PROCESSING

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RAPID THERMAL PROCESSING OF CZOCHRALSKI SILICON SUBSTRATES: DEFECTS, DENUDED ZONES, AND MINORITY CARRIER LIFETIME

NORTH CAROLINA STATE UNIVERSITY

G. S. Rozgonyi, D. K. Yang, Y. H. Cao, and Z. Radzimski

Rapid Thermal Processing of Czochralski Silicon: Objectives

To evaluate rapid thermal processing as a viable procedure for:

1. Czochralski substrate modification using high temperature defect-dissolution treatments,

2. Rapid junction activation following ion implantation

Diagnostic Tools

1. MOS Capacitor -- minority carrier lifetime

2. X-Ray Topography -- defect delineation

3. Nomarski Optical Microscopy & Preferential Chemical Etching -- defect delineation

4. Fourier Transform Infrared Microscopy -- oxygen precipitation kinetics

Metal Oxide Semiconductor Capacitor – C

1. Capacitance-voltage (C-V) measurements

2. Capacitance-time (C-t) measurements

3. C-V, C-t measurements at different temperatures T

4. Minority carrier generation and recombination lifetime (τ_g and τ_r)

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Change of Inversion Layer Charge Density with Time

$$\frac{dn_s}{dt} = \left(\underbrace{\frac{n_i (W - W_F)}{\tau_g} + n_i s}\right) + \left(\underbrace{\frac{n_i^2 D_n}{N_A L_n}}_{B}\right)$$

Room temperature   A » B   (Zerbst, 1966)

Elevated temperature A « B   (Schroder, 1984)

n_s - inversion layer charge density

W_F - final space charge region width

W - space charge width

n_i - intrinsic carrier density

D_n - diffusion constant

L_n - diffusion length

N_A - substrate doping concentration

τ_g - generation lifetime

s - surface recombination velocity

τ_r - recombination lifetime $(\tau_r = L_n^2/D_n)$

## Capacitance Versus Voltage (Sample Y2)

Cox= 340.278pF   Cfb= 327.203pF
Cmin/Cmax= .755   Cfb/Cox= .962   Qss= 2.272E+11ions/cm^2
Area= 7.58528E-03cm^2   Vfb(0)=-1.738Volts   Sample number = Y2
Nsub= 1.96658E+17cm^3   Vt= 4.374Volts

Cmin(inv.)= 256.967pF

Cmin(depl.)= 170.056pF

Wmax= .231Microns
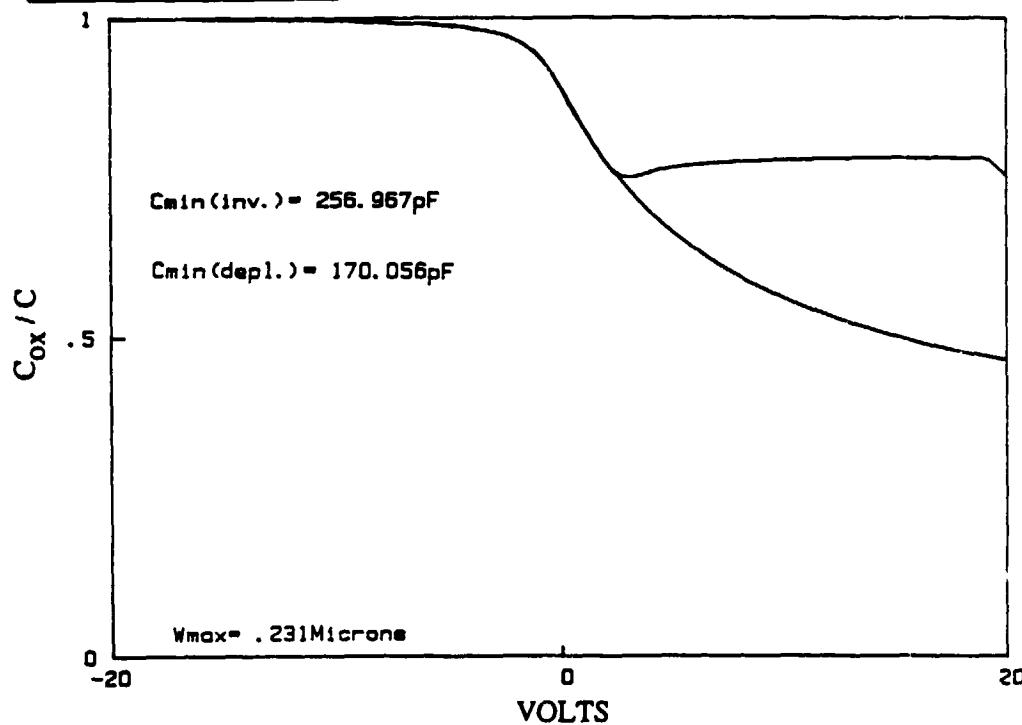
Capacitance Versus Voltage (Sample Z27)

