

HIGH-EFFICIENCY DEVICE RESEARCH

N86-29370

HEAVY DOPING CONSIDERATIONS AND MEASUREMENTS
IN HIGH-EFFICIENCY CELLS

UNIVERSITY OF FLORIDA

ORIGINAL PAGE IS
OF POOR QUALITY

F. Lindholm

HEAVY DOPING CONSIDERATIONS AND
MEASUREMENTS IN HIGH-EFFICIENCY
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PARK, K. MISIAKOSPRESENTATION ORDER

- HD POLYSILICON-CONTACTED CELLS
measurement method (S, r)
- HD POLYSILICON (MECHANISMS)

- ASSESSMENT OF AUGER LIFETIME
- MINORITY-CARRIER MOBILITY
expt. trapping model
- IMPROVED ACCURACY FOR ΔE_G
implications for μ and D
- LOW DOPED MINORITY-CARRIER μ
implications for HD μ and S

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description: FIRST USE OF HD
($\sim 10^{20}/\text{cm}^3$) POLY AS PASSIVANT
FOR BACK SURFACE, REPLACING BSF
REGION.

rationale:

- LOWER TEMP. PROCESSING (675°C)
- NON-CRITICAL DEPOSITION PROCESS
- POST-DEPOSIT HEATING UNIMPORTANT
- DROPS S EVEN IF DOPING $> 10^{17}/\text{cm}^3$

samples:

- N- AND P-BASES (2 $\Omega\text{-cm}$): CZ Si
- $2 \times 2 \text{ cm}$; $210 \pm 10 \mu\text{m}$ except ONE
- RESULTS AVERAGED, 10 TO 20 CELLS
- ESC AND ESC CONTROLS

results:

- S AND RED RESPONSE ($\lambda > 0.6 \mu\text{m}$)
- $S = 100 \text{ cm/s}$ FOR n-BASE.
- S and RSR BETTER THAN ROC AND
BSF
- FIRST PROOF THAT Si:B POLY WORKS
- SUMMARIZED ON TABLE (VG)
- ESCD METHOD MEASURES S (VG)

publication: LINDHOLM,
DEUGROSCHER, ARIENZO, ILES, LETT
ELECTRON DEV. LETT, 6/85

TABLE 1

Summary of measured parameters at 28° C, (no AR coating). The cells have area $A = 4 \text{ cm}^2$ and thickness of about $210 \pm 10 \mu\text{m}$ except for cell 2N which was $330 \mu\text{m}$ thick. The results are the average values from 10-20 cells.

Cell	Base type	back contact	V_{oc} (mV)	$I_{SCR}(\lambda > 0.6 \mu\text{m})$ (mA)	L (μm)	S (cm/s)
1P	p	ohmic	573	63	310-350	
2P	p	BSF	574	64	310-350	$4.2 \times 10^4 - 5 \times 10^4$
5P	p	poly-Si BSF	583	67.7	310-350	1100-1500

1N	n	ohmic	566	62.7	190-250	
2N	n	BSF	565	65.2	190-250	700-1000
5N	n	poly-Si BSF	591	65.5	190-250	100-160

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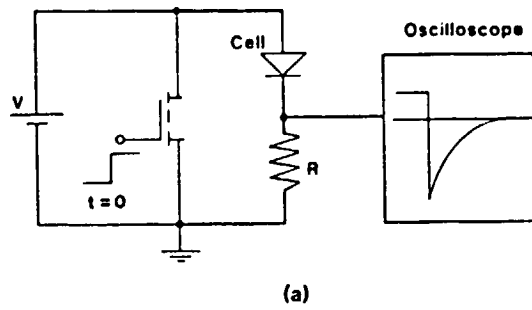


Fig. 4(a) Electronic circuit used in the SCCD method. The switching time of the power MOSFET is less than 100 nsec.

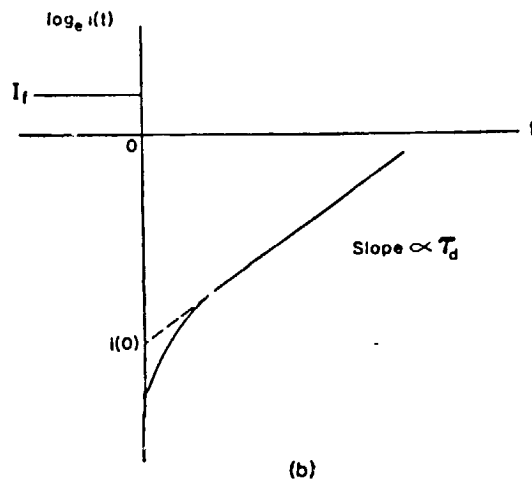


Fig. 4(b) Schematic illustration of the current decay displayed on a log scale.

