DO NOT WRITE YOUR NAME OR KAUST ID NUMBER ON THIS PAGE OR ANY OTHER PAGE

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EXAM ID NUMBER:________

COURSE NUMBER: EE 203

PROBLEM: 1

Problem 1 (20 points): You have at your disposition a specific set of tools and chemicals with the purpose of reproducing the cross-sectional profiles shown below. You are only allowed to use **one** photolithography step that can reach a critical dimension of 1 μm. For each of the profiles draw and briefly describe each of the steps that you would use to end up with the same profile. (The profile can consist of different materials unless otherwise stated).

Tools available:

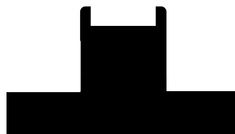
- Photolithography set (Spin coating, mask aligner [<u>min. feature is 1μm</u>], developing)
- Thermal oxidation
- PECVD tool for SiO_2, Si_3N_4, poly-silicon and amorphous silicon deposition.
- ICP-RIE tool for SiO_2, Si_3N_4, silicon, poly-silicon and amorphous silicon etching.
- DRIE tool for silicon.

Chemicals:

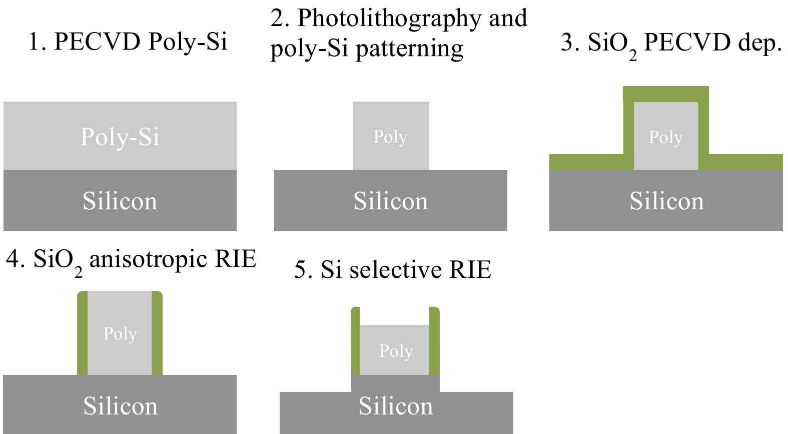
- NH_4F, HF, H_3PO_4, HCl, KOH (hot plates available)
- XeF_2 (Chamber available for vapor-based etching)

<u>Example:</u>

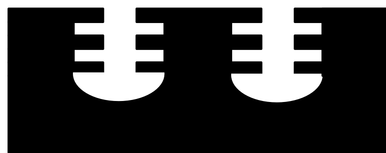
Profile:



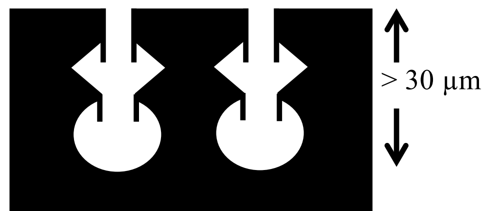
Solution:



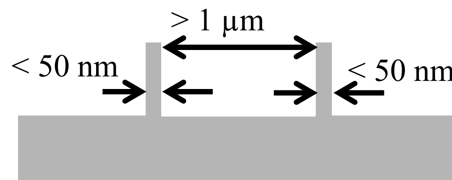
a. (3 points)



b. (7 points)



c. This profile is **<u>only</u>** Silicon (10 points)



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EXAM ID NUMBER:________

COURSE NUMBER: EE 203

PROBLEM: 2

Problem 2 (20 points): You have joined a research group and have been assigned the task of fabricating high-k/metal gate MOSFET devices. The good news is that there is an old fabrication baseline record available; the bad news is, the different steps have been scrambled and some details have been lost. Below you will find different steps in no particular order, including recipes and tools. Use this information to organize and complete the fabrication baseline for pMOSFET. (*Accurate step order – 12 points (0.5 points for each step). Accurate recipe details – 8 points distributed as below*)

