III. STEADY STATE PHOTOCONDUCTIVITY

1. PHOTOCONDUCTIVITY WITH OHMIC CONTACTS (P.C.) BASIC PRINCIPLES

2. NON-LINEAR LIGHT DEPENDENCE OF P.C.

3. BIAS LIGHT ILLUMINATION

4. COMPARISON OF P.C. WITH PHOTO-THERMAL DEFLECTION SPECTROSCOPY

5. INFRARED QUENCHING

6. PHOTOCONDUCTIVITY WITH BLOCKING CONTACTS (SOLAR CELL COLLECTION EFFICIENCY C.E.) BASIC PRINCIPLES

7. SAMPLE GEOMETRY AND TYPICAL EXPRIMENTAL RESULTS

8. INTERNAL PHOTOEMISSION

9. COMPARISON OF α DETERMINED FROM P.C. AND C.E.

10. C.E. WITH STRONGLY ABSORBED LIGHT

11. DIFFUSION LENGTH OF MINORITY CARRIERS FROM C.E.

INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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SPRING COLLEGE ON AMORPHOUS SOLIDS
AND THE LIQUID STATE

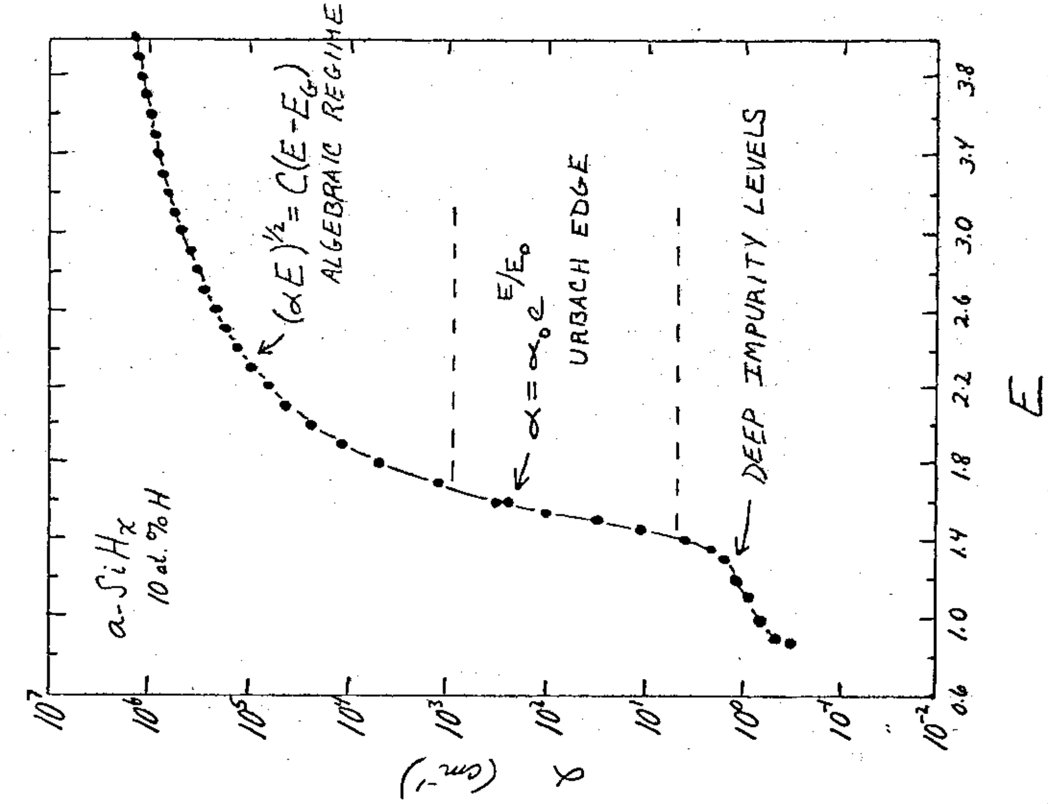
14 April - 18 June 1982

IMPURITIES, TRAPS AND RECOMBINATION CENTERS IN A SiHx

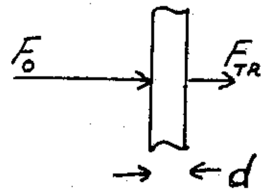
(Part III)

B. ABELES

Exxon Research and Engineering Co.
P.O. Box 45
Linden, N.J. 07036
U.S.A.



DIRECT OPT. ABSORPTION:[1]

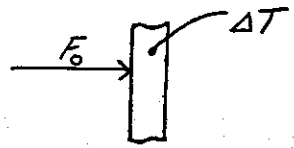


$$F_{TR} = F_0 e^{-\alpha d}$$

LIMIT:

$$\alpha d > .01$$
$$d = 10^{-4}\ cm$$
$$\alpha > 100\ cm^{-1}$$

PHOTO-THERMAL SPECTROSCOPY



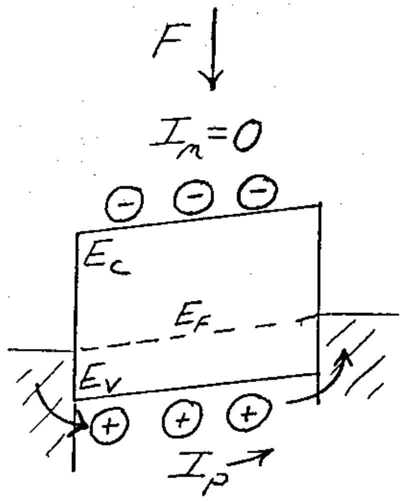
$$10^{-4} < \alpha d < 1$$

DETECTION:
ACCOUSTIC[3]
OPT. DEFLECTION[2]

