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HEAVY DOPING CONSIDERATIONS AND MEASUREMENTS IN HIGH-EFFICIENCY CELLS

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HEAVY DOPING CONSIDERATIONS AND MEASUREMENTS IN HIGH-EFFICIENCY CELLS (UNIVERSITY OF FLORIDA)

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<u>PRESENTATION ORDER</u>

- HD POLYSILICON-CONTACTED CELLS
  - measurement method (S, τ)
- 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

description: FIRST USE OF HD ($\sim 10^{20}/cm^3$) 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$>10^{17}/cm^3$

samples:
- N- AND P-BASES (2 Ω-cm): CZ Si
- 2x2 cm: 210±10μm except ONE
- RESULTS AVERAGED, 10 TO 20 CELLS
- ROC AND BSF CONTROLS

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

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

TABLE 1

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

Cell	Base type	Back contact	V_{OC} (mV)	$I_{SCR}(\lambda>0.6\mu m)$ (mA)	L (μm)	S (cm/s)
1P	p	ohmic	573	63	310-350	
2P	p	BSF	574	64	310-350	4.2×10^4-5×10^4
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

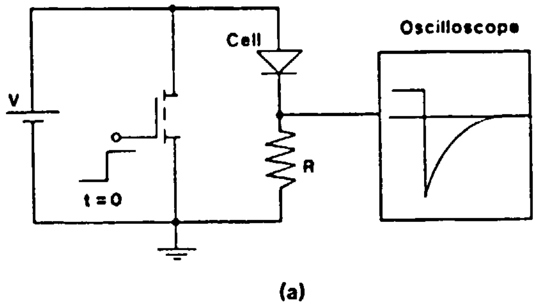


Fig. 4(a) Electronic circuit used in the SCCD method. The switching time of the power MOSFET is less than 100 nsec.

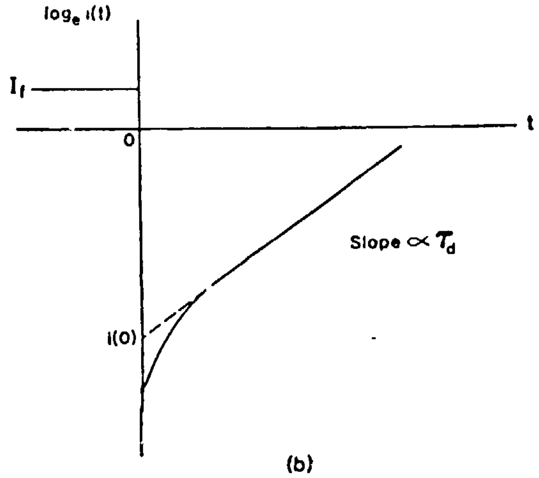


Fig. 4(b) Schematic illustration of the current decay displayed on a log scale.

FUTURE & ONGOING: HD POLY CONTACT

1. ONE ADDITIONAL RUN COMPLETED.
- P-BASE, ρ=0.15Ωcm, FZ Si, 8 mil.
- L(expected) >300μm, L(got)=125μm
PROCESS NOT UNDER CONTROL
- SLIGHT IMPROVEMENTS (I,V,RSR)
rationale: SHOW BSF ACTION FOR
ρ=0.15Ωcm

2. PRESENT RUN
- P-BASE, ρ=0.3Ωcm, FZ, 14 mils.
- POLY UNDER GRID LINES
rationale: REPLACES TUNNEL OXIDE
IDEA. AREAL INHOMOGENEITY ↓ ∴
$V_{OC}\uparrow$

3. NEAR FUTURE RUNS
USE THIN (<150μm) BASES OF
ρ~0.1Ωcm...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↔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~100Å
- D_p(interface) ~ 0.005 cm^2/s
- L_p(interface ~ 100Å
- C(As)max (interf) ~ 10^{21}/cc
- Grain size < 40Å or amorph.

