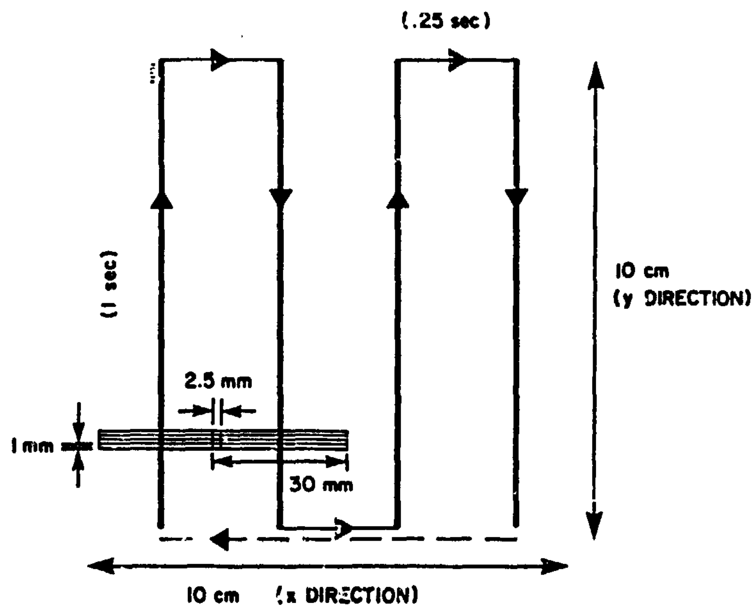
Fluence Measured Across Beam Width (at Lens)



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	$4.3 \times 10^{15} cm^{-2}$	$2.5 \times 10^{15} cm^{-2}$	$5 \times 10^{15} cm^{-2}$

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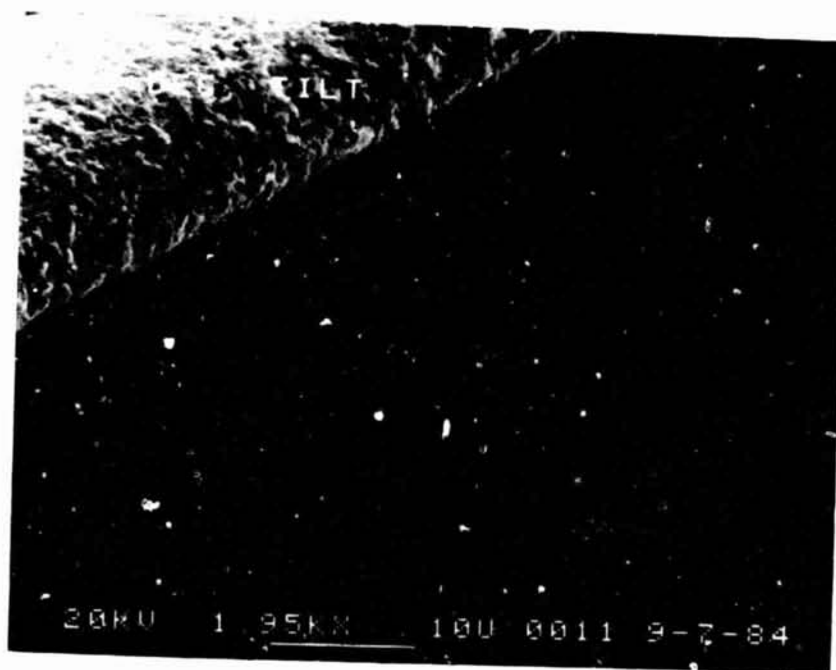
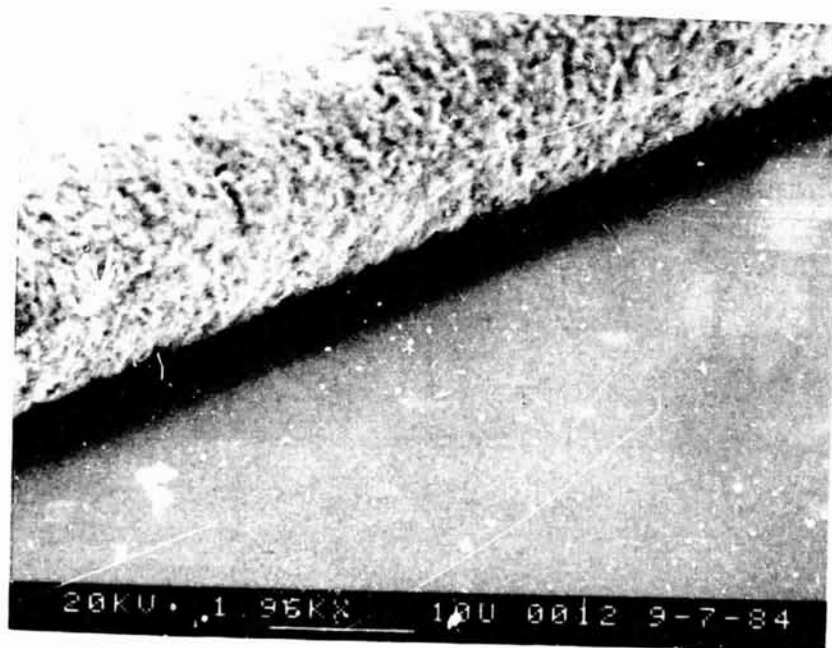
Pulsed Excimer Laser Annealing Polished Surfaces