Cox= 198.3pF   Cfb= 119.474pF
Cmin/Cmax= .187   Cfb/Cox= .602   Qss= 3.66E+10ions/cm^2
Area= .0044204cm^2   Vfb(0)=-.912Volts   Sample number = Z27
Neub= 7.213E+14cm^3   Vt=-.091Volts

Cmin(inv.)= 37.09pF

Cmin(depl.)= 4.862pF

C_{ox}/C

Wmax= 9.187Microns

VOLTS
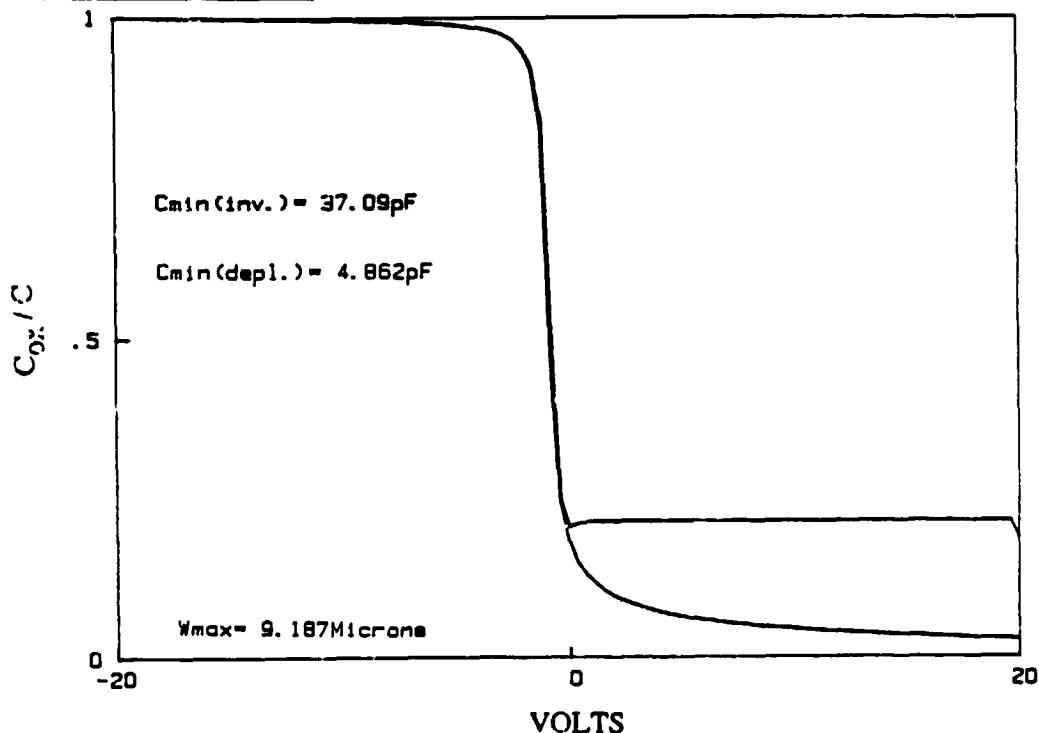
Zerbst Analysis (Room Temperature)
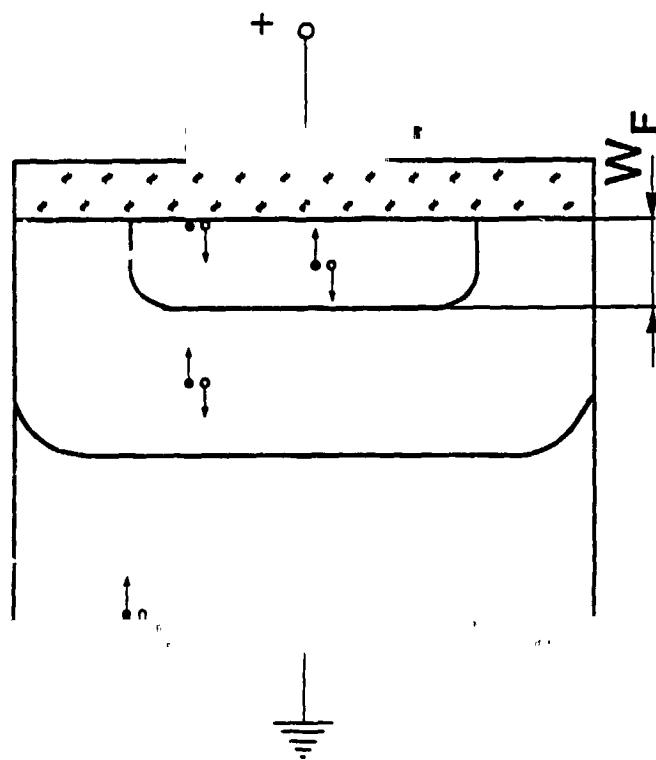