2) LOW-HI JCT IF N(low)<10^{18}/cc

IF N~10^{16}/cc, S≤15 cm/s
IF N>10^{18}/cc≤N(EFF),S≤1000 cm/s

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

publication: A. Neugroschel, et.
al, IEEE Trans. Electron
Devices, 807-816,4/85

(4) POLY MECHANISMS: KEY IDEAS

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

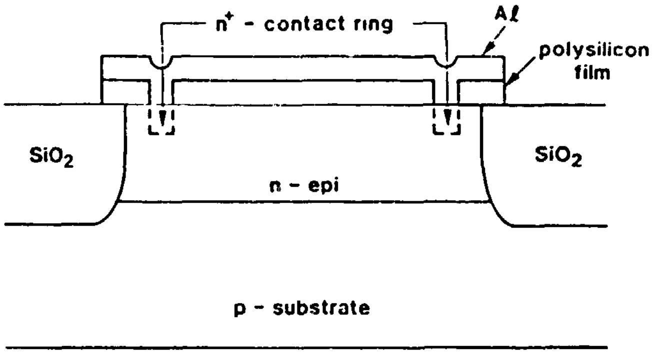
HERE USE THIN (0.8μm) N-EPI.
LOW DOPING (10^{14}/cc) ON 0.06 Ωcm
P-TYPE SUBSTRATE.

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

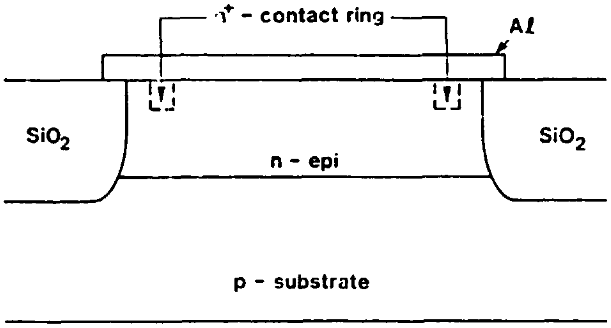
THICKNESS OF N-EPI VARIED.

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

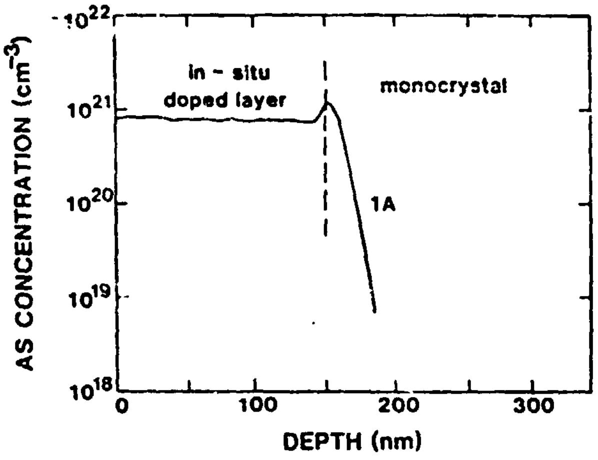
ELECTRICAL MEASUREMENTS VS. T
AND V TO SEPARATE THE CURRENT
COMPONENTS.


n+ - contact ring
Aℓ
polysilicon film
SiO2
SiO2
n - epi
p - substrate

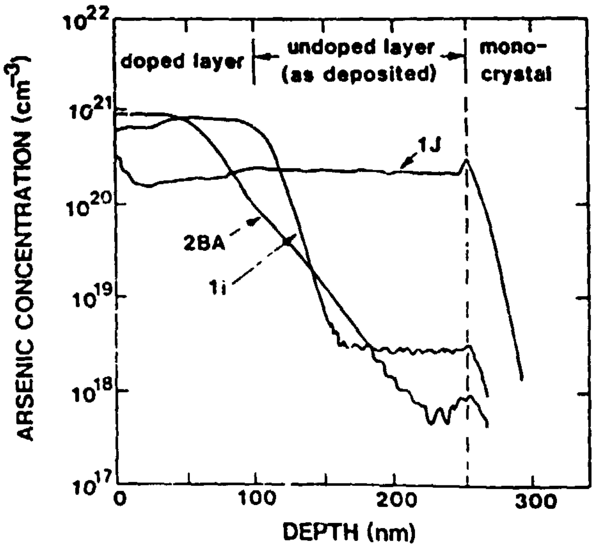
(a)


n+ - contact ring
Aℓ
SiO2
SiO2
n - epi
p - substrate

(b)


AS CONCENTRATION (cm^{-3})
10^{22}
10^{21}
10^{20}
10^{19}
10^{18}
in - situ doped layer
monocrystal
1A
0
100
200
300
DEPTH (nm)

(a)


ARSENIC CONCENTRATION (cm^{-3})
10^{22}
10^{21}
10^{20}
10^{19}
10^{18}
10^{17}
doped layer
undoped layer (as deposited)
mono- crystal
1J
2BA
1i
0
100
200
300
DEPTH (nm)