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FUTURE & ONGOING: HD POLY CONTACT

1. ONE ADDITIONAL RUN COMPLETED.
 - P-BASE, $\rho=0.15\Omega\text{cm}$, FZ Si, 8 mil.
 - L (expected) $\approx 300\mu\text{m}$, L (got) $= 125\mu\text{m}$
 - PROCESS NOT UNDER CONTROL
 - SLIGHT IMPROVEMENTS (I, V, RSR)
 - rationale: SHOW BSF ACTION FOR $\rho=0.15\Omega\text{cm}$

2. PRESENT RUN
 - P-BASE, $\rho=0.30\Omega\text{cm}$, FZ, 14 mils.
 - POLY UNDER GRID LINES
 - rationale: REPLACES TUNNEL OXIDE IDEA. AREAL INHOMOGENEITY \downarrow V_{OC} \uparrow

3. NEAR FUTURE RUNS
 - USE THIN ($\approx 150\mu\text{m}$) BASES OF $\rho \approx 0.10\Omega\text{cm}$... CONTACT BACK BY HD POLY... INTERLEAVE FRONT WITH OXIDE AND POLY/METAL CONTACT.

4. PREDICTIONS OF MAX η
 - IF USE ABOVE SCHEME, AND ASSUME RADIATIVE AND AUGER PROCESSES CONTROL τ , $\eta \approx 23\%$... SAH, TR JPL-056289-84-1... RESULTS BASED ON NUMBERS FOR S IN VU GRAPHS TO FOLLOW.

HD POLY (MECHANISMS)

description:

SPECIAL TEST STRUCTURES
CHEM. & STRUCT \leftrightarrow ELECTRICAL
DETERMINE S AT INTERFACE
HD POLY IS Si:As
NO INTERFACIAL OXIDE
CVD POLY AT 670°C

results: 2 MECHANISMS

- 1) LOW μ INTERFACE REGION $\sim 100\text{\AA}$
 - D_p (interface) $\sim 0.005 \text{ cm}^2/\text{s}$
 - L_p (interface) $\sim 100\text{\AA}$
 - $C(\text{As})_{\text{max}}$ (interf) $\sim 10^{21}/\text{cc}$
 - Grain size $< 40\text{\AA}$ or amorph.
- 2) LOW-HI JCT IF $N(\text{low}) < 10^{18}/\text{cc}$

IF $N \sim 10^{18}/\text{cc}$, $S \leq 15 \text{ cm/s}$

IF $N > 10^{18}/\text{cc} \leq N(\text{EFF})$, $S \leq 1000 \text{ cm/s}$

implications: HD POLY CAN CUT
RECOMBINATION LOSS AT BOTH FRONT
AND BACK SURFACES

publication: A. Neugroschel, et.
al., IEEE Trans. Electron
Devices, 807-814, 4/85

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(11) POLY MECHANISMS: KEY IDEAS

PREVIOUS WORK ON POLY/N+.
HARD TO SEPARATE S AND τ .

HERE USE THIN (0.8 μ m) N-EPI.
LOW DOPING (10^{18} /cc) ON 0.06 Ω cm
P-TYPE SUBSTRATE.

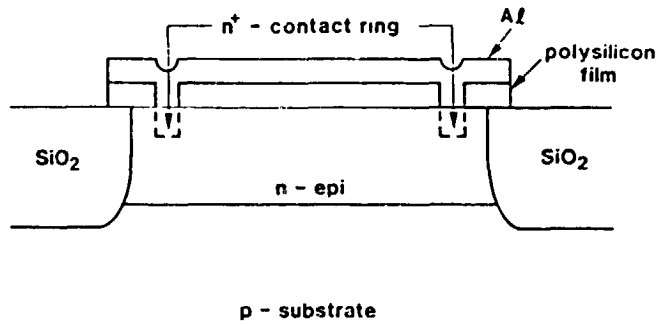
SAMPLES: METAL/POLY/N-EPI/P+
CONTROLS: METAL/N-EPI/P+

THICKNESS OF N-EPI VARIED.