$$\frac{-d\,(C_{ox}/C)}{dt} \quad vs \quad \frac{C_F}{C-1}$$

$\tau_g \propto$ slope

$s \propto$ intercept

Schroder Analysis (Elevated Temperature)
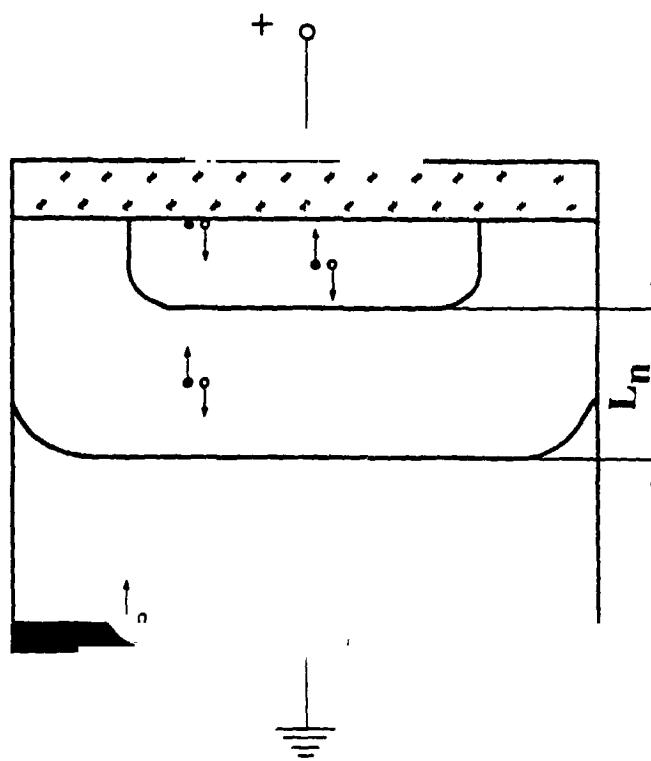
$$\tau_r \ \propto \ L_n^2$$

$$1 - (C_F / C)^2 \quad vs \quad time$$

$$L_n \ \propto \ slope$$

Capacitance Versus Time (Sample Z27)