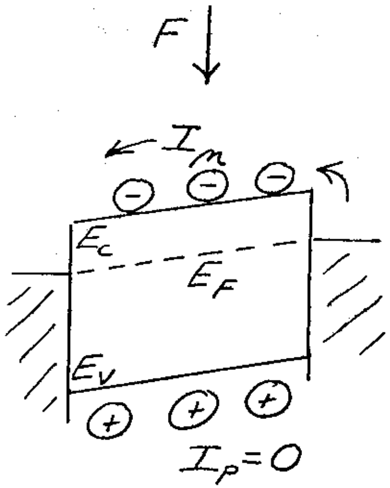
1. CODY ET. AL., SOLAR CELLS 2, 227 (1980)
2. JACKSON ET. AL., JOURNAL DE PHYSIQUE C4, 293 (1981)
3. YAMASAKI ET. AL., JOURNAL DE PHYSIQUE C4, 297 (1981)

PHOTOCONDUCTIVITY

A. SECONDARY P.C.



ohmic contact to E_V



ohmic contact to E_c

For electrons: $I_F = q n \mu_n E$

$$n = \tau_n \alpha F G$$

n = free photogenerated carriers

μ_n = free carrier mobility

τ_n = free carrier lifetime

α = optical absorption

F = photon flux (photons/cm² sec)

G = photogeneration Quantum eff. ($G \approx 1$ in a-SiH_x)

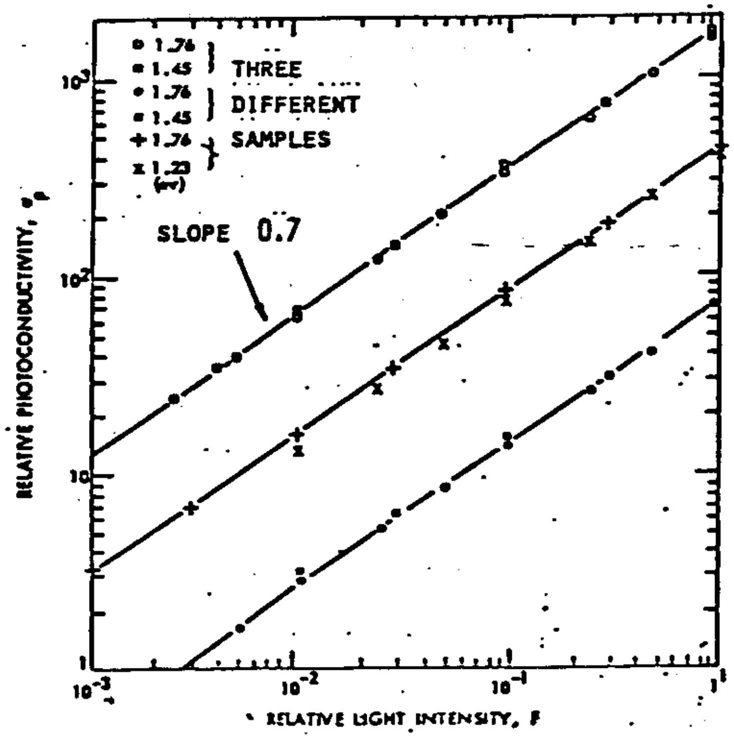
E = ELECTRIC FIELD

POWER LAW RELATION BETWEEN PHOTOCONDUCTIVITY AND LIGHT INTENSITY

- PHOTOCOND α (LIGHT INTENS.)$^{\gamma}$

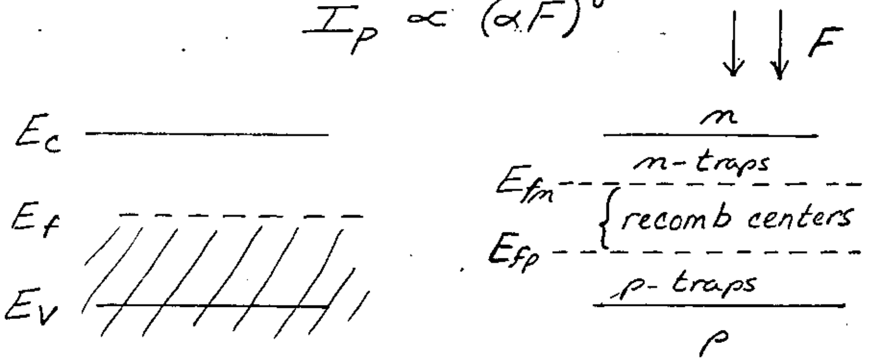
$$\gamma = \frac{T_c}{T_c + T} = 0.7$$

- CONSEQUENCE OF EXP. DISTRIB. OF RECOMBINATION CENTERS



NON LINEAR LIGHT DEPENDENCE

$$I_p \propto (\alpha F)^\gamma$$



LIGHT INTRODUCES NEW RECOMB. C.

