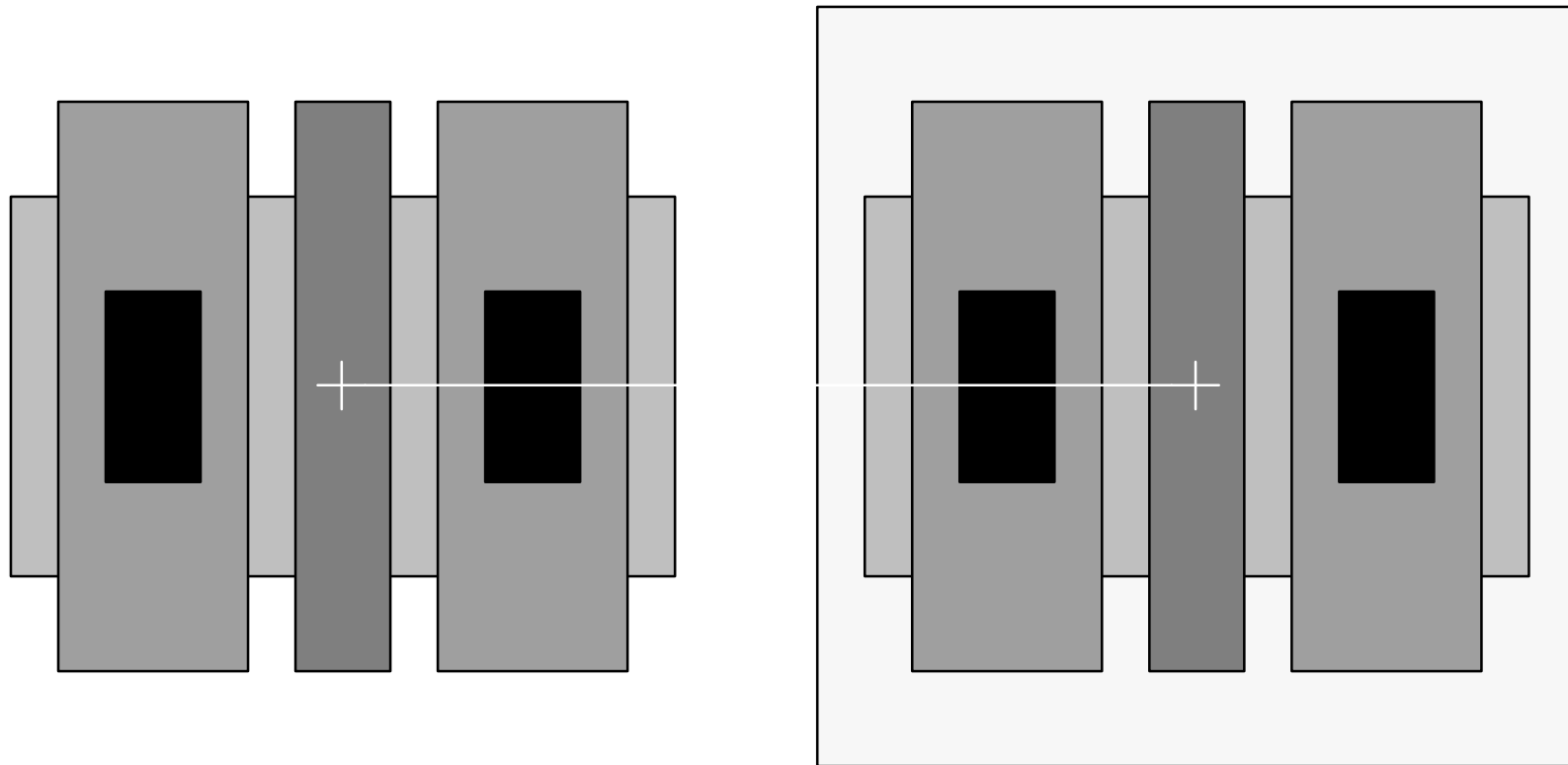
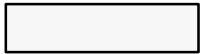






TCAD: Process and Device Simulation

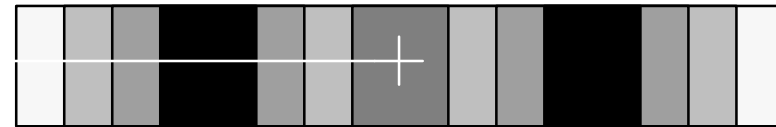
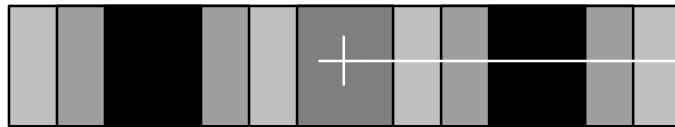
2- μm N-well CMOS Process Flow

Mask for the 2- μm N-well CMOS Process



<i>Pattern</i>					
	NWELL	ACTIVE	POLY1	METAL	CONTACT
<i>Field</i>	dark	clear	clear	clear	dark

1-D Cutline of the Mask



	<u>Mask</u>		<u>Field</u>	
NWELL	—————		dark	
ACTIVE	—————	—————	clear	
POLY1	—		—	clear
METAL	—————	—————	clear	
CONTACT	—————	—————	dark	

2- μ m N-well CMOS Process Steps

1. **Starting wafer**
2. **Initial oxidation**
3. **N-well photolithography**
4. **Oxide and photoresist etch**
5. **N-well implant oxidation**
6. **N-well implant**
7. **N-well drive-in**
8. **Oxide etch**
9. **Pad oxidation**
10. **Nitride deposition**
11. **Active photolithography**
12. **Plasma nitride etch**
13. **Field implant photolithography**
14. **Field implant**
15. **Photoresist removal**
16. **Field (LOCOS) oxidation**
17. **Nitride and pad oxide etch**
18. **Sacrificial oxidation**
19. **Threshold implant**
20. **Sacrificial oxide etch**
21. **Gate oxidation**
22. **Poly-Si deposition**
23. **Gate definition**
24. **Plasma polysilicon etch**
25. **N+ S/D photolithography**
26. **N+ S/D implant**
27. **Photoresist removal**
28. **N+ anneal**
29. **P+ S/D photolithography**
30. **P+ S/D implant**
31. **Photoresist removal**
32. **PSG deposition and densification**
33. **Contact photolithography**
34. **Contact etch**
35. **Metallization**
36. **Metal photolithography**
37. **Metal etch**
38. **Truncate/reflect Nmos**

2- μm CMOS Process Flow

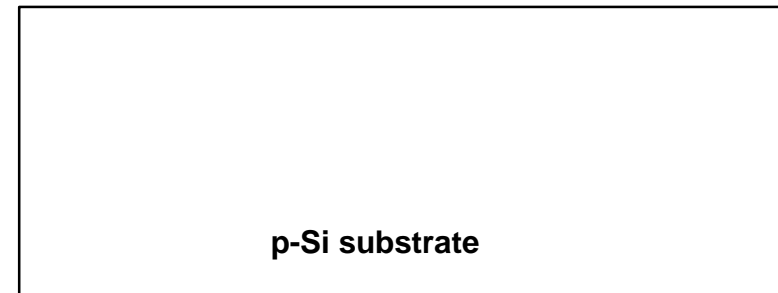
Process step

1. *Starting wafer:*

<100>

B-doped, 10 $\Omega\text{-cm}$

Cross-sectional view



2. *Initial oxidation:*

25 min., 750 \rightarrow 1000 $^{\circ}\text{C}$, $\text{N}_2=3$ SLM, $\text{O}_2=50$ SCCM

