SURFACE AND BULK-LOSS REDUCTION RESEARCH BY LOW-ENERGY HYDROGEN DOPING

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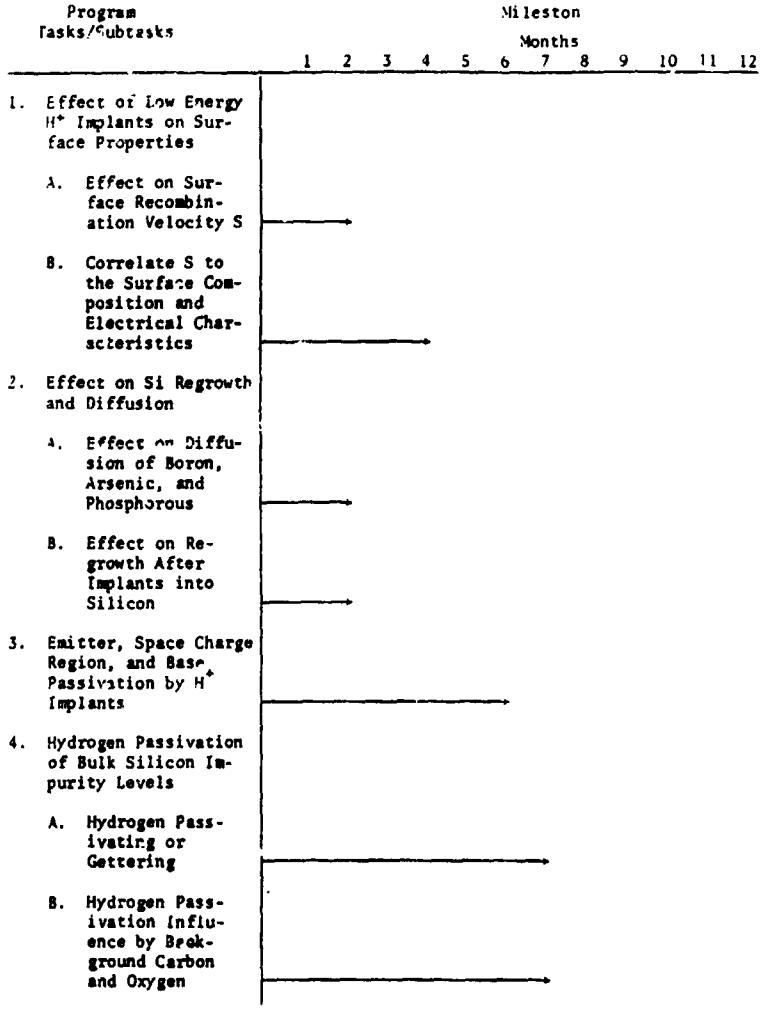
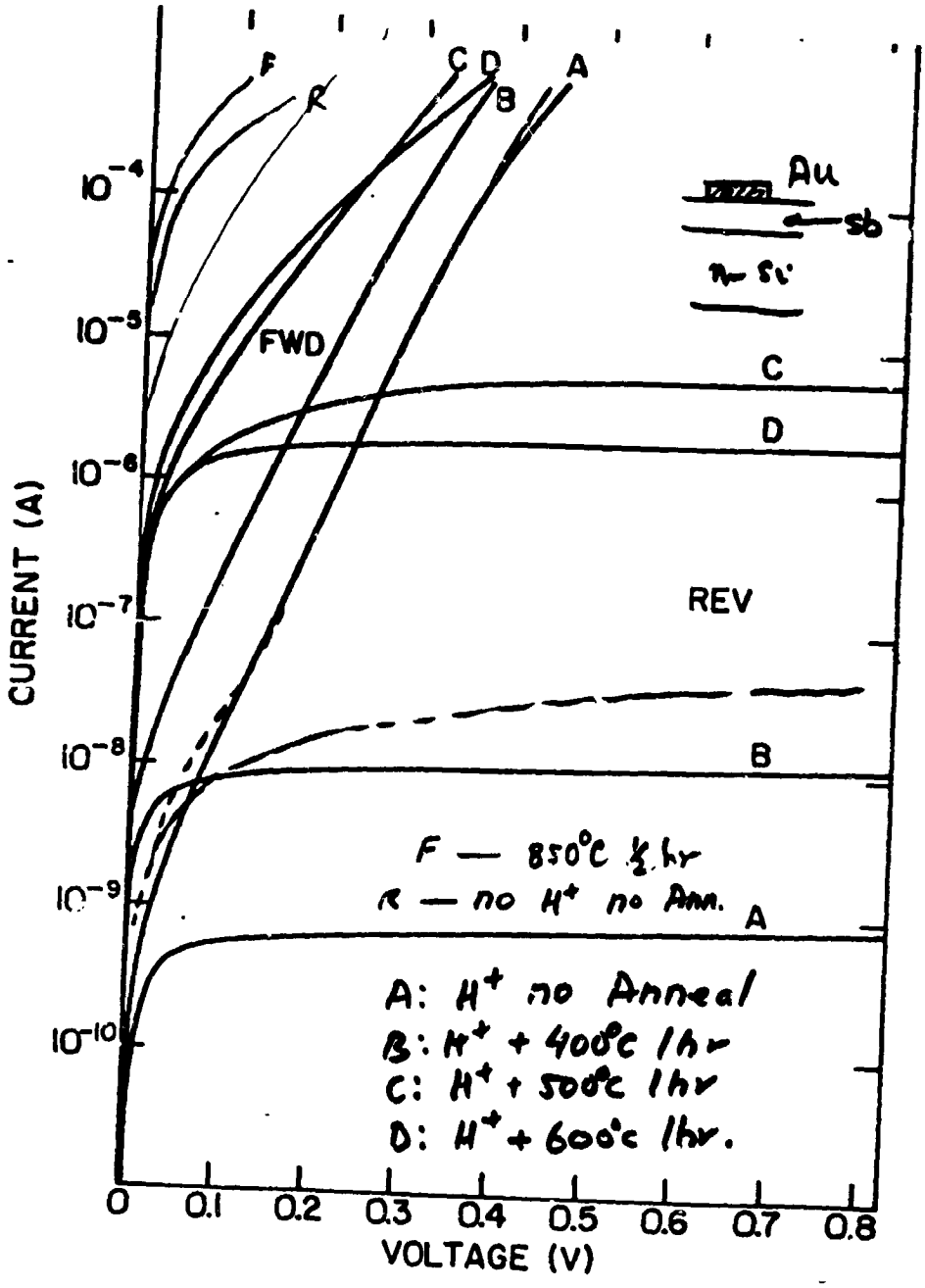
Junction Properties Determined by:

* 1. EMITTER S_p
2. EMITTER : DIFFUSION LENGTH AND WIDTH
* 3. Heavy doping effects in the emitter.
4. EFFECTIVE FIELDS IN THE EMITTER
* 5. Space-charge recombination
* 6. BASE : DIFFUSION LENGTH AND WIDTH.
7. BACK SURFACE S.

Program Plan




F
R
C
D
B
A
Au
Sb
n- Si
FWD
REV
C
D
B
A
CURRENT (A)
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
F — 850°C ½ hr
R — no H+ no Ann.
A: H+ no Anneal
B: H+ + 400°C 1hr
C: H+ + 500°C 1hr
D: H+ + 600°C 1hr.
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
VOLTAGE (V)

H^+ showed a suppression of space charge recombination currents.

CAN H^+ IONS MODIFY S_p ?

. DIODES WHERE EMITTER INJECTION EFFICIENCY < 1

. SHALLOW EMITTERS
. SPIRE SOLAR CELLS.

. J_{ob} from spectral response.
. J_{rec} subtraction.
. J_{oe} determined.
. USE A MODEL FOR HEAVY DOPING and EXTRACT S_p.

Processing	J_0 (pA/cm^2)	J_{oe} (pA/cm^2)
4412-SC as is	3.78	1.71
4412-SC no oxide	7.13	5.06
4412-SC no oxide after H$^+$	3.90	1.83

$J_{ob} = 2.07 \times 10^{-12}$ A/cm^2

$$J_{oe} = \frac{q\, n_i^2}{\int_0^{W_E} \frac{N_D(x)}{D_p(x)} \cdot \frac{n_i^2}{n_{ieff}^2(x)}\, dx + \frac{N_D(0)}{S_p} \cdot \frac{n_i^2}{n_{ieff}^2(0)}}$$

Model	S_p with oxide	S_p no oxide	S_p no oxide with H$^+$
Roulston	1.53×10^4	5.66×10^4	1.65×10^4

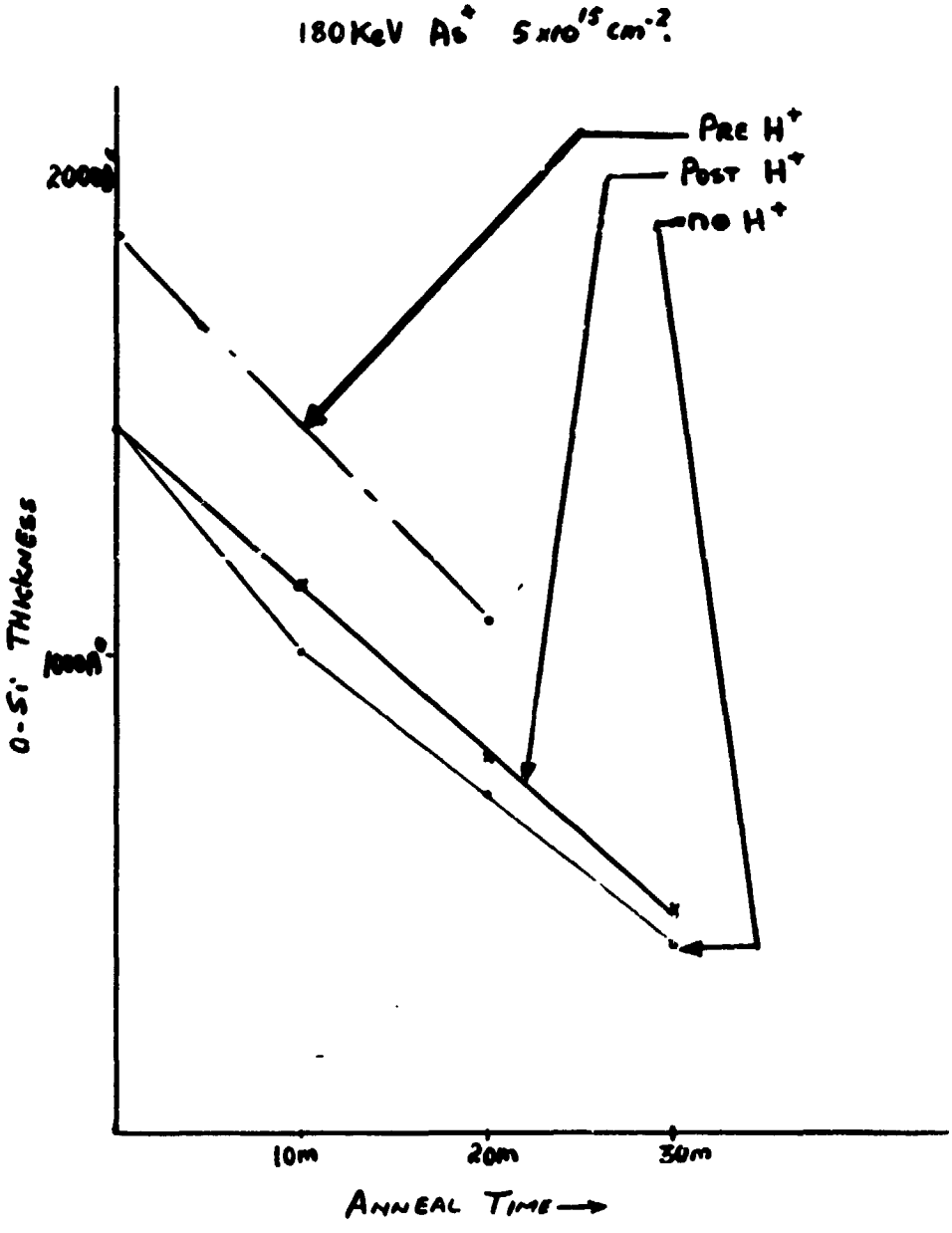
J_{oe} (with oxide) = 3.786×10^{-12} A/cm^2.