$$\sigma_L = \alpha F q \mu_n \tilde{\tau}_n$$

$$\tilde{\tau}_n = \tau(\alpha F)$$

$$\sigma_L = q \mu_n \alpha F \times \tau(\alpha F)$$

$$\sigma_L = const\,(\alpha F)^\gamma$$

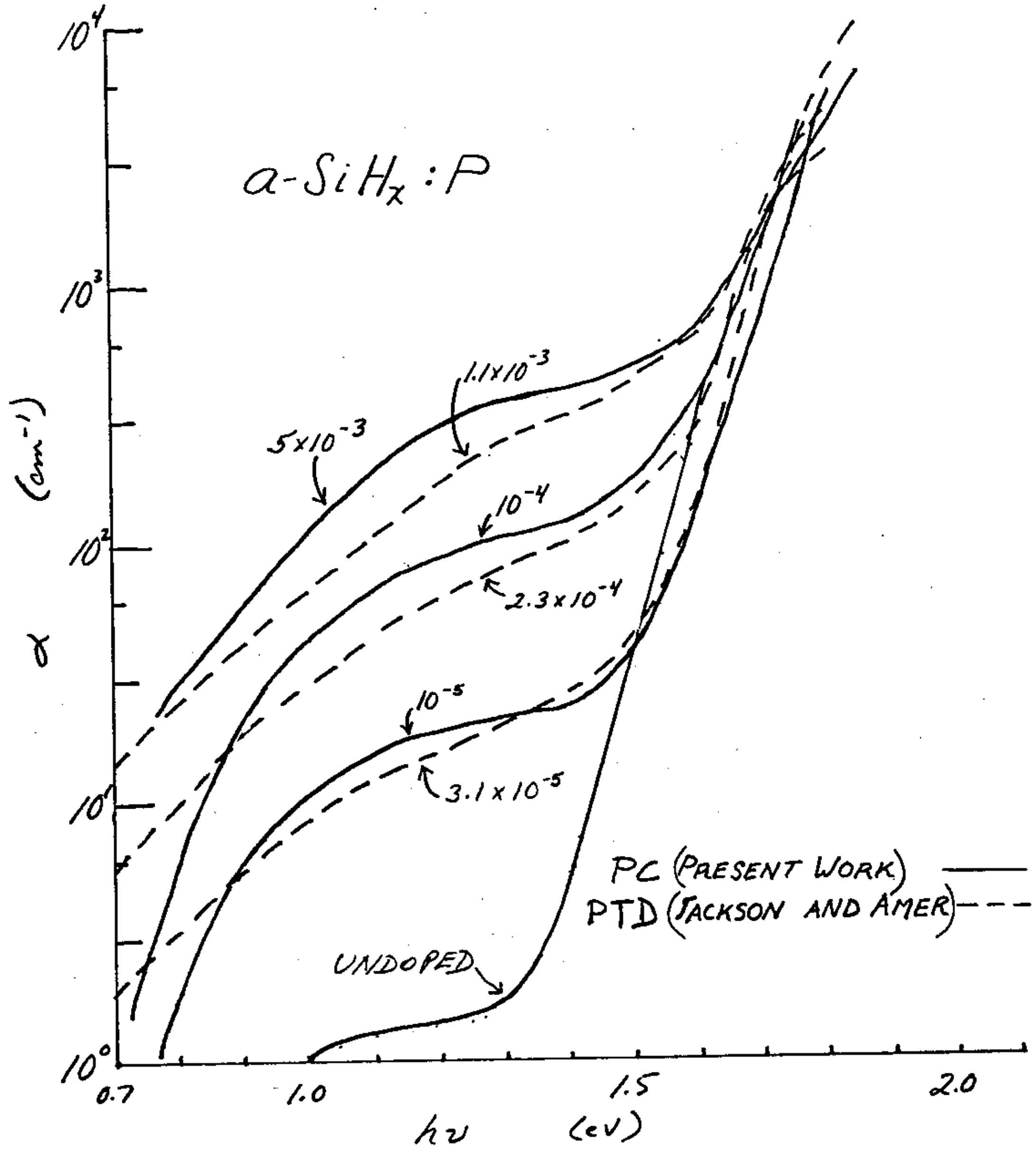
$$\gamma = 0.5 - 1$$

DC (white light) BIAS ILLUMINATION F_0 ($\gamma = 1$)

$$F = F_0 + \Delta F$$

$$\tilde{\tau}_n = \tau(n_0 + \alpha \Delta F)$$

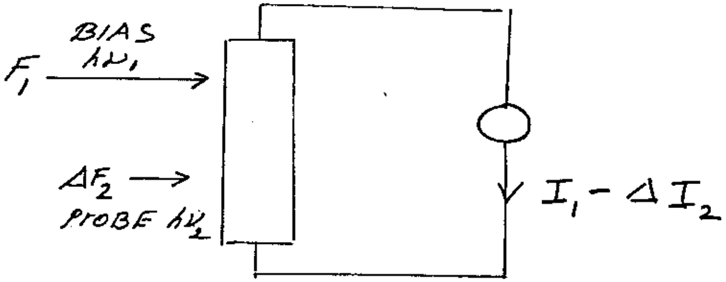
$$\Delta\sigma_L = \alpha \Delta F \underbrace{q \mu_n \tau(n_0)}_{constant}$$

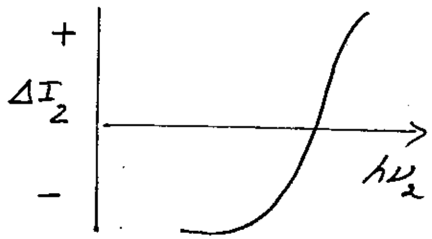


INFRARED QUENCHING[1,2,3]

THERMAL QUENCHING[2]

SUPRA LINEARITY

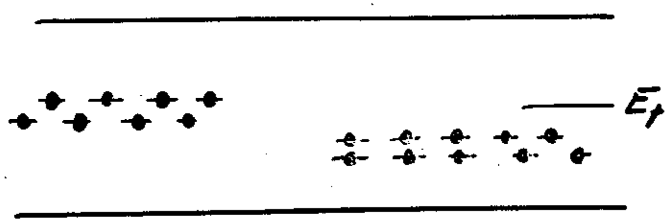




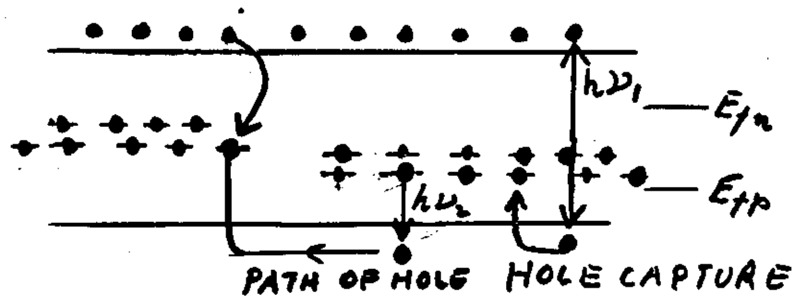
1. P.D. PERSANS AND H. FRITZSHE
JOURNAL DE PHYSIQUE C4-597 (1981)
2. P.E. VANIER, A.E. DELAHOY AND R.W. GRIFFITH
J. APPL. PHYS 52, 5235 (1981)
3. A. ROSE, CONCEPTS IN PHOTOCONDUCTIVITY.