5 min., 1000 $^{\circ}\text{C}$, dry $\text{O}_2=3$ SLM

50 min., 1000 $^{\circ}\text{C}$, steam $\text{H}_2=3$ SLM, $\text{O}_2=1.7$ SLM

5 min., 1000 $^{\circ}\text{C}$, dry $\text{O}_2=3$ SLM

25 min., 1000 \rightarrow 750 $^{\circ}\text{C}$, dry $\text{N}_2=3$ SLM

Target: $t_{ox} = 3800 \text{ \AA}$



2- μm CMOS Process Flow (Cont'd)

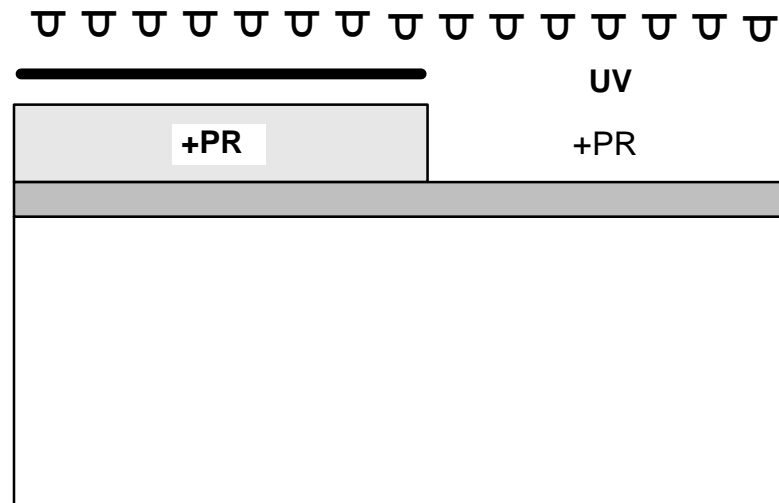
Process step

Cross-sectional view

3. *N-well photolithography:*

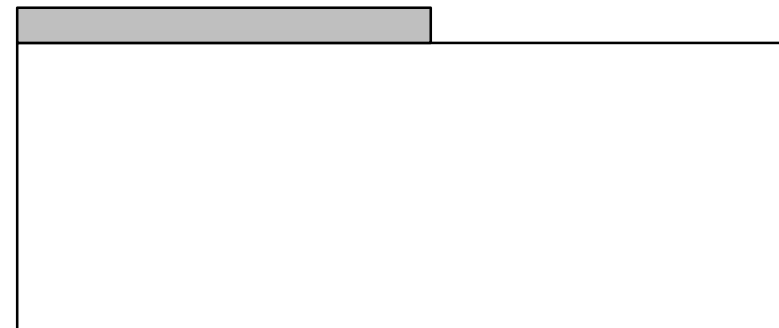
Mask: NWELL

Deposit positive photoresist (+PR)
Masking
Exposure
Development



4. *Oxide and photoresist etch:*

Etch SiO_2
Strip all photoresist



2- μm CMOS Process Flow (Cont'd)

Process step

5. *N-well implant oxidation:*

20 min., 750 \rightarrow 1000 $^{\circ}\text{C}$, $\text{N}_2=3$ SLM, $\text{O}_2=50$ SCCM
5 min., 1000 $^{\circ}\text{C}$, dry $\text{O}_2=3$ SLM
8 min., 1000 $^{\circ}\text{C}$, steam, $\text{H}_2=3$ SLM, $\text{O}_2=1.7$ SLM
5 min., 1000 $^{\circ}\text{C}$, dry $\text{O}_2=3$ SLM
20 min., 1000 \rightarrow 750 $^{\circ}\text{C}$, dry $\text{N}_2=3$ SLM

Target: $t_{\text{ox}} = 1000 \text{ \AA}$

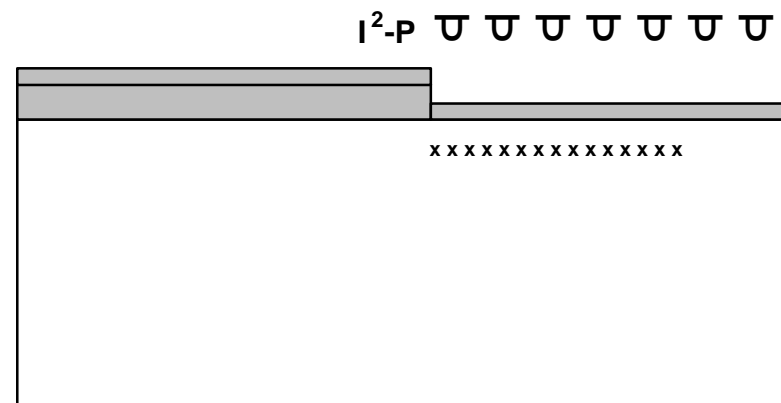
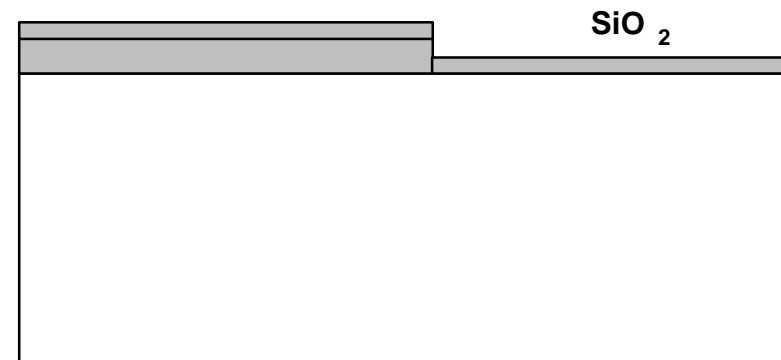
6. *N-well implant:*

Implant P

Dose: $5 \times 10^{12} \text{ cm}^{-2}$

Energy: 150 KeV

Cross-sectional view



2- μm CMOS Process Flow (Cont'd)

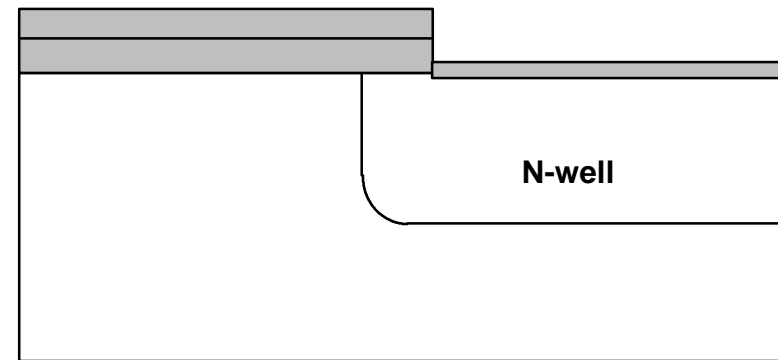
Process step

7. *N-well drive-in:*

60 min., 750 \rightarrow 1150 $^{\circ}\text{C}$, $\text{N}_2=3$ SLM, $\text{O}_2=50$ SCCM
260 min., 1150 $^{\circ}\text{C}$, $\text{N}_2=3$ SLM, $\text{O}_2=3.5$ SLM
60 min., 1150 $^{\circ}\text{C}$, dry $\text{N}_2=3$ SLM
60 min., 1150 \rightarrow 750 $^{\circ}\text{C}$, dry $\text{N}_2=3$ SLM