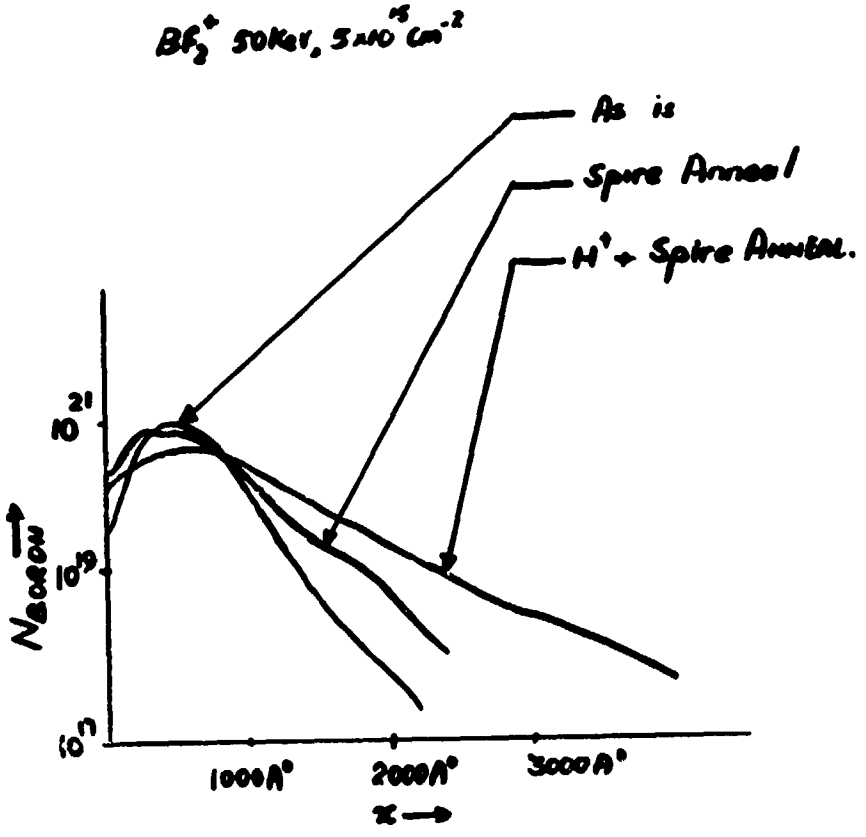
J_{oe} (without oxide) = 7.13×10^{-12} A/cm^2.

J_{oe} (no oxide + 0.4 keV H$^+$) = 3.90×10^{-12} A/cm^2.

Emitres

- ARBITRARY Doping PROFILE
- 1-d FINITE DIFFERENCE FORMULATION
- EFFECTIVE FIELDS AS $N_D = f(x)$
- HEAVY Doping EFFECT AS $n_{ie}(x)$
- $\frac{1}{\tau} = \frac{1}{\tau_0} + \frac{1}{\tau_0} \frac{n}{N_{ref}} + C_n n^2$
- SOLVE FOR MIN. CARRIER CONC. WITH NEUMANN b.c AT FRONT SURFACE AND DIRICHLET b.c AT THE EMITTER EDGE.
- PARAMETER EXTRACTION by MINIMIZATION OF SQUARE OF DEVIATION OF CALCULATED AND MEASURED SR.


180KeV As+ 5x10^15 cm^-2
PRE H+
POST H+
no H+
2000Å
1000Å
O-Si THICKNESS
10m
20m
30m
ANNEAL TIME



Conclusions

- DEMONSTRATED PASSIVATION LEADING TO SPACE CHARGE CURRENT REDUCTION.
- DEMONSTRATED H^+ CAN REDUCE Sp. NEEDS MORE WORK FOR OPTIMIZATION.
- DEVELOPMENT OF A NUMERICAL CODE FOR CALCULATING SR AND EXTRACT PARAMETERS.
- INVESTIGATION OF REGROWTH AND DOPANT REDISTRIBUTION IN (H^+ PROCESSED) IMPLANT AMORPHIZED LAYERS.