SENSITIZING CENTERS K^s

$$K_p^s \gg K_{n,p}^r \gg K_n^s$$



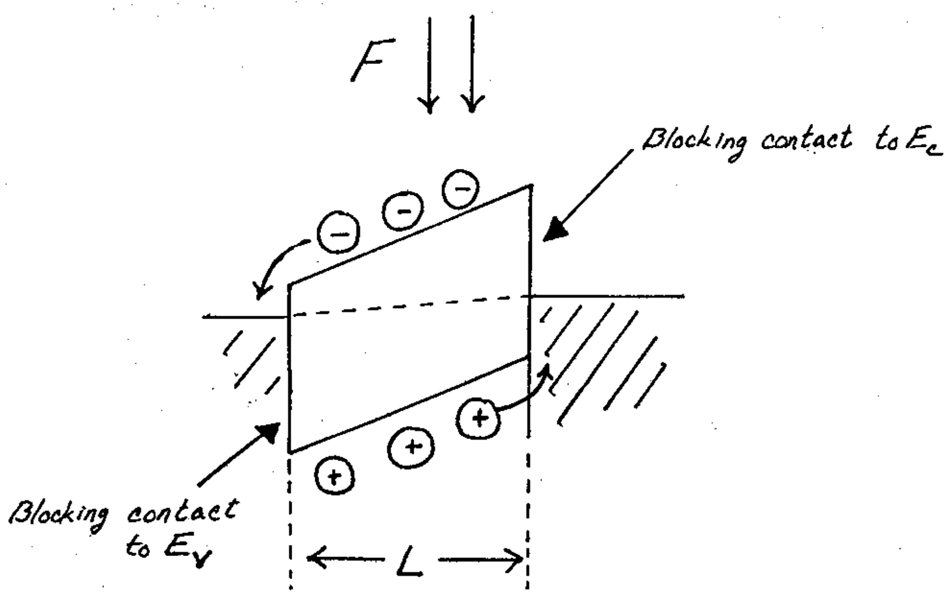
SENSITIZING C. ENHANCE τ_n



$h\nu_2$ OPENS RECOMBINATION CHANNEL FOR ELECTRONS

B. PRIMARY PHOTOCONDUCTIVITY

(SOLAR CELL COLLECTION EFFICIENCY)



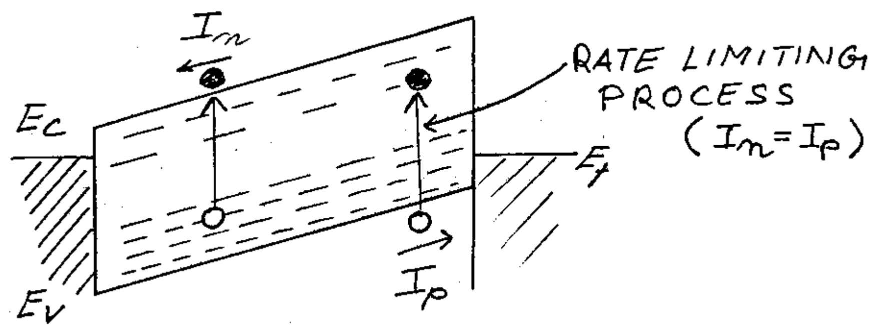
$$I_F = \eta L \alpha F q$$

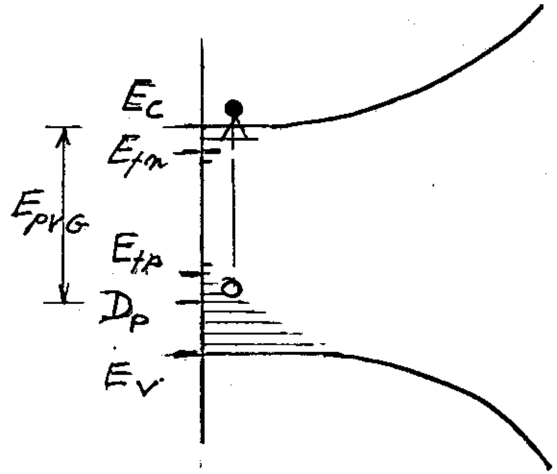
L = film thickness

$\eta \leq 1$ collection efficiency

$\eta = 1$ with no recombination

FOR $h\nu < V_{PVG}$ ONLY FREE HOLE GENERATION CONTRIBUTES TO η.