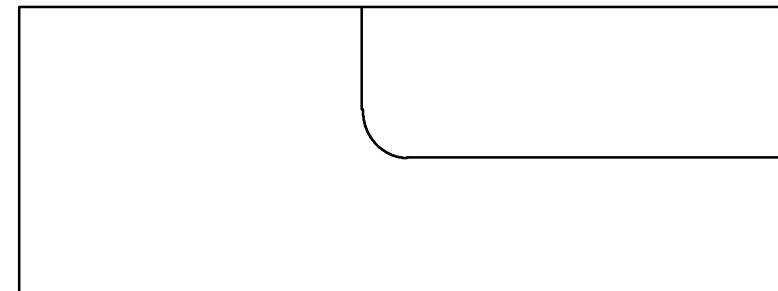
Target: $x_j = 3.4 \mu\text{m}$

Cross-sectional view



8. *Oxide etch:*

Strip all SiO_2



2- μm CMOS Process Flow (Cont'd)

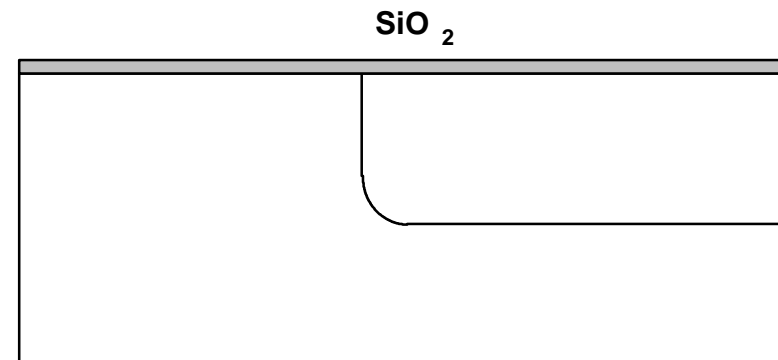
Process step

9. **Pad oxidation:**

20 min., 750 \rightarrow 950 $^{\circ}\text{C}$, $\text{N}_2=3$ SLM, $\text{O}_2=50$ SCCM
60 min., 950 $^{\circ}\text{C}$, dry $\text{O}_2=3$ SLM
20 min., 950 \rightarrow 750 $^{\circ}\text{C}$, dry $\text{N}_2=3$ SLM

Target: $t_{\text{ox}} = 300 \text{ \AA}$ (*measure*)

Cross-sectional view

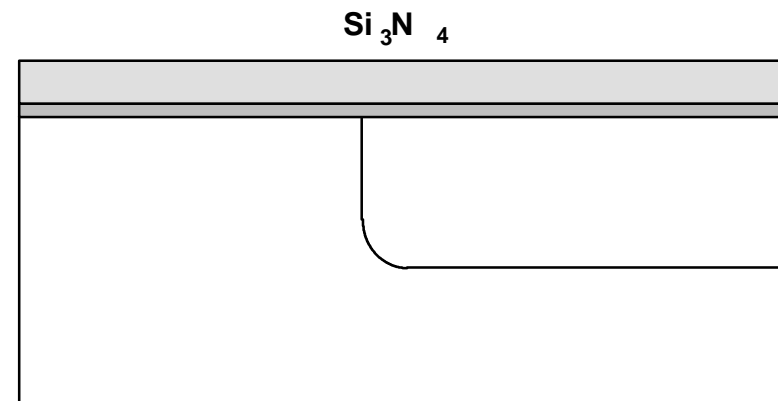


10. **Nitride deposition:**

Deposit Si_3N_4 : 1300 \AA

[Deposit Si_3N_4 : 1300 $\text{\AA} + \Delta t_{\text{SiN}}$]

($\Delta t_{\text{SiN}} = ?$ See: 13 – 15)



2- μm CMOS Process Flow (Cont'd)

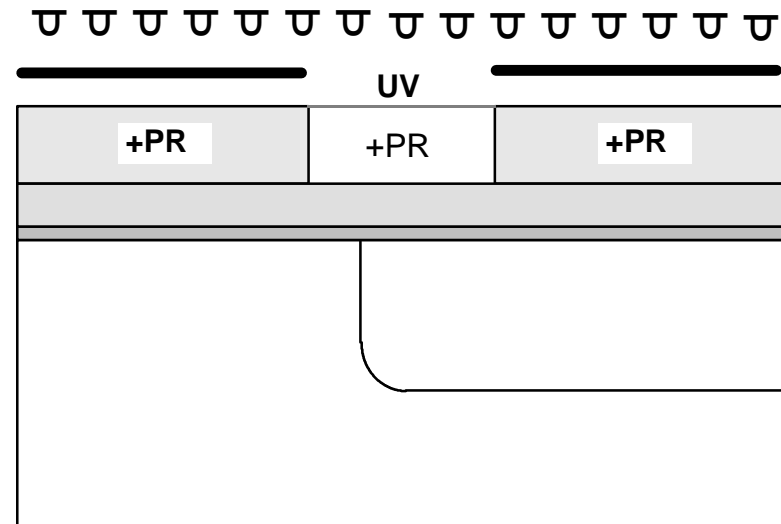
Process step

Cross-sectional view

11. *Active photolithography:*

Mask: ACTIVE

- Deposit positive photoresist
- Masking
- Exposure
- Development



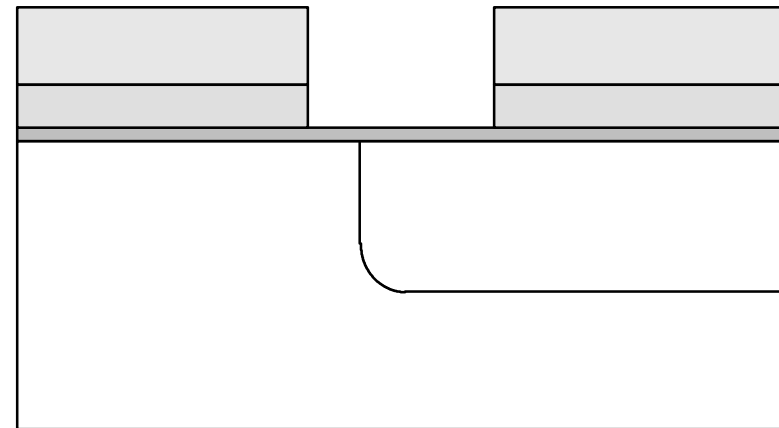
2- μm CMOS Process Flow (Cont'd)

Process step

Cross-sectional view

12. *Plasma nitride etch:*

Etch Si_3N_4



2- μm CMOS Process Flow (Cont'd)

Process step

Cross-sectional view

13. *Field implant photolithography:*

(Photoresist-on-photoresist process)

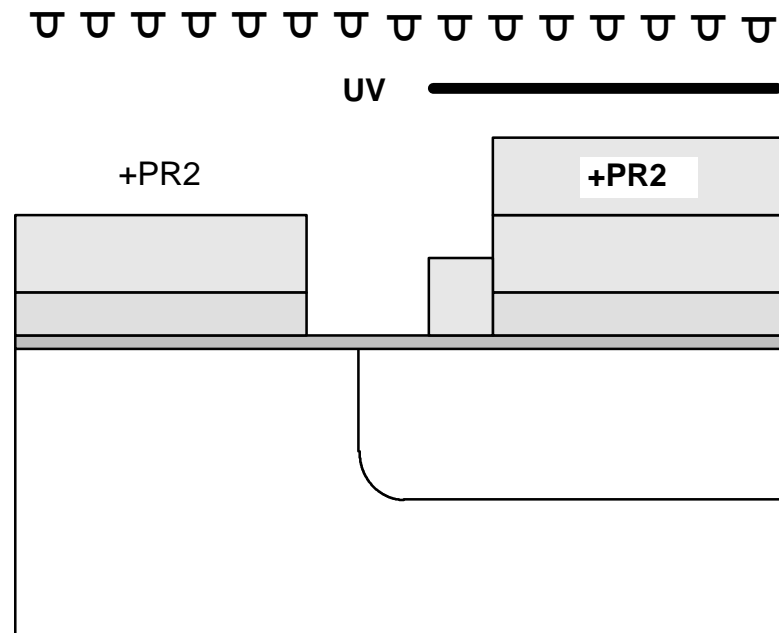
Mask: Reverse of N WELL

Deposit positive photoresist

Masking

Exposure

Development



2- μm CMOS Process Flow (Cont'd)