Sample number - Z27
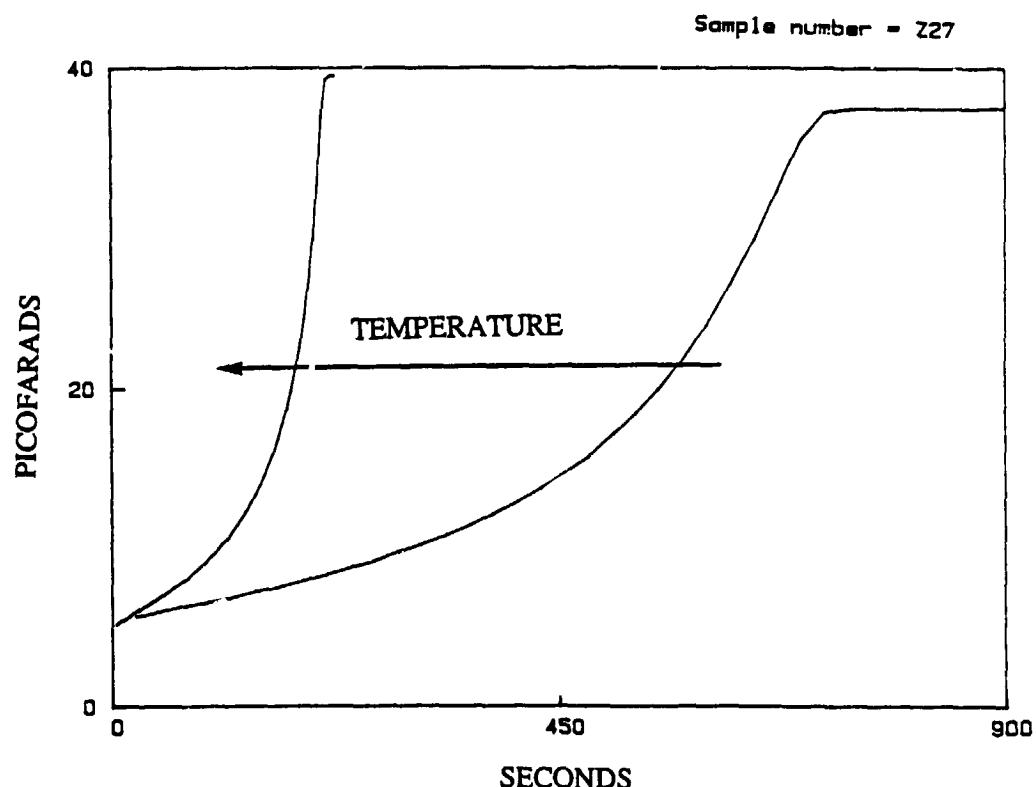
X-Ray Topography

1. X - Ray Source: Marconi-Elliot GX-21
   (15!.W, Rotating anode)

2. Cameras: - Lang Transmission
             - Double Crystal

3. Sample treatment conditions:
   i.   Virgin
   ii.   Lo-Hi + RTP combination
   iii. Li decoration

Surface Recombination Velocity/X-Ray Topography

MoK_α 220   X30

V: Virgin

A: $700^\circ C / 16h$ dry O_2 + 0.0425HCL

B: $1100^\circ C / 10$min dry O_2 + 60min wet O_2 + 10min dry O_2

V   B   A   A + B
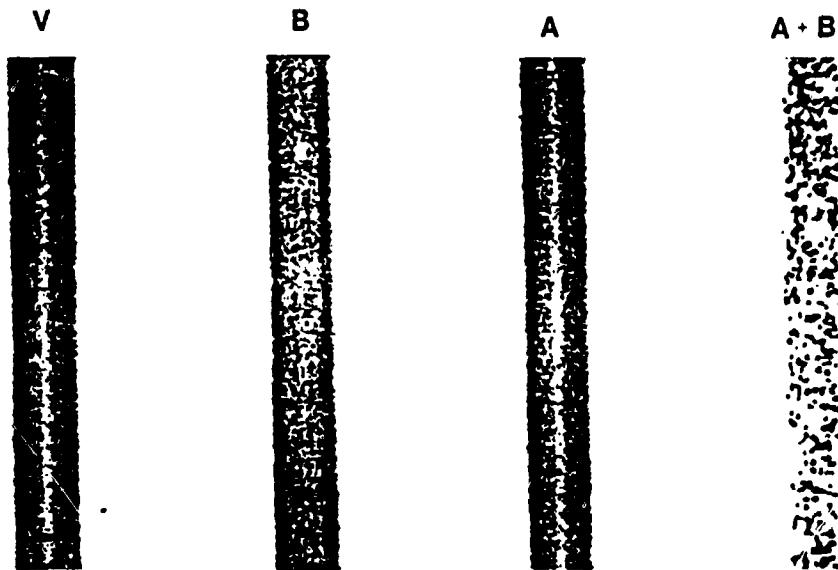
Nomarski Optical Microscopy and Preferential Chemical Etching

Etchant: Secco

Observation: 1. Depth of denuded zone (DZ)
2. Density and size of oxygen precipitates, stacking faults and dislocation.

P: $700^\circ C/16h$ dry $O_2+2\%$ HCl$+1100^\circ C/(10min$ dry$+65min$ wet$+10min)O_2+2\%$ HCl
$+1100^\circ C/15min$ dry $O_2+2\%$ HCl