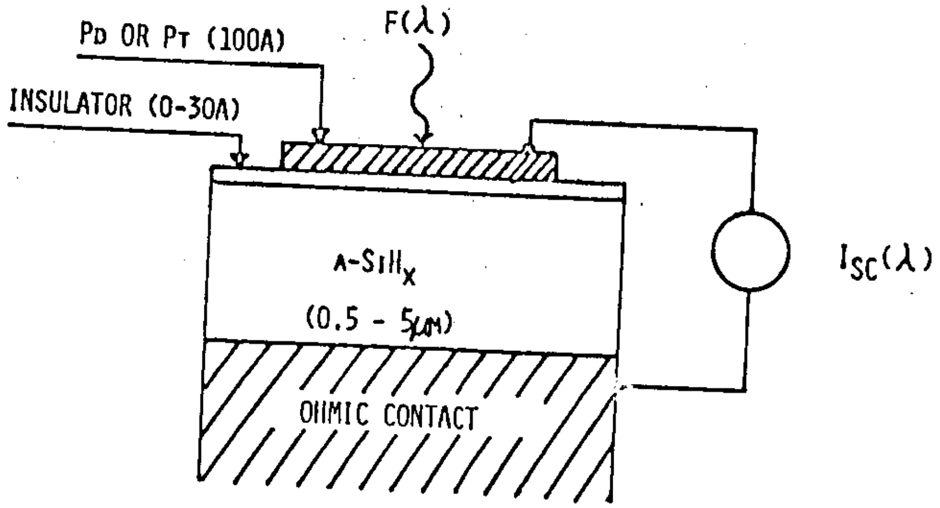


PHOTOVOLTAIC GAP*

$$E_{PVG} = E_C - D_p$$

* E. YABLONOVITCH, T. TIEDJE AND H. WITZKE (TO BE PUBLISHED)