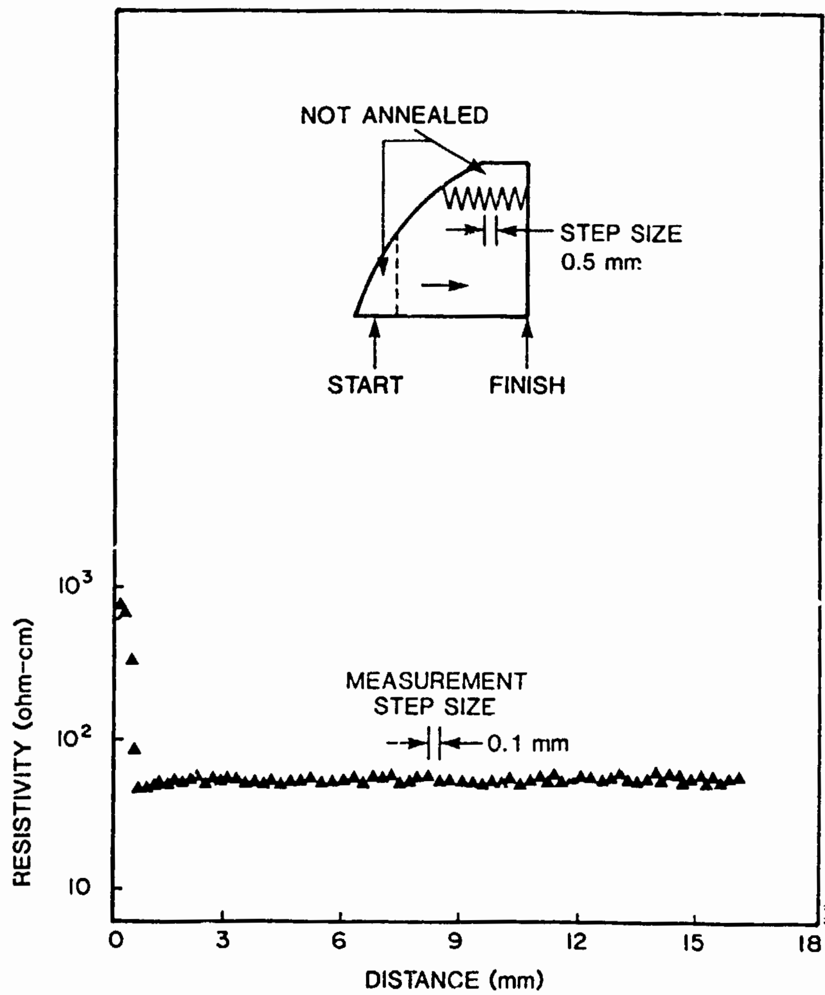


FURNACE ANNEAL

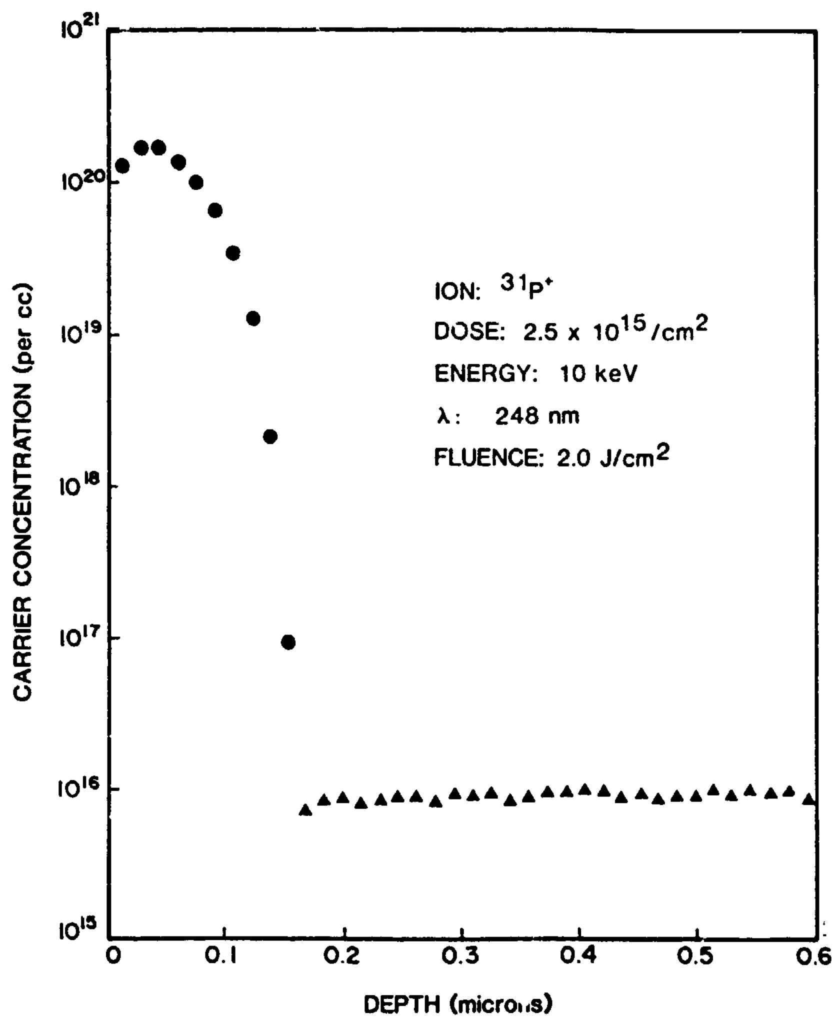


PELA

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 (?)	

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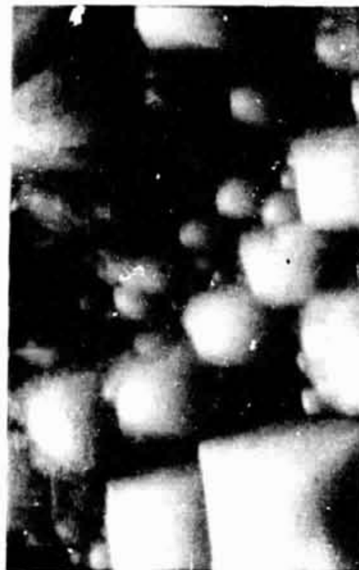
Melting of Texture-Etched Surfaces

