

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

PENNSYLVANIA STATE UNIVERSITY

S. Fonash

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.**

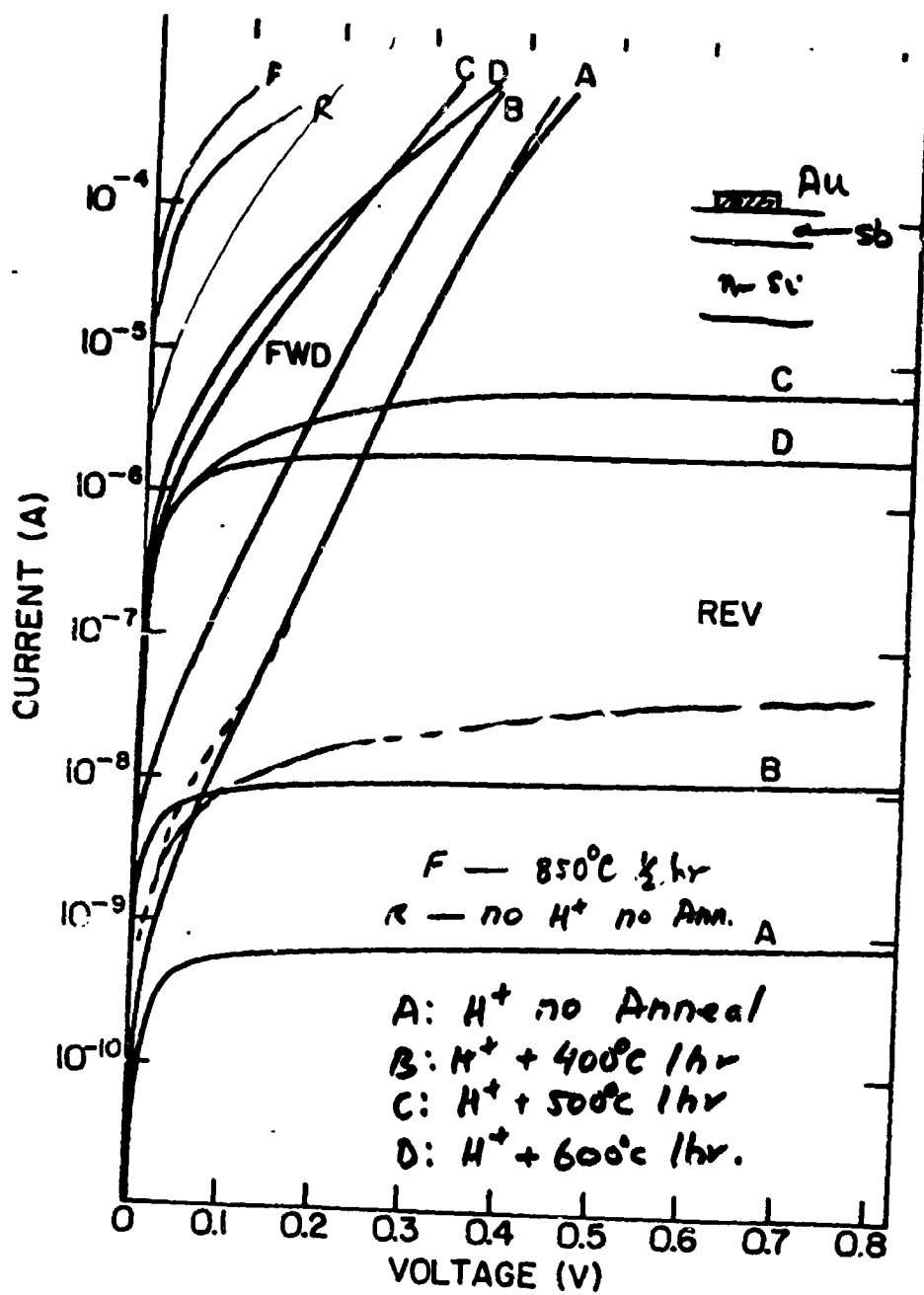
PRECEDING PAGE BLANK NOT FILLED

# HIGH-EFFICIENCY DEVICE RESEARCH

## Program Plan

Program Tasks/Subtasks	Milestone Months												
	1	2	3	4	5	6	7	8	9	10	11	12	
1. Effect of Low Energy H <sup>+</sup> Implants on Surface Properties													
A. Effect on Surface Recombination Velocity S		→											
B. Correlate S to the Surface Composition and Electrical Characteristics				→									
2. Effect on Si Regrowth and Diffusion													
A. Effect on Diffusion of Boron, Arsenic, and Phosphorous				→									
B. Effect on Regrowth After Implants into Silicon				→									
3. Emitter, Space Charge Region, and Base Passivation by H <sup>+</sup> Implants									→				
4. Hydrogen Passivation of Bulk Silicon Impurity Levels													
A. Hydrogen Passivating or Gettering										→			
B. Hydrogen Passivation Influence by Background Carbon and Oxygen											→		