MIS SOLAR CELL STRUCTURES



COLL. EFF. $\eta(\lambda) = \frac{I_F(\lambda)}{e F(\lambda)}$

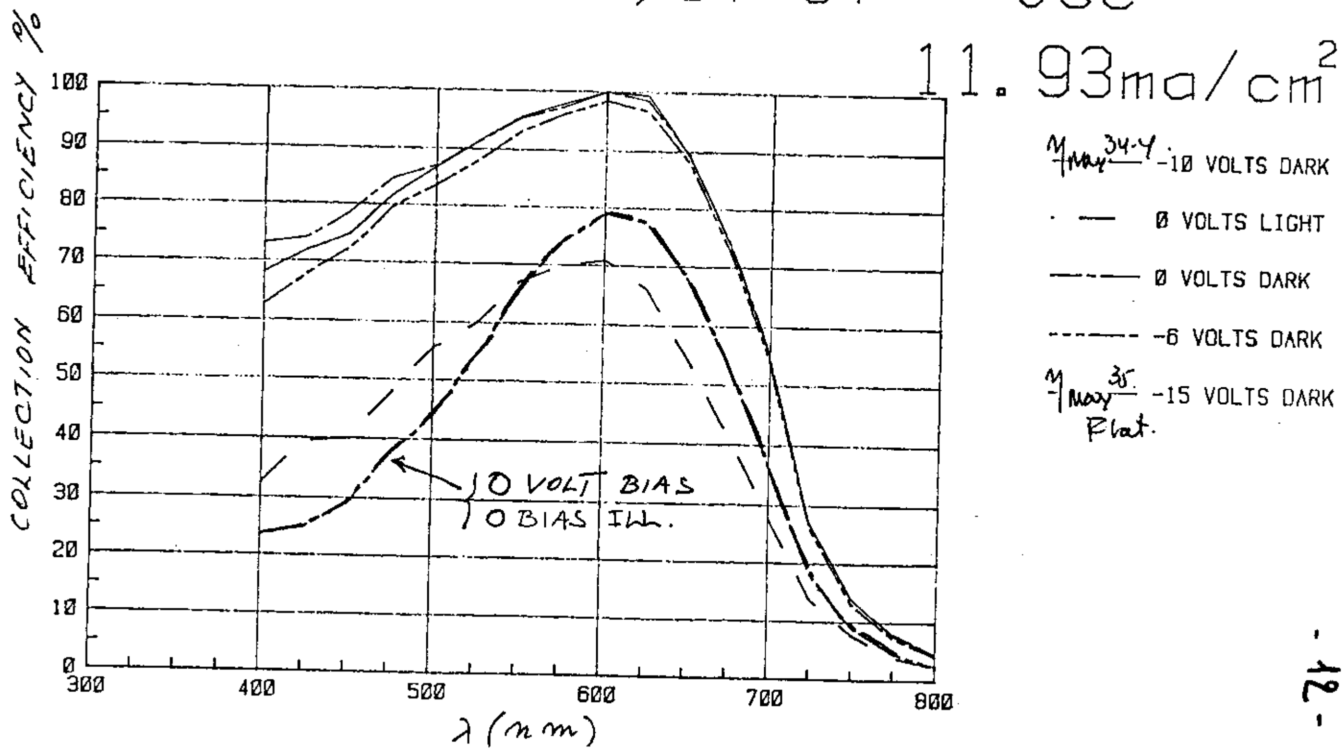
SHORT CIRCUIT CURRENT

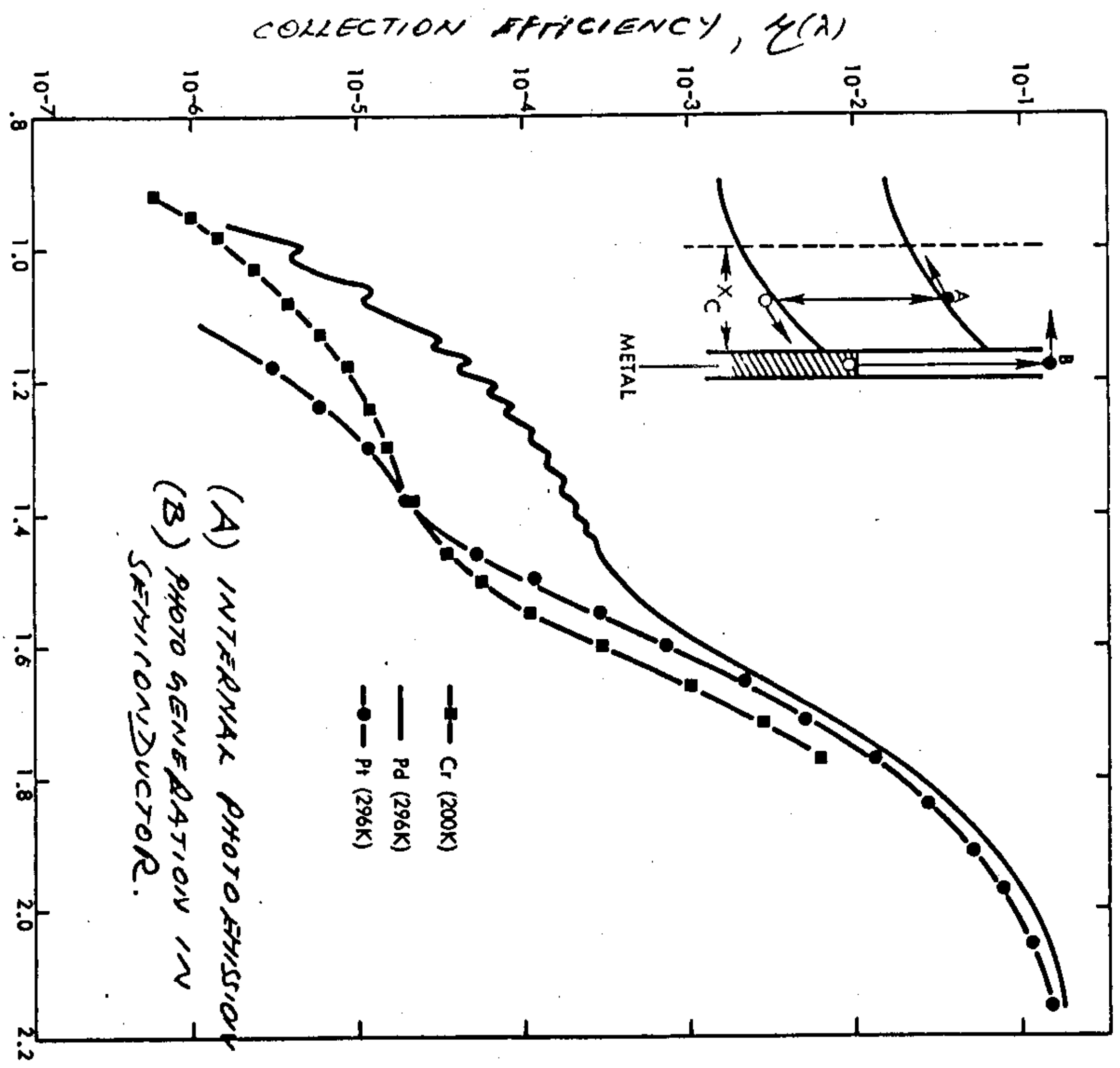
$$I_{sc} = \int \eta(\lambda)\, S(\lambda)\, d\lambda$$

$S(\lambda)$ solar flux.

BR 811022A-1; A4 T= 34.4%

Pd 10-23-81; ST ST J^{i}_{sc} = 11.93ma/cm^2





<u>COLLECTION EFFICIENCY $\eta(\lambda)$</u>

(SUB BAND GAP EXCITATION)