NOT PULSED



1.4 J/cm^2 1 PULSE

2 PULSES

>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

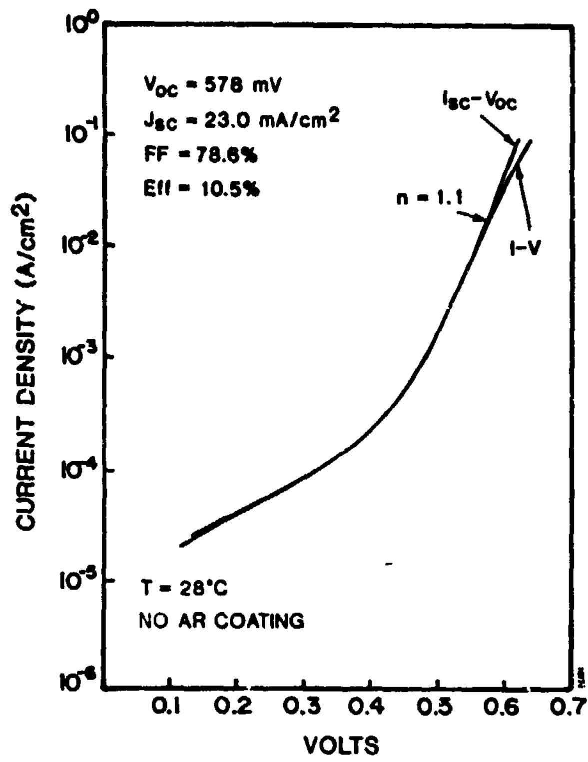
V_{oc} = 578 mV

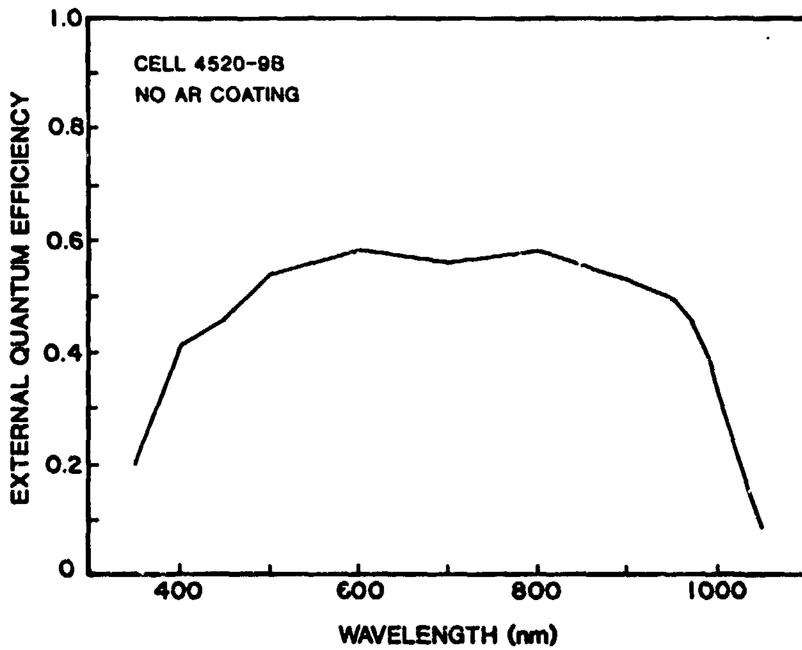
J_{sc} = 23.0 mA/cm^2

FF = 78.6%

EFF = 10.5%

WITH AN AR COATING, EFFICIENCY WOULD BE ABOUT 15%


V_{oc} = 578 mV
J_{sc} = 23.0 mA/cm2
FF = 78.6%
Eff = 10.5%
I_{sc}-V_{oc}
n = 1.1
I-V
T = 28°C