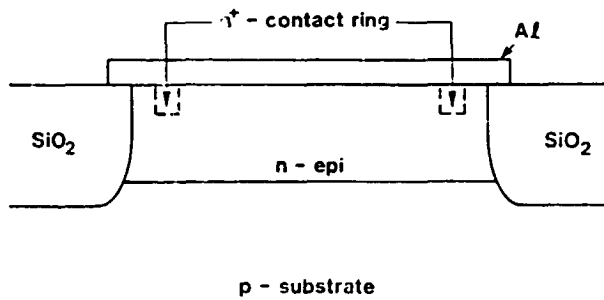
VARIOUS TYPES OF 1500A POLY
AND HEAT TREATMENTS STUDIED WITH
TEM AND SIMS TO REVEAL STRUCTURE
AND CHEMISTRY

ELECTRICAL MEASUREMENTS VS. T
AND V TO SEPARATE THE CURRENT
COMPONENTS.

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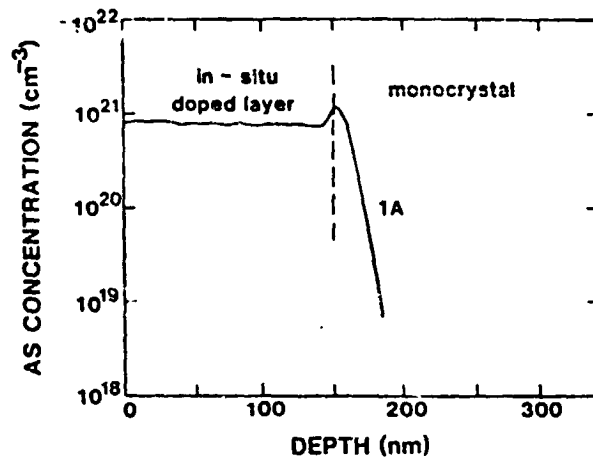


(a)

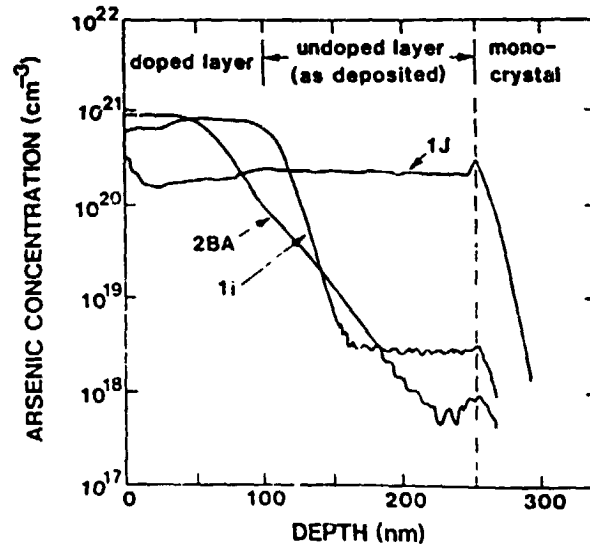


(b)

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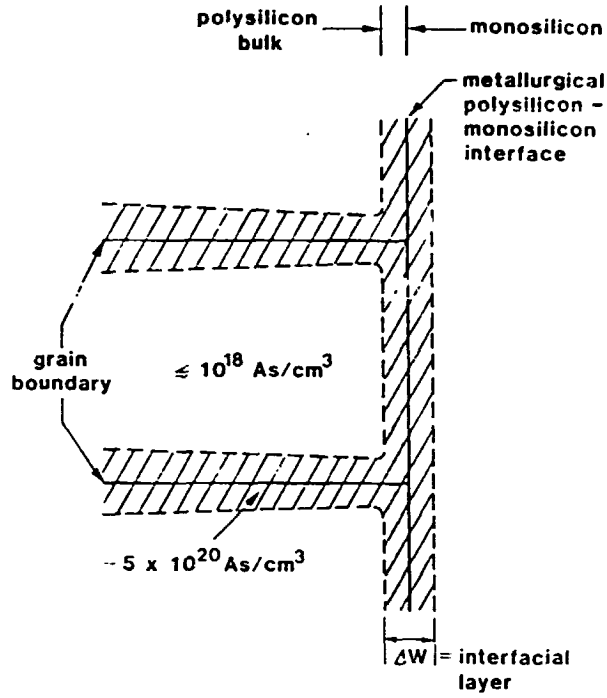