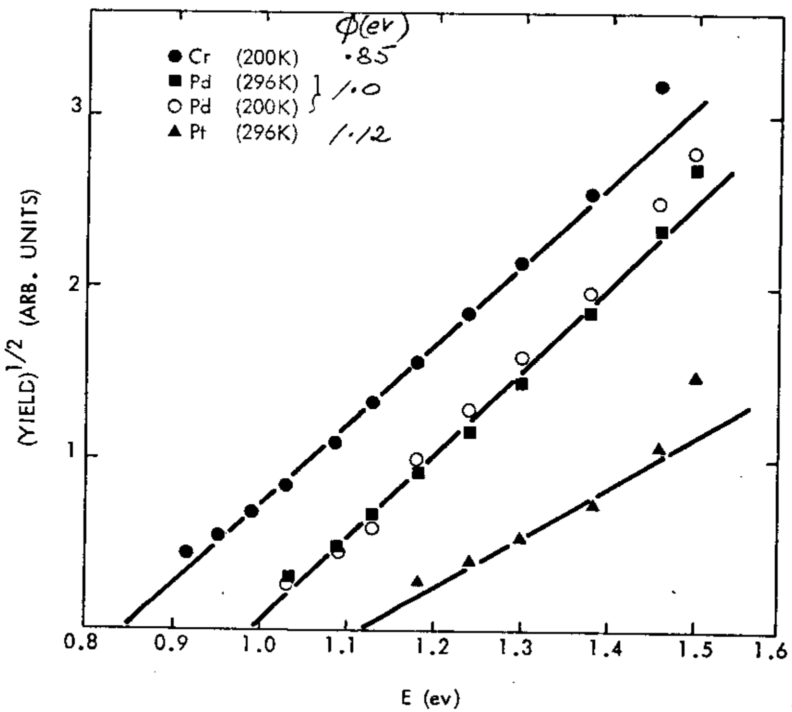
$\eta = \eta(IPE) + \eta(SEMICOND)$

$\sqrt{\eta(IPE)} \propto h\nu$

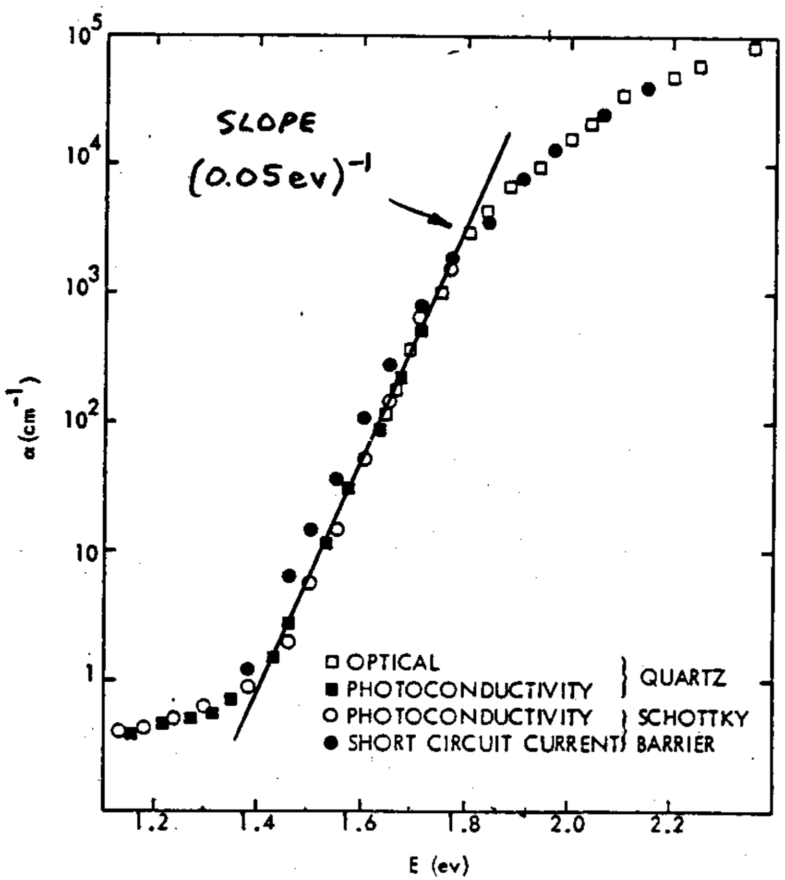
$\eta(SEMICOD) \propto x_c \alpha$

x_c COLLECTION WIDTH

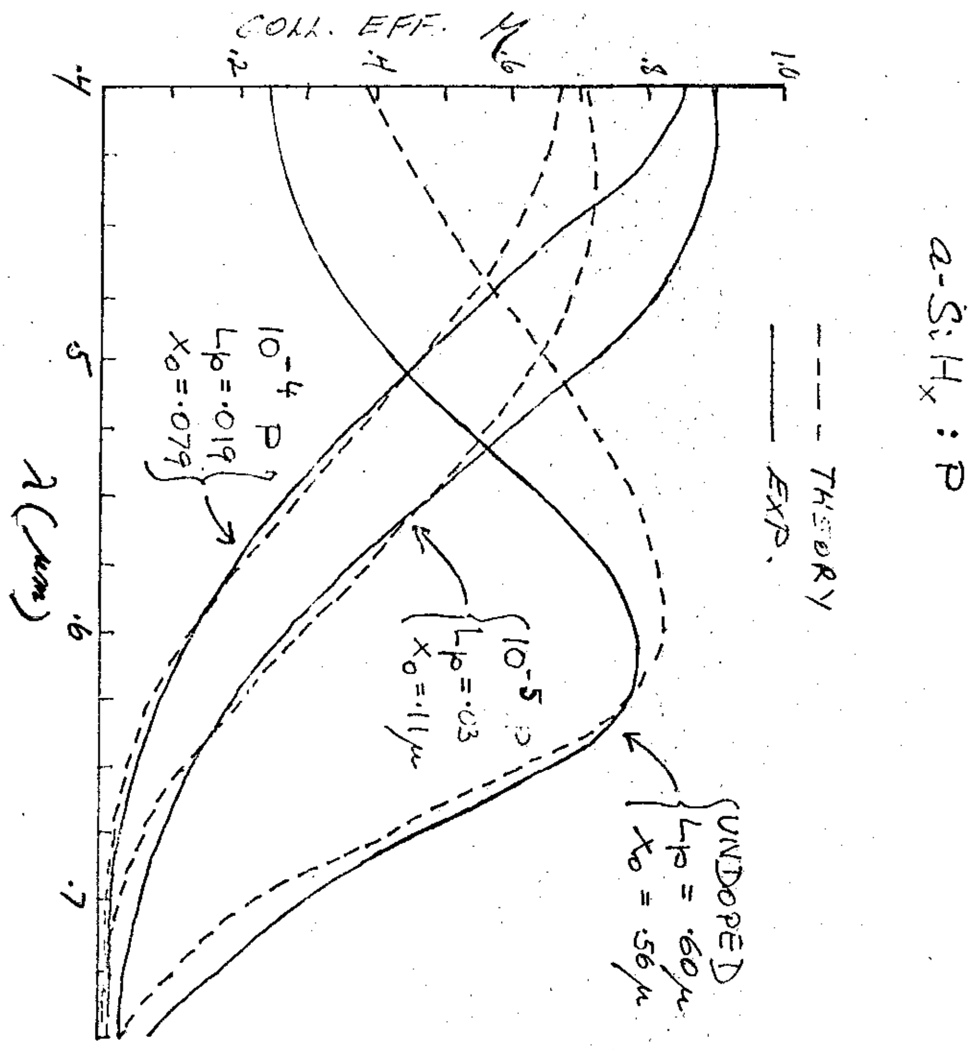
$\alpha(\lambda)$ OPTICAL ABSORPTION



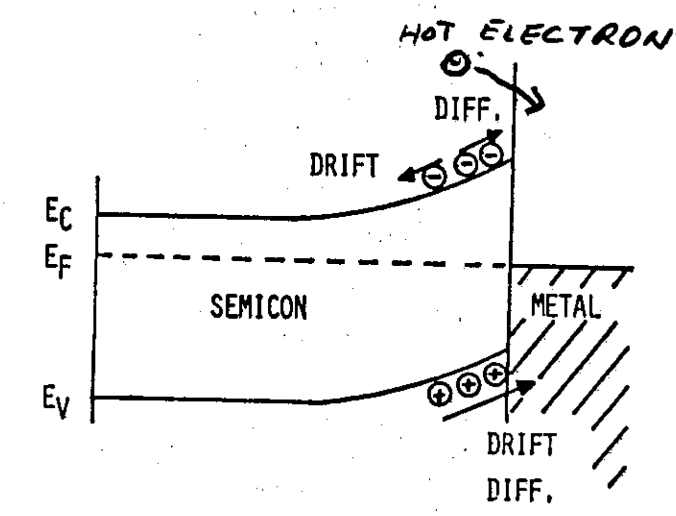
OPTICAL ABSORPTION EDGE



Abeles, Wronski, Tiedje, Cody SSC (1980)