NO AR COATING
CURRENT DENSITY (A/cm2)
VOLTS
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)
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

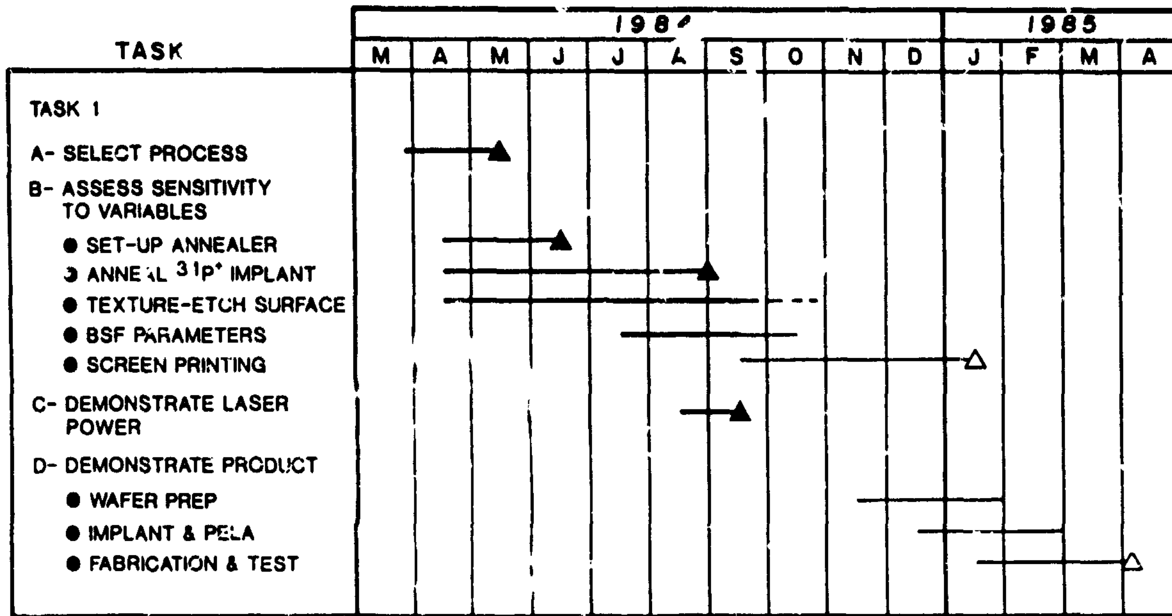
Anneal Parameters

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] [illegible]ED WAFERS, LESS FOR TEXTURED WAFERS.
- WAVELENGTH (KrF [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.