Fabrication baseline for pMOSFET:

1. Starting substrate: _-type, _____ doped, 4" (_ _ _) silicon wafer (0.5 points)
2. Ion implantation (I/I): Dose= $5x10^{13}$ cm^2 with ___ at 10 KeV (0.5 points)
3. Photolithography: ECI 3027: 4 µm, bright field mask, hard contact
4. Photolithography: ECI 3027: 4 µm, ____ field mask, soft contact. (0.5 points)
5. Photolithography: _____, AZ 1512: 1.4 µm, _____ field mask, V+H contact (0.5 points)
6. PR Removal: Acetone for 5 min.
7. PR Removal: Acetone for 5 min.
8. PR Removal: Acetone for 5 min.
9. RCA cleaning: (3 group points)
   - SPM/Piranha at ___°C for 10 minutes (SPM/Piranha: H_2SO_4/____ – 4:1) (1 points)
   - SC1 at 75°C for 10 minutes (SC1= _____/H_2O_2/H_2O – 1:1:20) (0.5 points)
   - Diluted-HF at ___ for 30 seconds (0.5 points)
   - SC2 at 75°C for 10 minutes (SC2= ___/H_2O_2/H_2O – 1:1:20) (0.5 points)
   - ________ at 40°C for 30 seconds. (0.5 points)
10. SPM/Piranha at ___°C for 5 min. (+0.5 extra)
11. Vapor HF at __°C for 15 seconds. (+0.5 extra)
12. RTP: Annealing at ___°C for 30s in 200 sccm Ar (0.5 points)
13. RTP: Annealing at 950°C for 30s in 200 sccm Ar
14. High Temperature Furnace: (1 group point)
    - ___ oxidation growth at 1100°C for 15 min.
    - ___ oxidation growth at 1100°C for 26 min.
    - ___ oxidation growth at 1100°C for 15 min.
15. ALD: High k/ metal gate stack deposition: (1 group point)
    - 10 nm ____: 100 cycles, 300°C, TMA dose: 15ms, 80 mTorr, O_2 plasma.
    - 20 nm ____: 200 cycles, 250°C, $TiCl_4$ dose: 0.2s, 230mTorr, Ar plasma.
16. PECVD: 100nm poly-silicon, ___°C, $10W_{RF}$, 1000mTorr, 50 sccm ___, 450 sccm Ar (0.5)
17. PECVD: 50nm ____, 300°C, $20W_{RF}$, 850mTorr, 23sccm SiH_4, 20sccm NH_3, 980sccm N_2 (0.5)
18. Sputtering: Ni nm Ni, 400 W, 5 mTorr, 25 sccm Ar
19. Sputtering: 200 nm Ar, 500 W, 5 mTorr, 25 sccm Ar
20. RIE:
    - 80°C, 1500 W_{ICP}, 50 W_{RF}, 40 mTorr, 10 sccm Cl_2, 40 sccm BCl_3, 10 sccm Ar
    - 80°C, 1500 W_{ICP}, 150 W_{RF}, 20 mTorr, 40 sccm Cl_2, 10 sccm BCl_3;
    - 80°C, 1500 W_{ICP}, 50 W_{RF}, 40 mTorr, 10 sccm Cl_2, 30 sccm BCl_3, 20 sccm Ar;
    - 80°C, 150 W_{RF}, 900 mTorr, 100 sccm O_2
21. RIE: 800 W_{ICP}, 70 W_{RF}, 10 mTorr, 15 sccm SF_6, 4 sccm O_2
22. RIE: 1500 W_{ICP}, 100 W_{RF}, 10 mTorr, 5 sccm O_2, 40 sccm CHF_3
23. RIE: 2000 W_{ICP}, 50 W_{RF}, 10 mTorr, 10 sccm SF_6, 90 sccm CHF_3
24. RIE: 1500 $W_{ICP,}$ 100 W_{RF}, 10 mTorr, 40 sccm C_4F_8 + 5 sccm O_2