Process step

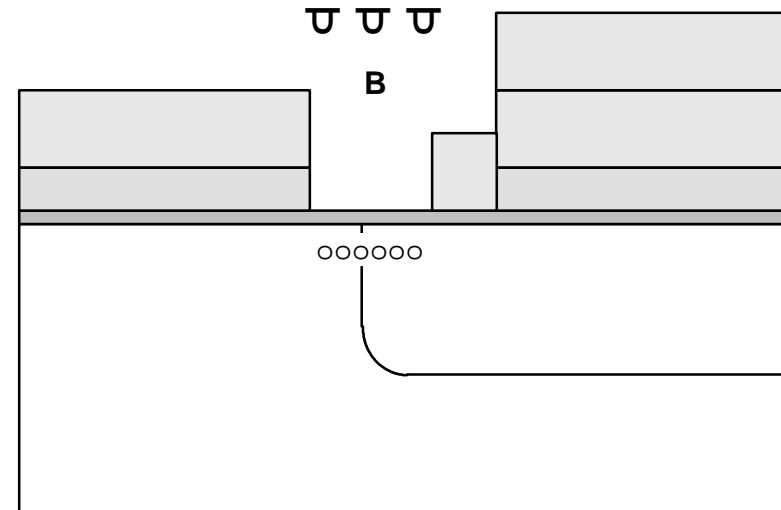
Cross-sectional view

14. *Field implant.*

Implant B

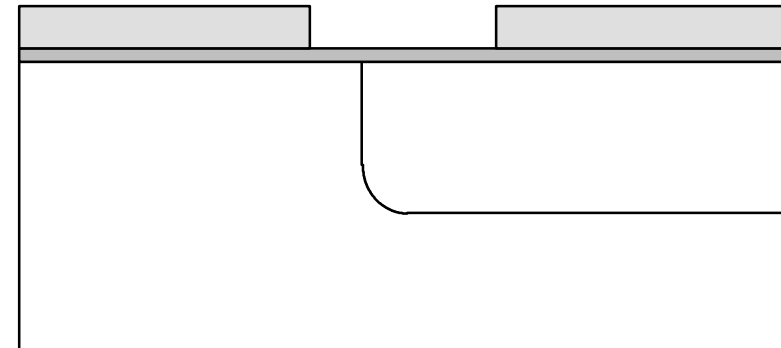
Dose: $1.5 \times 10^{13} \text{ cm}^{-2}$

Energy: 70 KeV



15. *Photoresist removal.*

Strip all photoresist



2- μm CMOS Process Flow (Cont'd)

Process step

Cross-sectional view

13 *Field implant photolithography:*

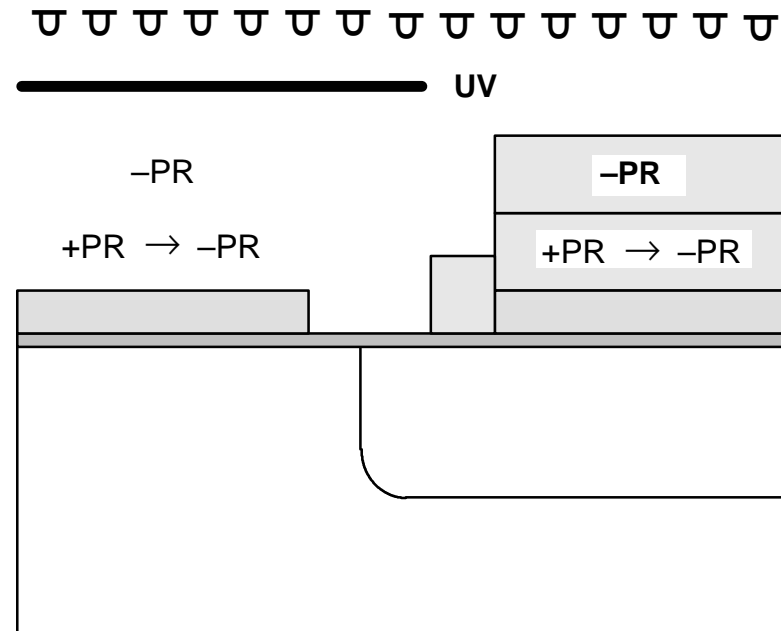
Mask: NWELL

Deposit *negative* photoresist

Masking

Exposure

Development



2- μm CMOS Process Flow (Cont'd)

Process step

14 *Field implant:*

Implant B

Dose: $1.5 \times 10^{13} \text{ cm}^{-2}$

Energy: 70 KeV

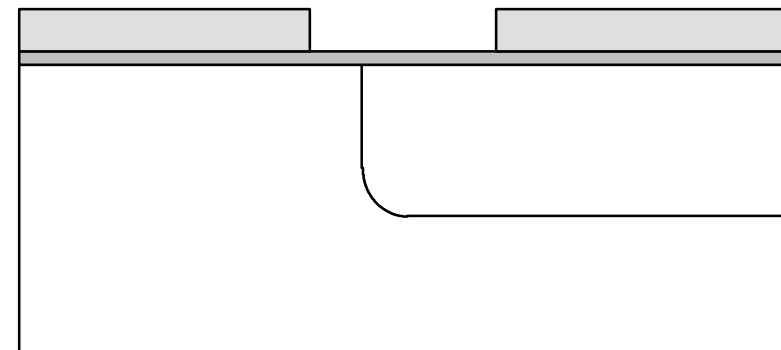
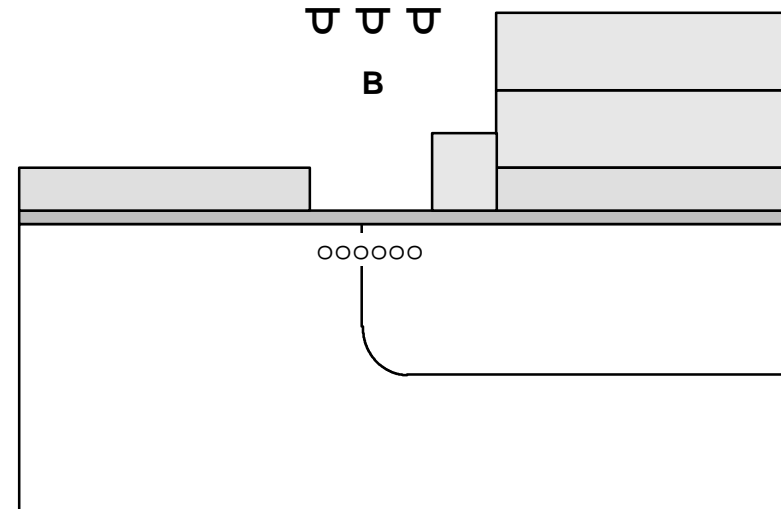
15 *Photoresist removal:*

Strip all photoresist

[Etch Si_3N_4 : Δt_{SiN}]

(Remaining $t_{\text{SiN}} = 1300 \text{ \AA}$)

Cross-sectional view



2- μm CMOS Process Flow (Cont'd)

