LOSS MECHANISMS IN HIGH-EFFICIENCY SOLAR CELLS

C.T. SAH ASSOCIATES

C. Tang Sah

Study of Material Properties and High-Efficiency Solar-Cell Performance on Material Composition: Project Tasks

(1) EFFICIENCY-LIMITING IMPURITY AND DEFECT LEVEL CHARACTERIZATION.

(2) COMPUTER MODELING OF CELL PERFORMANCE.

● (3) FUNDAMENTAL LIMITATIONS.

● (4) PRACTICAL SOLUTIONS.

● To be discussed here.

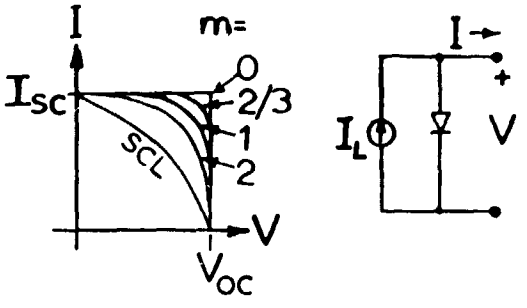
Outline

(3) FUNDAMENTAL LIMITATIONS

* Best Cell I-V Curve.
* State-of-the-Art and Fundamental Limit.
* Summary of Limiting Recombination Losses.

(4) PRACTICAL SOLUTIONS

* Design alternatives
* Test Structure No.1.



$$I = I_L - I_m e^{\frac{qV}{mkT}}$$

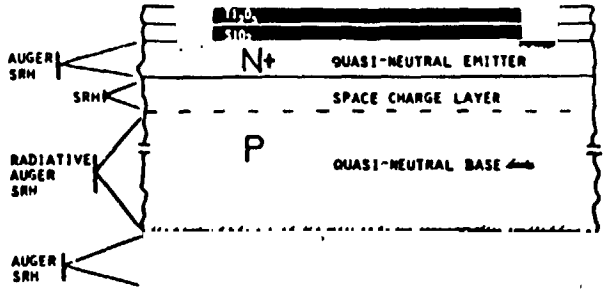
or $$= I_L - I_{SCL}$$

BEST: $m = 1$ or less

for $IV = max.$ $J_{SC} = High$

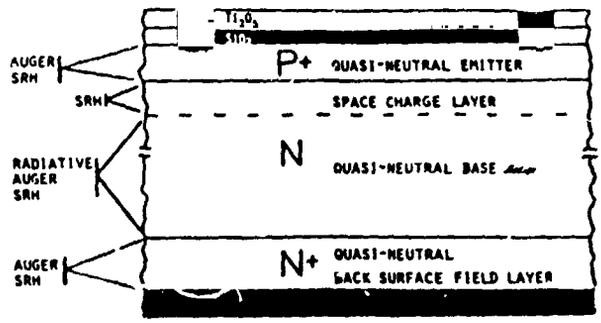
$V_{OC} = High$

1984
1985 Production 16%



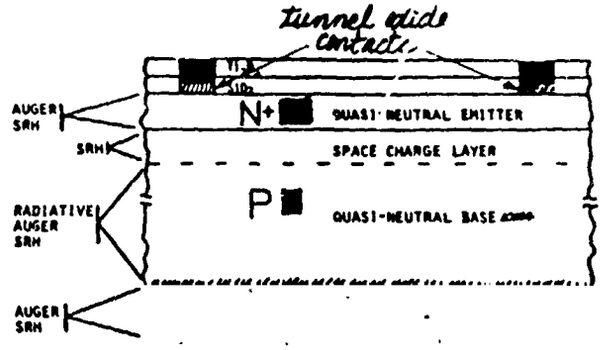
Major Recombination Loss Sites:
Interfaces: FRONT CONTACT, BACK
Base

1984 SPIRE (Spitzer) 18% $N^+P\Gamma^+$
1978 SANDIA 18% P^+NN^+



Major Recombination Loss Sites:
Interfaces: FRONT CONTACT
Base

Green 19%



Major Recombination Loss Sites:
Interfaces: ~~FRONT CONTACT~~ eliminated
BACK CONTACT
Base:

State of the Art and Fundamental Limited Silicon Solar Cells

	SOURCE	Jm (A)	JSC (mA)	VOC (mV)	FF	EFF (%)	LOSS MECHANISM	m	SEFF cm/s)	CELL TYPE
FUNDAMENTAL LIMITED	THEORY	5E-16	36	840	0.864	25.4	RadRec Base	1	3.1	DC
	THEORY	3E-22	36	786	0.897	25.	AugerH Base	2/3	0.3	DC
	THEORY	2E-17	36	776	0.858	24.0	AugerL Base	1	18	N+/P/P+
	ESTIMATE	4E-15	36	769	0.861	23.8	SRH PolyEmi	1	1 2/100	P+/N/N+
STATE-OF-THE-ART	Green Theory	3E-13	36	653	0.811	19.1				M/I/N/P
		3E-13	36	660	0.840	20.0	SRH Base	1	850	
	Spitzer Theory	1E-12	36	622	0.801	18.0				
		1E-12	36	627	0.834	18.9	SRH Base	1	1100	N+/P/P+
	Rohatgi Theory	2E-12	36	605	0.786	17.2				
		2E-12	36	605	0.830	18.2	SRH Base	1	650	N+/P/P+
	ASEC Theory	1E-12	35	620	0.793	17.1				
		1E-12	35	620	0.833	17.9	SRH Base	1	880	N+/P

Upper four theory: T=24C, ni=1E10, Area=1cm^2, XB=50um, NB=1E17, DB=20, tB=100um, $C^n n_i^2$=6E5, C^n_L=C^n=2.8E-31, C^n_H=C^n+C^p=3.8E-31cm^2/s.

Summary of Efficiency-Limiting Mechanisms

EFFICIENCY RANGE (%)	CURRENT STATUS	LIMITING MECHANISMS AND RECOMBINATION SITES	MAXIMUM DARK CURRENT J1(A/cm^2)
25+	Must eliminate all emitter recomb. losses.	Interband Auger and radiative in base.	5.0E-16
20-24	Must reduce all base recomb. losses.	SRH at traps at the contact and oxide/ silicon interface. Use poly-Si barrier for contacts.	2.0E-15 to 2.0E-13
18-20	Current best cells.	SRH at traps in the base layer.	2.0E-13 to 2.0E-12
<18	Current production.	SRH at traps in both the base and emitter.	>2.0E-12

Floating Emitter Solar-Cell Transistor

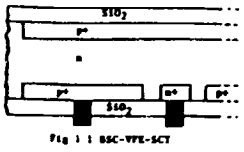


Fig. 1.1 BSC-VFE-SCT

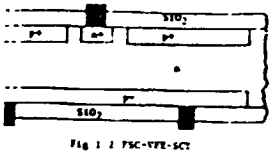


Fig. 1.2 FSC-VFE-SCT

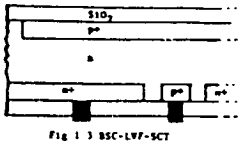


Fig. 1.3 BSC-LVF-SCT

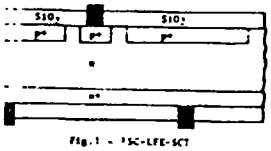


Fig. 1.4 FSC-LFE-SCT

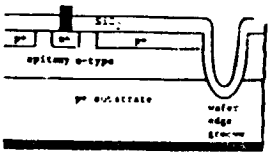


Fig. 1.5 FSC-VFE-SCT

From

"Floating Emitter Solar Cell Transistor," Docket No.16467, JPL Office of Patents and Technology Utilization, March 20, 1984.

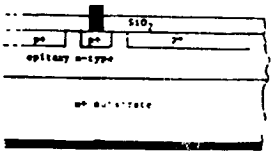


Fig. 1.6 FSC-LFE-SCT