HIGH-EFFICIENCY DEVICE RESEARCH



## HIGH-EFFICIENCY DEVICE RESEARCH

$H^+$  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  $S_p$ .

# HIGH-EFFICIENCY DEVICE RESEARCH

ORIGINAL PAPER  
OF POOR QUALITY

Processing	$J_o$ (pA/cm <sup>2</sup> )	$J_{oo}$ (pA/cm <sup>2</sup> )
4412-5C as is	3.78	1.71
4412-5C no oxide	7.13	5.06
4412-5C no oxide after H <sup>+</sup>	3.90	1.83

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

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

Model	$S_p$ with oxide	$S_p$ no oxide	$S_p$ no oxide with H <sup>+</sup>
Roulston	$1.53 \times 10^4$	$5.66 \times 10^4$	$1.65 \times 10^4$

$$J_{oe} \text{ (with oxide)} = 3.786 \times 10^{-12} \text{ A/cm}^2$$

$$J_{oe} \text{ (without oxide)} = 7.13 \times 10^{-12} \text{ A/cm}^2$$

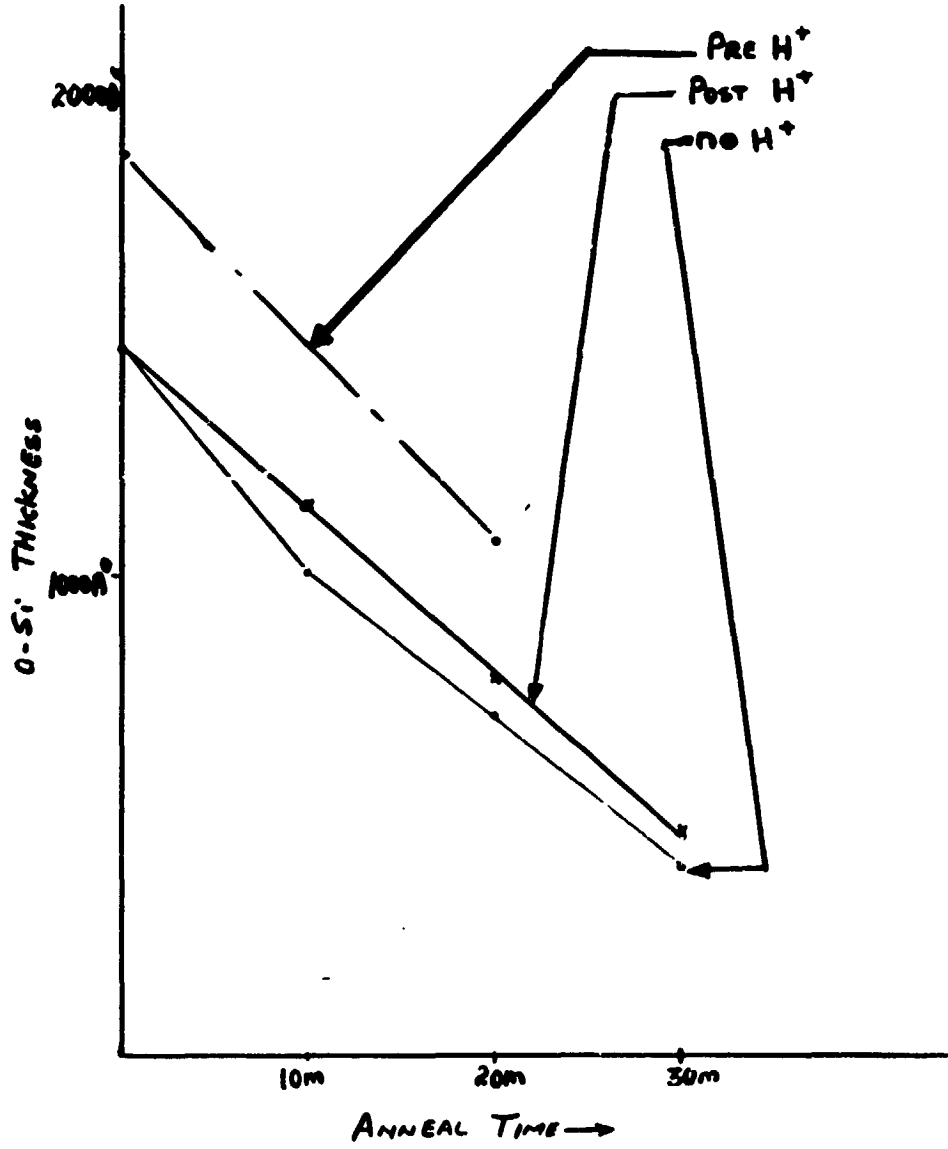
$$J_{oe} \text{ (no oxide + 0.4 keV H}^+) = 3.90 \times 10^{-12} \text{ A/cm}^2$$