Process step

16. *Field (LOCOS) oxidation:*

20 min., 750 \rightarrow 950 $^{\circ}\text{C}$, $\text{N}_2=3$ SLM, $\text{O}_2=50$ SCCM
5 min., 950 $^{\circ}\text{C}$, dry $\text{O}_2=3$ SLM
125 min., 1000 $^{\circ}\text{C}$, steam $\text{H}_2=3$ SLM, $\text{O}_2=1.7$ SLM
5 min., 950 $^{\circ}\text{C}$, dry $\text{O}_2=3$ SLM
20 min., 950 \rightarrow 750 $^{\circ}\text{C}$, dry $\text{N}_2=3$ SLM

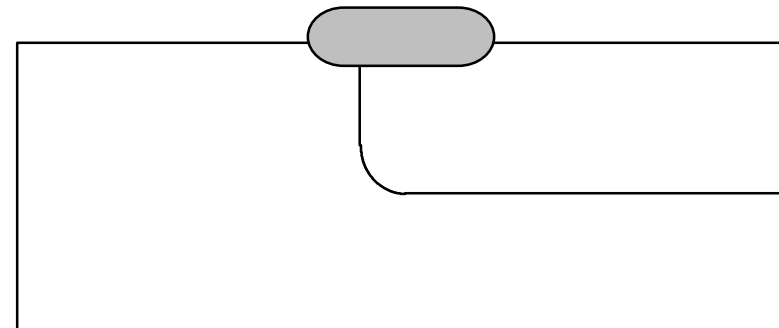
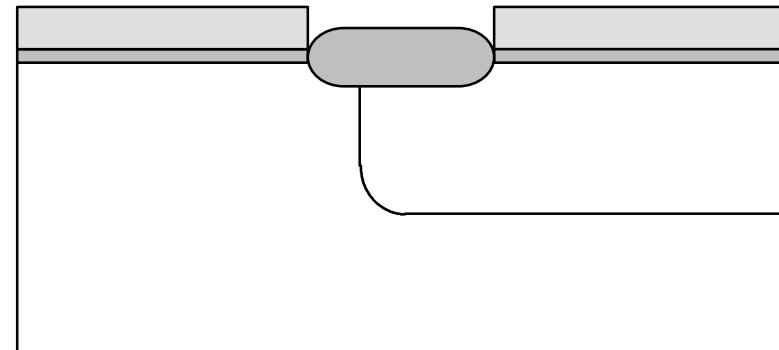
Target: $t_{\text{ox}} = 6500 \text{ \AA}$

17. *Nitride and pad oxide etch:*

Strip all Si_3N_4

Etch SiO_2 : $\sim 300 \text{ \AA}$ (?)

Cross-sectional view



2- μm CMOS Process Flow (Cont'd)

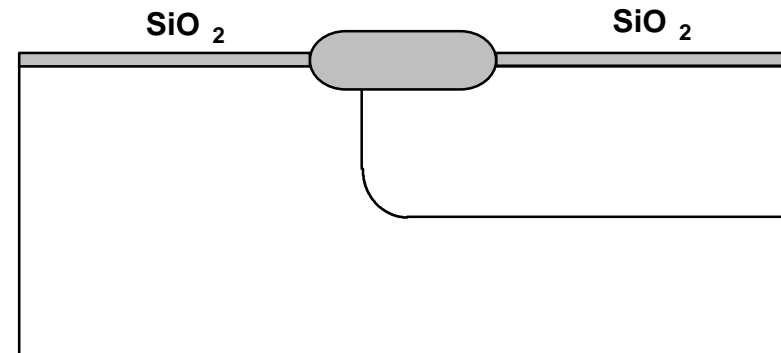
Process step

18. **Sacrificial oxidation:**

20 min., 750 \rightarrow 950 $^{\circ}\text{C}$, $\text{N}_2=3$ SLM, $\text{O}_2=50$ SCCM
30 min., 950 $^{\circ}\text{C}$, dry $\text{O}_2=3$ SLM
20 min., 950 \rightarrow 750 $^{\circ}\text{C}$, dry $\text{N}_2=3$ SLM

Target: $t_{ox} = 200 \text{ \AA}$ (*measure*)

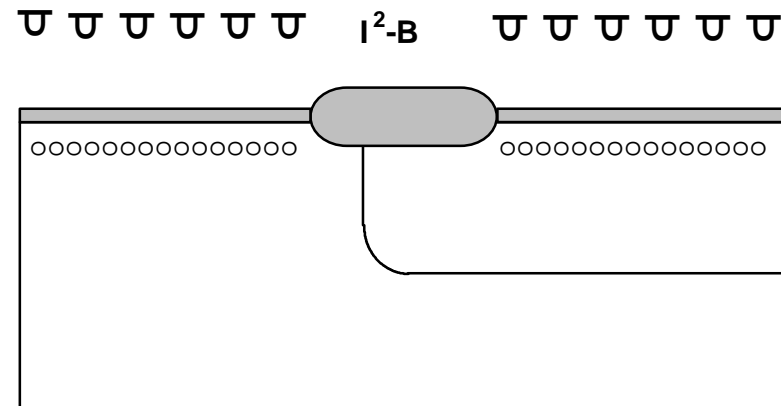
Cross-sectional view



19. **Threshold implant.**

Implant B

Dose: $2 \times 10^{12} \text{ cm}^{-2}$
Energy: 30 KeV



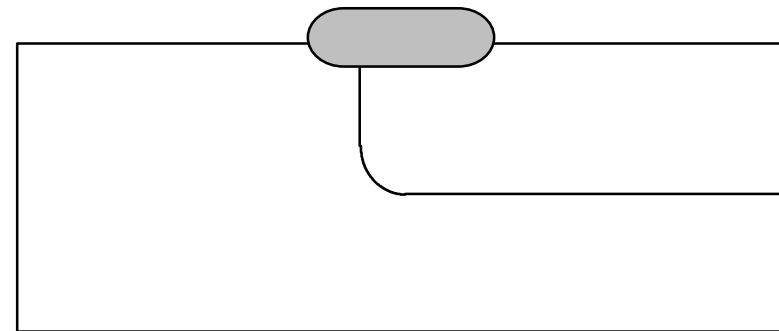
2- μm CMOS Process Flow (Cont'd)

Process step

20. *Sacrificial oxide etch:*

Etch SiO_2 : $\sim 200 \text{ \AA}$ (?)

Cross-sectional view



21. *Gate oxidation:*

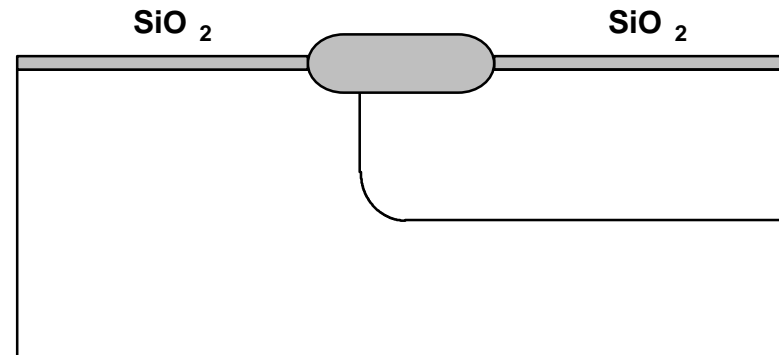
20 min., 750 \rightarrow 950 $^{\circ}\text{C}$, $\text{N}_2=3 \text{ SLM}$, $\text{O}_2=50 \text{ SCCM}$