COLLECTION EFFICIENCY FOR STRONGLY ABSORBED LIGHT



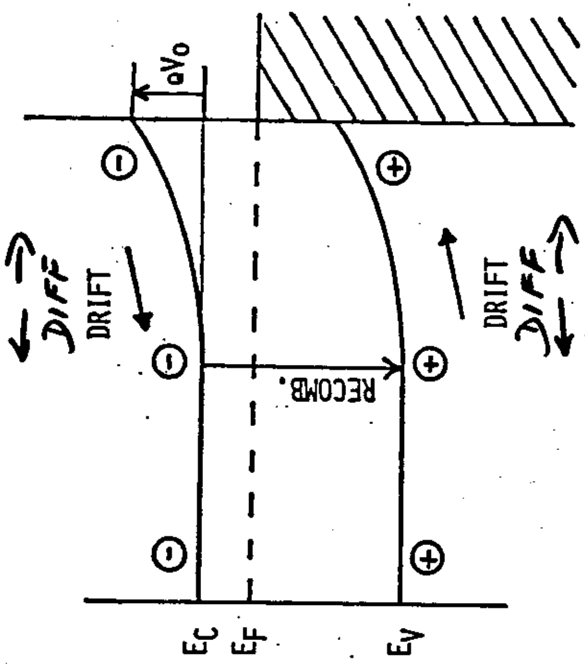
1. INSENSITIVE TO BULK RECOMBINATION

2. SENSITIVE TO ELECTRIC FIELD AT SURFACE OR RELATIVE STRENGTHS OF DIFFUSION AND DRIFT CURRENTS OF ELECTRONS

COLL. EFF. IS REDUCED BECAUSE OF DIFFUSION LOSSES OF ELECTRONS.

B. ABELES, C.R. WRONSKI, Y. GOLDSTEIN, G.D. CODY S.S.C. 41, 251 (198[illegible])
A. ROTHWARF APPL. PHYS LETT. 40, 694 (1982)

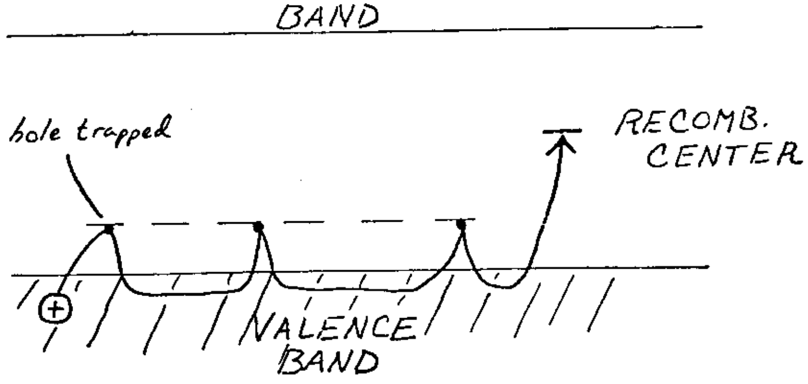
COLLECTION EFFICIENCY FOR WEAKLY ABSORBED LIGHT



1. SENSITIVE TO BULK RECOMBINATION
2. SENSITIVE TO BUILT IN POTENTIAL V_0
3. ONLY WEAKLY DEPENDENT ON WIDTH DEPLETION REGION

CAN BE USED TO MEASURE DIFFUSION LENGTH OF CARRIERS

DIFFUSION LENGTH L OF PHOTO-CARRIER



$$L_p = \sqrt{\tau_p D_p}$$

$$D_p = \frac{\mu_p kT}{q}.$$

τ_p = Free carrier life time

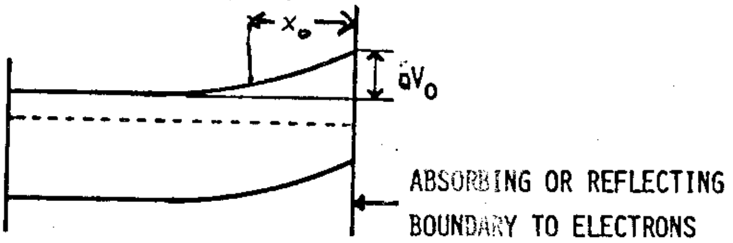
μ_p = Free carrier mobility

L IS DETERMINED ON SOLAR CELL FROM COLLECTION EFF.[1] OR SURFACE PHOTOVOLTAGE[2].

(1) B. ABELES ET. AL., SOLID STATE COM. 41, 251 (1982)

(2) A.R. MOORE, APPL. PHYS. LETT. 40, 404 (1982)

THEORETICAL MODEL*



$$\frac{d}{dx}\left(D_n \frac{dn}{dx} - q\mu_n n E\right) + G - R = 0$$

1. $\frac{d}{dx}\left(D_p \frac{dp}{dx} + q\mu_p p E\right) + G + R = 0$
2. $V = V_o \exp(-x/x_o)$
3. $R = p/\tau_p$
4. QUANTUM EFFICIENCY UNITY

PARAMETERS:

$\alpha(\lambda)$; x_o ; L_p ; L ; V_o

$$L_p = (kT\mu_p\tau_p/q)^{\frac{1}{2}}$$

* D. GUTKOWICZ-KRUSIN