(a)



(b)

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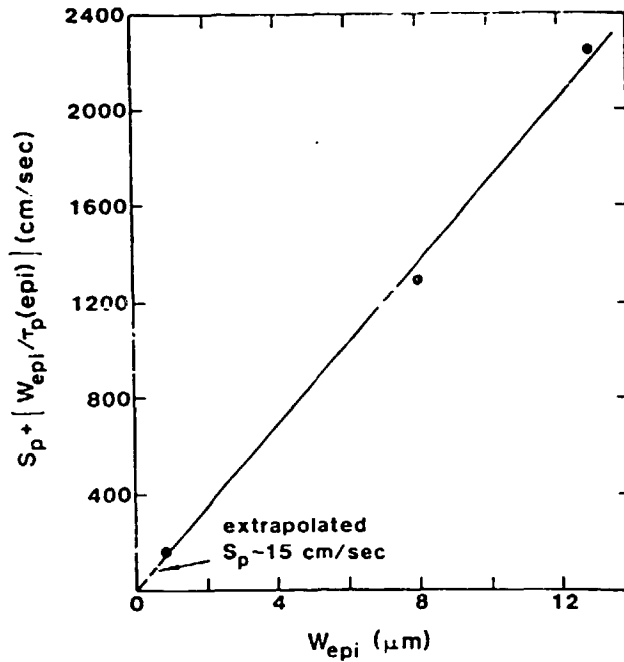


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TABLE I

Summary of heat treatments and electrical measurements. Heat treatments for polysilicon contacts were performed in argon. Electrical measurements were done at 25°C.

CONTACT	DEVICE	HEAT TREATMENT	J_{po} ($10^{-13}A/cm^2$)	S_{pmax} (cm/sec)
Undoped	1E	none	$(5.8 \pm 0.4) \times 10^3$	$\sim 10^6$
Polysilicon (1500 Å)	1F	800°C, 64 hrs	$(5.5 \pm 0.5) \times 10^3$	$\sim 10^6$
	1G	900°C, 5 min	$(5.5 \pm 0.5) \times 10^3$	$\sim 10^6$
In-situ	1A	none	7 ± 0.3	175
Doped	1B	800°C, 64 hrs	10 ± 1.5	250
Polysilicon (1500 Å)	1C	900°C, 5 min	6.6 ± 0.5	175
	1D	900°C, 15 min	6.5 ± 0.3	165
	2BE	1000°C, 15 min	6 ± 0.5	165
Bilayer:	1I	none	$(4.2 \pm 0.2) \times 10^3$	$\sim 10^6$
1500 Å undoped +	1J	800°C, 64 hrs	4.9 ± 0.6	175
1000 Å in-situ	1K	900°C, 15 min	$(4.2 \pm 0.2) \times 10^3$	$\sim 10^6$
doped	1L	850°C, 14 hrs	5.2 ± 0.6	180
	2BA	750°C, 8 hrs	$(4.0 \pm 0.3) \times 10^3$	$\sim 10^6$
Metal		450°C, 20 min	$(5 \pm 1) \times 10^3$	$\sim 10^6$
Reference				



• HD POLYSILICON-CONTACTED CELLS

• measurement method (S, τ)

• HD POLYSILICON (MECHANISMS)

• ASSESS AUGER τ (J. Appl. Phys)

• MINORITY-CARRIER MOBILITY

• expt: trap model (SOLAR CELLS)

• IMPROVED ACCURACY FOR ΔE_G

• if $10^{20}/\text{cc}$, $188 \rightarrow 169 \text{meV}$

• minority hole $\mu = 12$, $D = 0.3$

• HD DOPED MINORITY-CARRIER μ

• based on transit time

• Doping $\sim 10^{18}/\text{cc}$

• electron minority $\mu \approx \text{maj } \mu$

• hole minority $\mu = 1.3 \mu(\text{maj})$

• implications for HD μ and S

• IEEE Electron Dev Lett.

• FC DECAY FOR τ DETERMINATION

• if large defect density,

• (inferred) τ . Explained via

• multiple time constants for

• transient decay via bound

• states. (SOLAR CELLS).