60 min., 950 $^{\circ}\text{C}$, dry $\text{O}_2=3 \text{ SLM}$

20 min., 950 $^{\circ}\text{C}$, dry $\text{N}_2=3 \text{ SLM}$

20 min., 950 \rightarrow 750 $^{\circ}\text{C}$, dry $\text{N}_2=3 \text{ SLM}$

Target: $t_{\text{ox}} = 300 \text{ \AA}$



2- μm CMOS Process Flow (Cont'd)

Process step

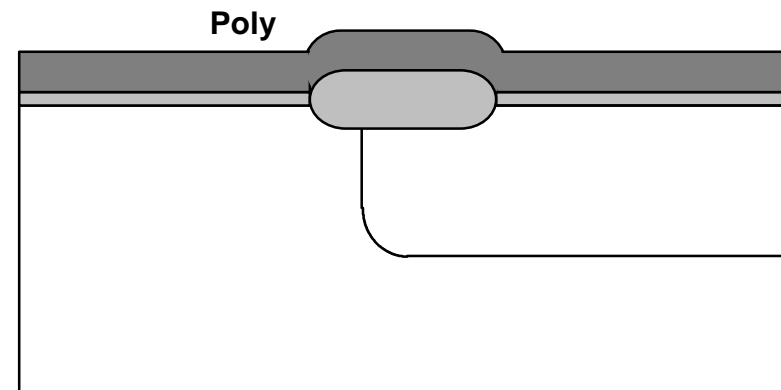
Cross-sectional view

22. *Poly-Si deposition:*

Deposit polysilicon: 4500 Å

P-doped: 10^{20} cm^{-3}

Temperature: 610 °C



2- μm CMOS Process Flow (Cont'd)

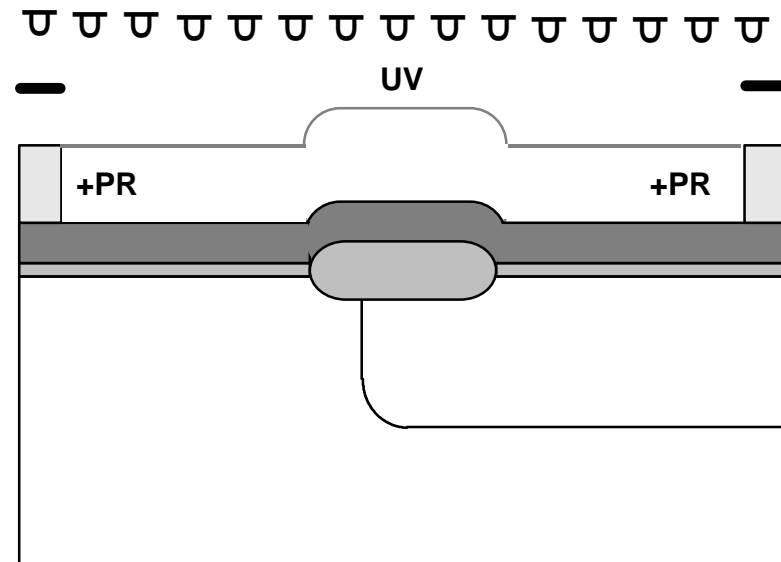
Process step

Cross-sectional view

23. **Gate definition:**

Mask: POLY1

- Deposit positive photoresist
- Masking
- Exposure
- Development



2- μm CMOS Process Flow (Cont'd)

Process step

24. *Plasma polysilicon etch:*

Etch poly-Si

Strip all photoresist

25. *N+ S/D photolithography:*

Mask: NWELL

Deposit *negative* photoresist

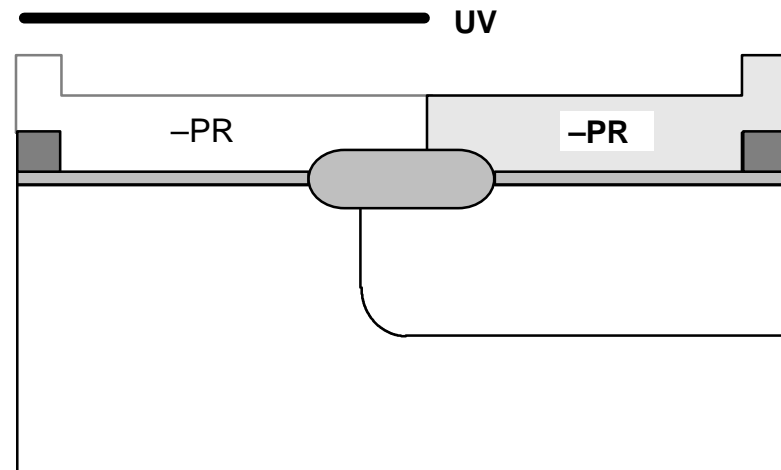
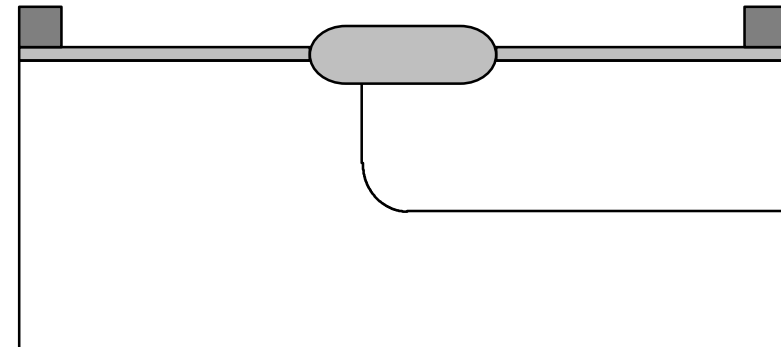
Masking

Exposure

Development

In practice, *positive* photoresist with reverse of NWELL mask, or a separate *N+ S/D* mask

Cross-sectional view



2- μm CMOS Process Flow (Cont'd)

Process step

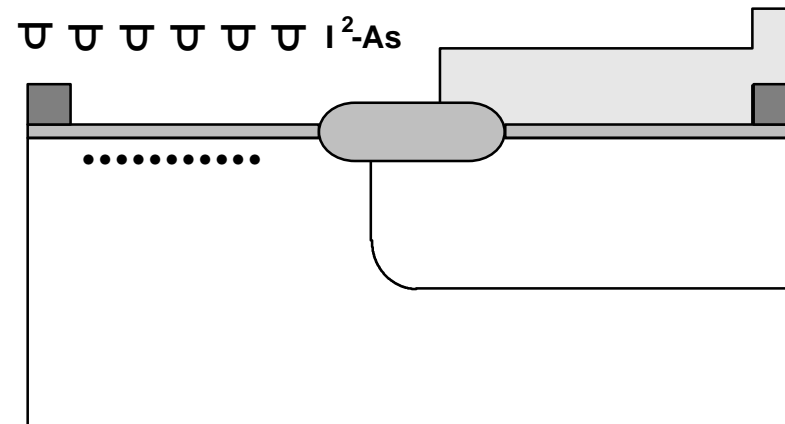
26. *N+ S/D implant.*

Implant As

Dose: $5 \times 10^{15} \text{ cm}^{-2}$

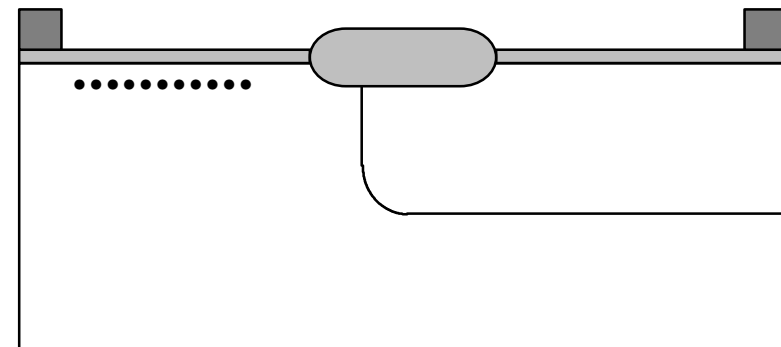
Energy: 130 KeV
(Gaussian)