## Emitres

- **ARBITRARY Doping PROFILE**
- **1-D FINITE DIFFERENCE FORMULATION**
- **EFFECTIVE FIELDS AS  $N_D = f(x)$**
- **HEAVY DOPING EFFECT AS  $n_{i,eff}(x)$**
- $\frac{1}{\epsilon} = \frac{1}{\epsilon_0} + \frac{1}{\epsilon_0} \frac{q}{4\pi n_f} + C_n n^2$
- **SOLVE FOR MIN. CARRIER CONC. WITH NEUMANN b.c. at front surface and DIRICHLET b.c. at the barrier edge.**
- **PARAMETER EXTRACTION by MINIMIZATION OF SQUARE OF DEVIATION OF CALCULATED AND MEASURED SR.**

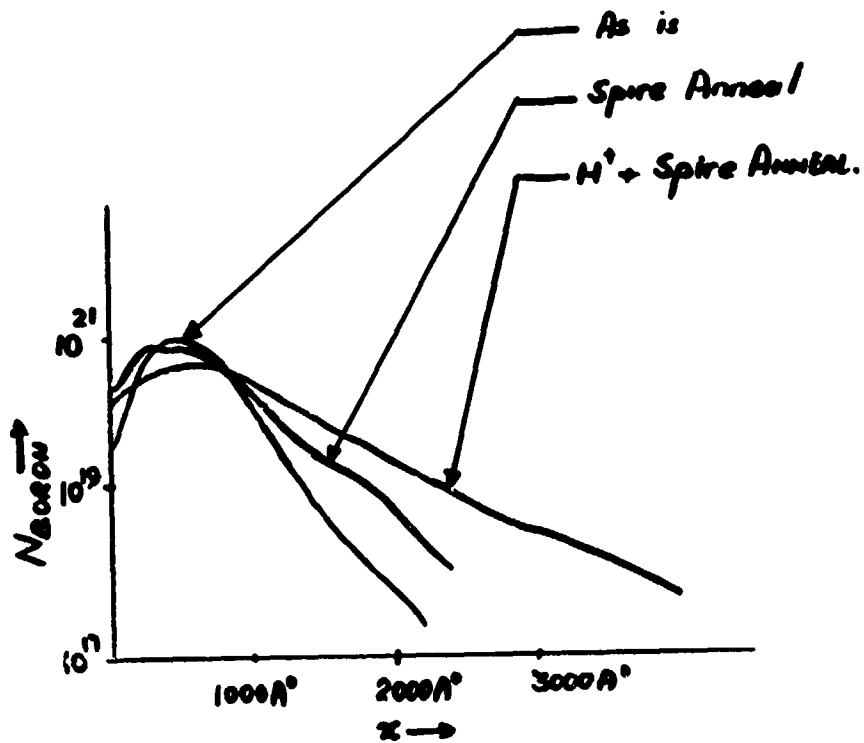
HIGH-EFFICIENCY DEVICE RESEARCH

180 KeV As<sup>+</sup> 5 x 10<sup>15</sup> cm<sup>-2</sup>



# HIGH-EFFICIENCY DEVICE RESEARCH

$BF_3^+$  50keV,  $5 \times 10^{15} \text{ cm}^{-2}$



## Conclusions

- DEMONSTRATED PASSIVATION LEADING TO SPACE CHARGE CURRENT REDUCTION
- DEMONSTRATED  $H^+$  CAN REDUCE  $S_p$   
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.