(b)

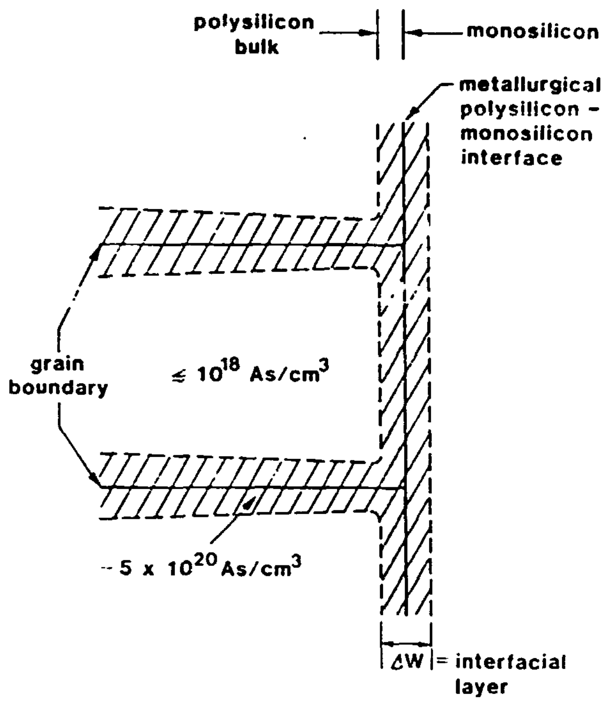
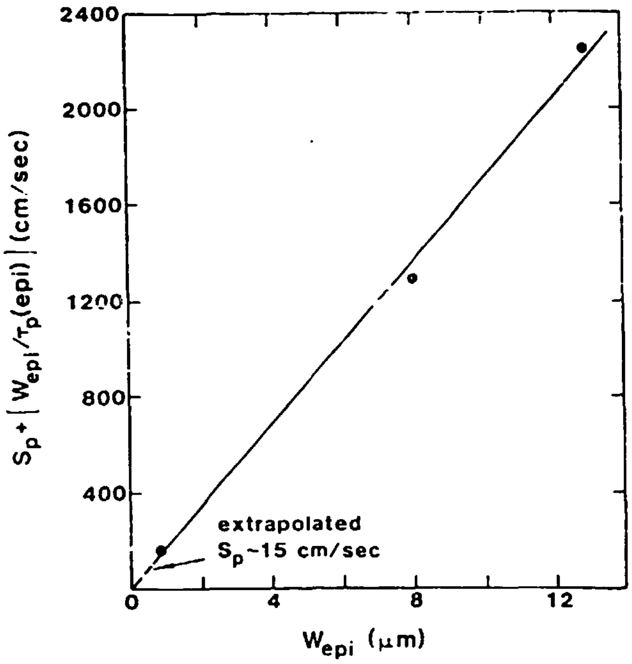

polysilicon bulk
monosilicon
metallurgical polysilicon - monosilicon interface
grain boundary
≤ 10^18 As/cm^3
~5 x 10^20 As/cm^3
ΔW = interfacial layer

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 Polysilicon (1500 Å)	1E	none	$(5.8 \pm 0.4) \times 10^3$	$\sim 10^6$
	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 Doped Polysilicon (1500 Å)	1A	none	7 ± 0.3	175
	1B	800°C, 64 hrs	10 ± 1.5	250
	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: 1500 Å undoped + 1000 Å in-situ doped	1I	none	$(4.2 \pm 0.2) \times 10^3$	$\sim 10^6$
	1J	800°C, 64 hrs	4.9 ± 0.6	175
	1K	900°C, 15 min	$(4.2 \pm 0.2) \times 10^3$	$\sim 10^6$
	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 Reference		450°C, 20 min	$(5 \pm 1) \times 10^3$	$\sim 10^6$



- 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}/cc, 188→169meV
  minority hole μ=12, D=0.3
- LD. DOPED MINORITY-CARRIER μ
  based on transit time
  Doping ~ 10^{19}/cc
  electron minority μ ≃ maj μ
  hole minority μ = 1.3 μ(maj)
  implications for HD μ and S
  IEEE Electron Dev Lett.
- PC DECAY FOR τ DETERMINATION
  If large defect density,
  τ(inferred) τ. Explained via
  multiple time constants for
  transient decay via bound
  states. (SOLAR CELLS).