Cross-sectional view



27. *Photoresist removal.*

Strip all photoresist



2- μm CMOS Process Flow (Cont'd)

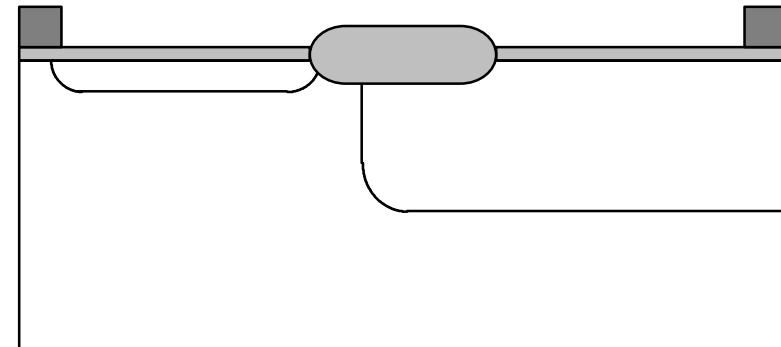
Process step

Cross-sectional view

28. *N+ anneal:*

20 min., 750 \rightarrow 950 $^{\circ}\text{C}$, $\text{N}_2=3$ SLM
60 min., 950 $^{\circ}\text{C}$, dry $\text{N}_2=3$ SLM
20 min., 950 \rightarrow 750 $^{\circ}\text{C}$, dry $\text{N}_2=3$ SLM

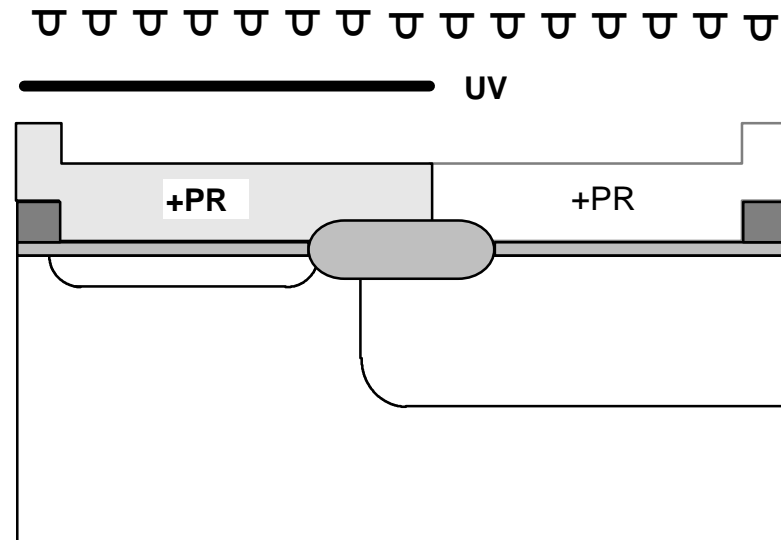
Target: $x_j = 0.35 \mu\text{m}$



29. *P+ S/D photolithography:*

Mask: NWELL

Deposit positive photoresist
Masking
Exposure
Development



2- μm CMOS Process Flow (Cont'd)

Process step

30. *P+ S/D implant.*

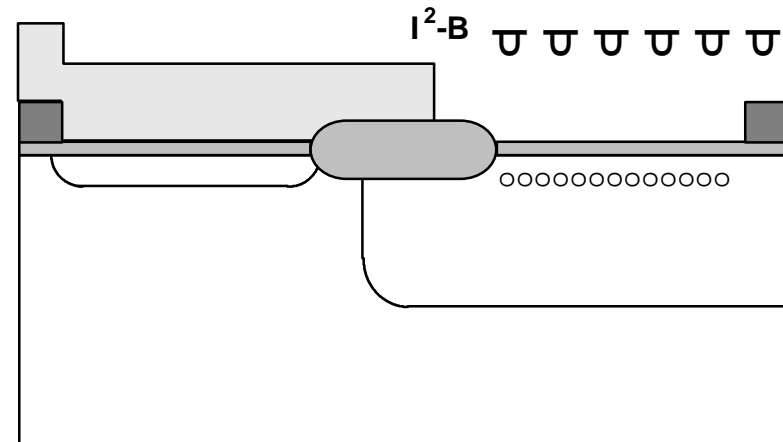
Implant B

Dose: $5 \times 10^{15} \text{ cm}^{-2}$

Energy: 40 KeV

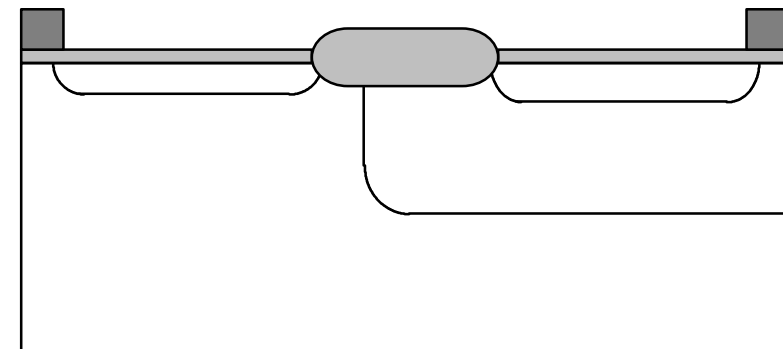
Target: $x_j = 0.55 \mu\text{m}$

Cross-sectional view



31. *Photoresist removal.*

Strip all photoresist



2- μm CMOS Process Flow (Cont'd)

Process step

Cross-sectional view

32. *PSG deposition and densification:*

Deposit SiO_2 : 7000 Å

P-doped: 10^{20} cm^{-3}

Densification:

10 min., 750→950 °C, $\text{N}_2=3$ SLM

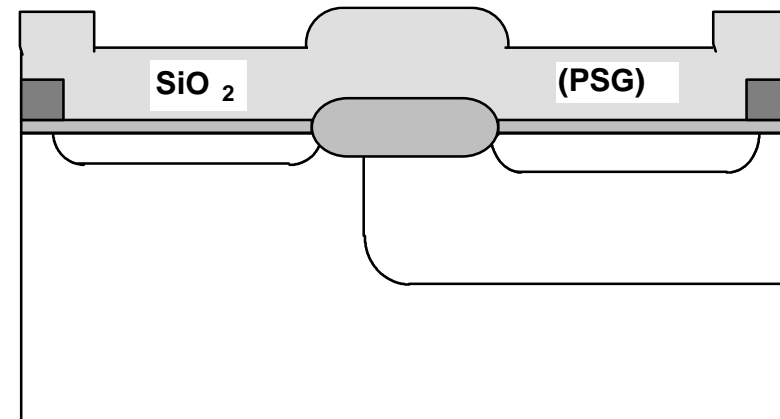
5 min., 950 °C, dry $\text{O}_2=3$ SLM

20 min., 950 °C, steam $\text{H}_2=3$ SLM, $\text{O}_2=1.7$ SLM

5 min., 950 °C, dry $\text{N}_2=3$ SLM

10 min., 950→750 °C, dry $\text{O}_2=3$ SLM

Target: $x_{jn} = 0.35 \mu\text{m}$ $x_{jp} = 0.6 \mu\text{m}$



2- μm CMOS Process Flow (Cont'd)