V: Virgin

X: RTA $1200^\circ C/2$ min Ar

V + P

X + P
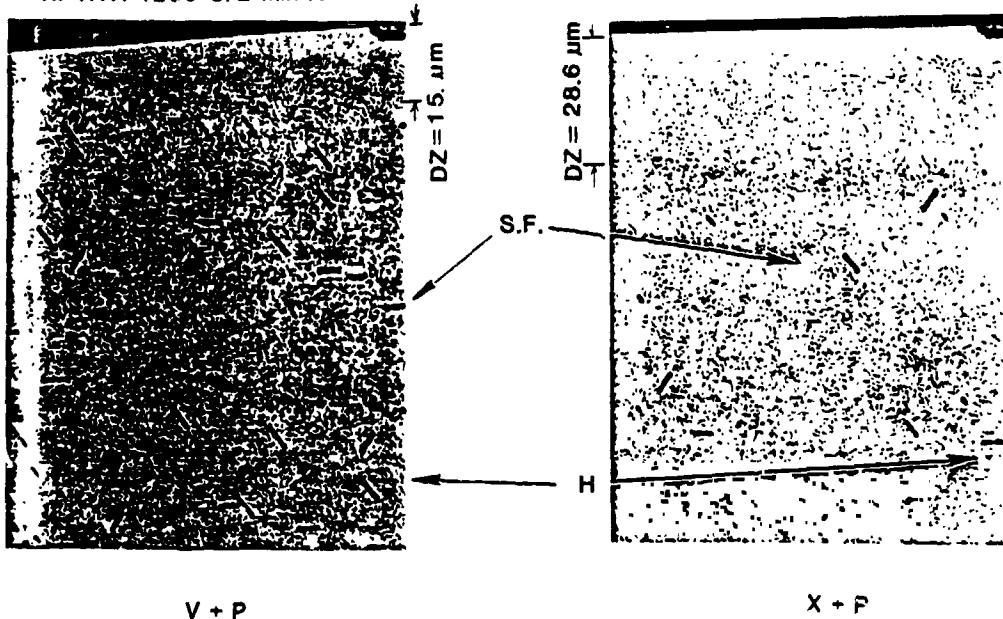
Minority Carrier Lifetime (Units in μs)

P, $18\Omega-cm$
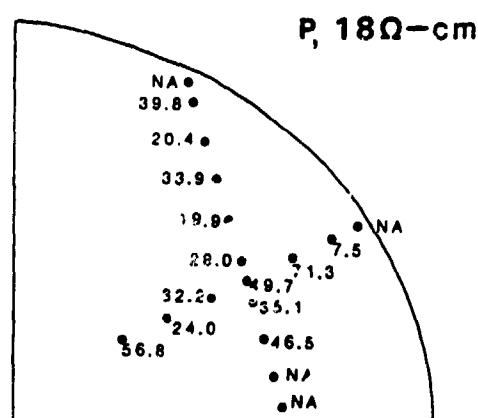
Heat Treatment

RTP(1200°C/2min) in Ar
+1100°C/(10min dry+65min wet+10min dry)O$_2$
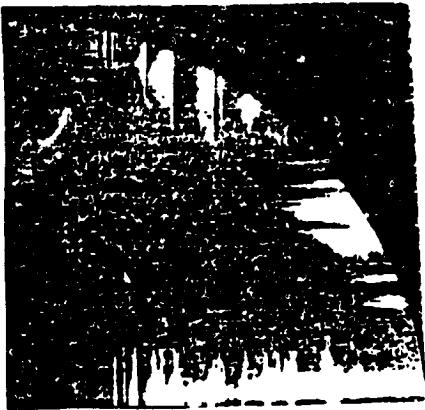
Heat Treatment of Samples

A : 700°C/16h dry O$_2$ + 2% HCl

B : 1100°C/(10 min dry+65 min wet+10 min dry)O$_2$ + 2% HCl

C : 1100°C/15 min dry O$_2$

V : Virgin
X : RTP 1200°C/2 min in Ar
Y : 1200°C/30 min in Ar
Z : 1250°C/30 min in dry O$_2$ + 2% HCl
w : 1250°C/30 min in Ar

Arrays of Heat Treatments

	C	A+C	B+C	A+B+C
V	V+C	V+A+C	V+B+C	V+A+B+C
X	X+C	X+A+C	X+B+C	X+A+B+C
Y	Y+C	Y+A+C	Y+B+C	Y+A+B+C
Z	Z+C	Z+A+C	Z+B+C	Z+A+B+C
W	W+C	W+A+C	W+B+C	W+A+B+C

Heat Treatment of Samples

A : $700^{\circ}C/16h$ dry O_2 + 2% HCl

B : $1100^{\circ}C/(10$ min dry+65 min wet+10 min dry$)O_2$ + 2% HCl

C : $1100^{\circ}C/15$ min dry O_2 + 2% HCl

V : Virgin
X : RTP $1200^{\circ}C/2$ min in Ar
Y : $1200^{\circ}C/30$ min in Ar   C
Z : $1250^{\circ}C/30$ min in dry O_2 A + C
    + 2% HCl   B + C
W: $1250^{\circ}C/30$ min in Ar   A + B + C

Minority Carrier Lifetime (τ_g, μs)

	V+C	X+C	X+A+B+C
Group Z1	111.0	15.6	83.8
Group Z2	57.5	85.7	159.0
	V+C	Z+C	Z+A+B+C