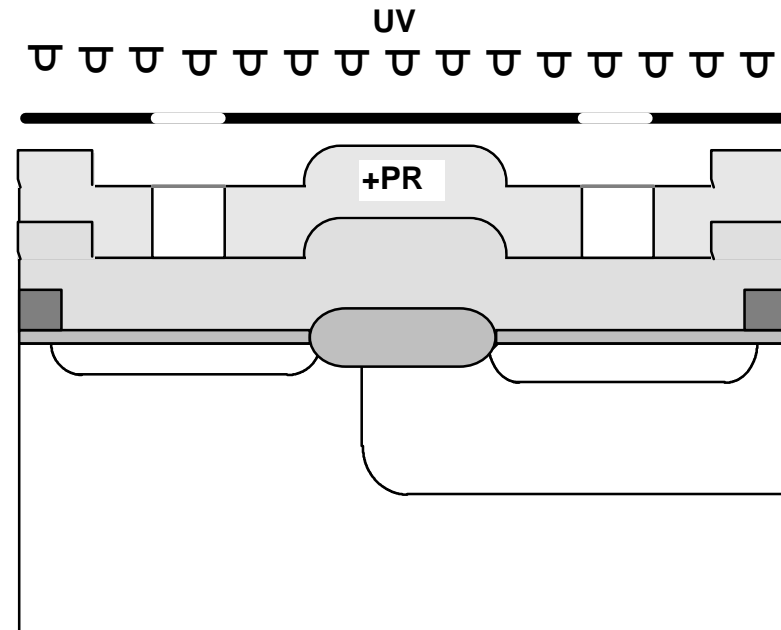
Process step

Cross-sectional view

33. **Contact photolithography:**

Mask: CONTACT

- Deposit positive photoresist
- Masking
- Exposure
- Development



2- μm CMOS Process Flow (Cont'd)

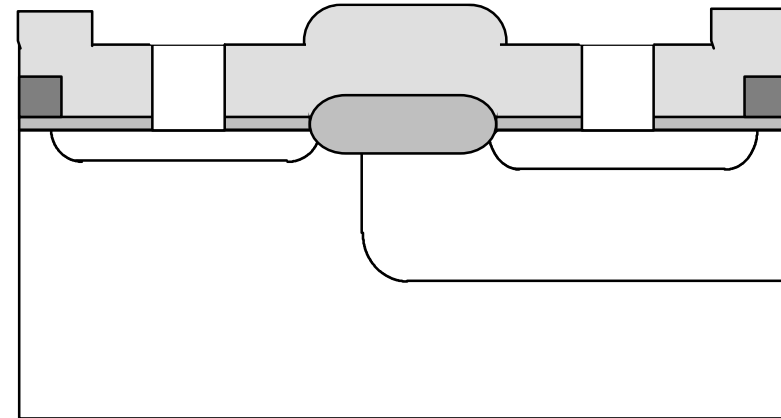
Process step

Cross-sectional view

34. **Contact etch:**

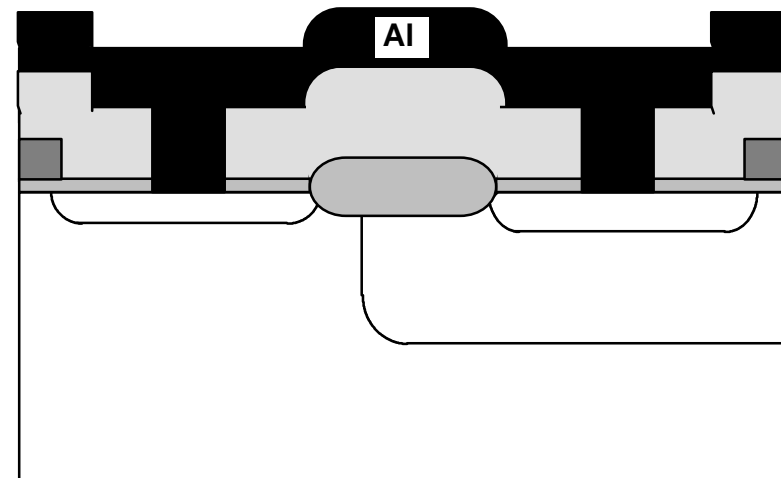
Etch SiO_2

Strip all photoresist



35. **Metallization:**

Deposit Al: 6000 Å



2- μm CMOS Process Flow (Cont'd)

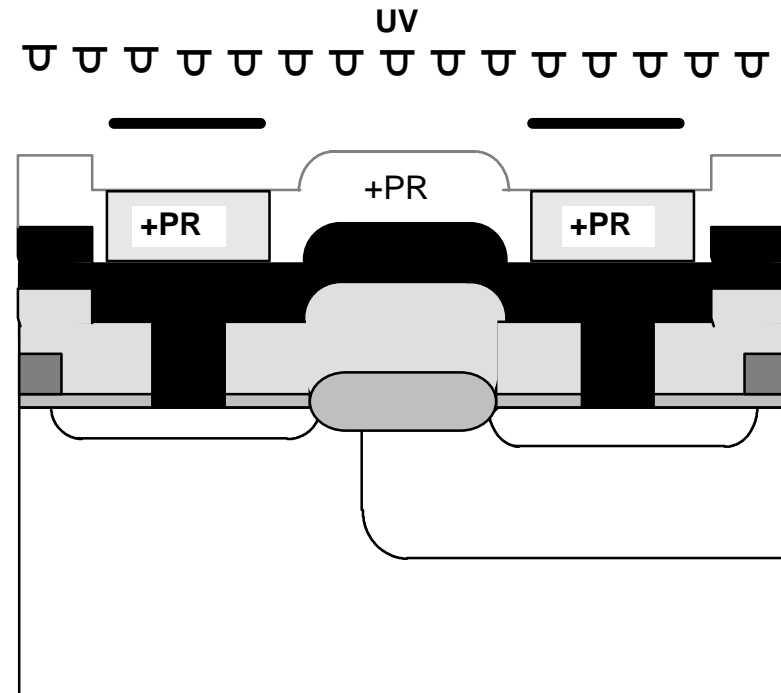
Process step

Cross-sectional view

36. *Metal photolithography:*

Mask: METAL

- Deposit positive photoresist
- Masking
- Exposure
- Development



2- μm CMOS Process Flow (Cont'd)

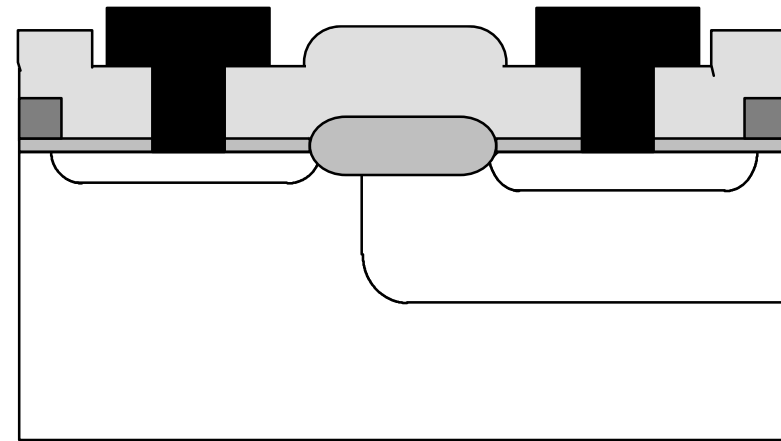
Process step

37. *Metal etch:*

Etch Al

Strip all photoresist

Cross-sectional view



38. *Truncate/reflect Nmos:*

Truncate right

Reflect left

Electrode bottom

