EE143 Microfabrication Technology
Spring 2012
Prof. J. Bokor

Midterm Exam 1

Name: Solutions

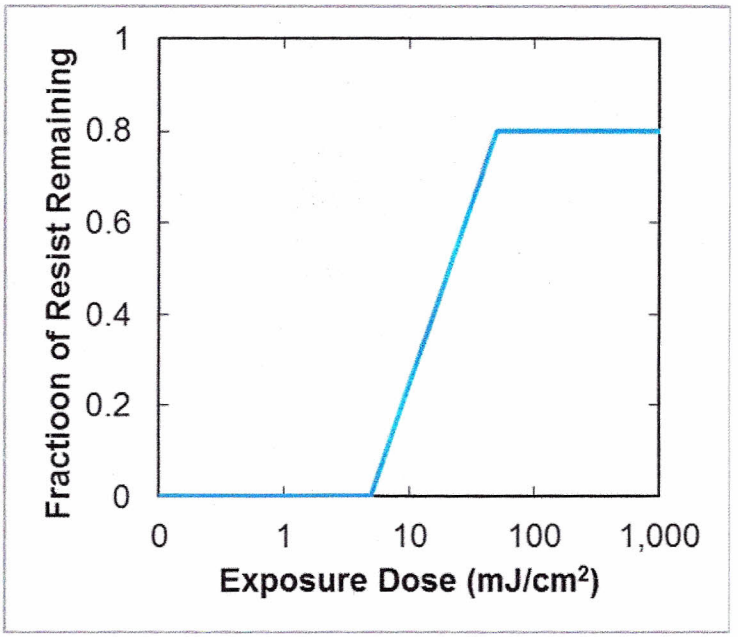
Signature: _____

SID: _____

CLOSED BOOK. ONE 8 1/2" X 11" SHEET OF NOTES, AND SCIENTIFIC POCKET CALCULATOR PERMITTED. MAKE SURE THE EXAM PAPER HAS 12 PAGES. DO ALL WORK ON THE EXAM PAGES. USE THE BACK OF PAGES IF NECESSARY.

TIME ALLOTTED: 80 MINUTES

1. Lithography (25 points)
Assume a photoresist has the following contrast curve, including top loss:



a. Is this positive or negative photoresist? (3 points)

negative

b. We will use this photoresist as an etch mask for RIE etching of Si. The etch process has a silicon-to-photoresist selectivity of 10:1. If we want to etch 3μm into the Si plus a 15% overetch, what is the minimum thickness of photoresist we should spin onto the wafer? (5 points)

We need to etch $1.15 \times 3\mu m = 3.45\mu m$ Si
This would etch 345 nm of resist
Due to 20% top loss, we need
a minimum of $345nm/8 = \underline{431nm}$

contact lithography

c. When we align a mask to a previous layer on a 150mm wafer at room temperature (20°C), we get the following alignment errors (in μm):

	Top	Right	Center	Left	Bottom
X	-1.6	-1.3	-1.1	-0.9	-0.6
Y	0.6	1.3	0.8	0.3	1.0

(in nm) (in rad) (in μm)

What are the translational, rotational, and thermal run-in/run-out errors? At what temperature should we be exposing our wafer? (The linear expansion coefficient of the glass reticle is 8.5×10^{-6}/°C and that of Si is 3×10^{-6}/°C) (12 points)

Assume Center error is translational.

So translation error $(x, y) = \underline{(-1.1, 0.8)}$

Subtracting this out we have

	T	R	C	L	B
X	-0.5	-0.2	0	0.2	0.5
Y	-0.2	0.5	0	-0.5	0.2

rotational error is

0.5μm counterclockwise

rotation angle is $\frac{0.5 \times 10^{-6}}{75 \times 10^{-3}} = \boxed{6.67 \times 10^{-6} \text{ rad}}$

$\delta_R = r * \Delta T(\alpha_{mask} - \alpha_{Si})$ runout r≡wafer radius

$\Delta T = \delta_R / r(\alpha_{mask} - \alpha_{Si})$

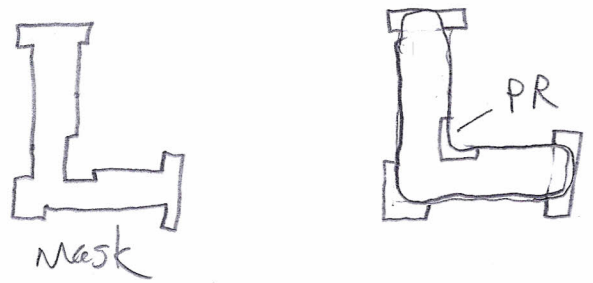
$= (-0.2 \times 10^{-6}) / [(75 \times 10^{-3})(8.5 - 3) \times 10^{-6}] = -0.48C$

Need to compensate so raise temp +0.48C to $\boxed{20.48C}$

d. What is optical proximity correction? Illustrate using a diagram. (5 points)

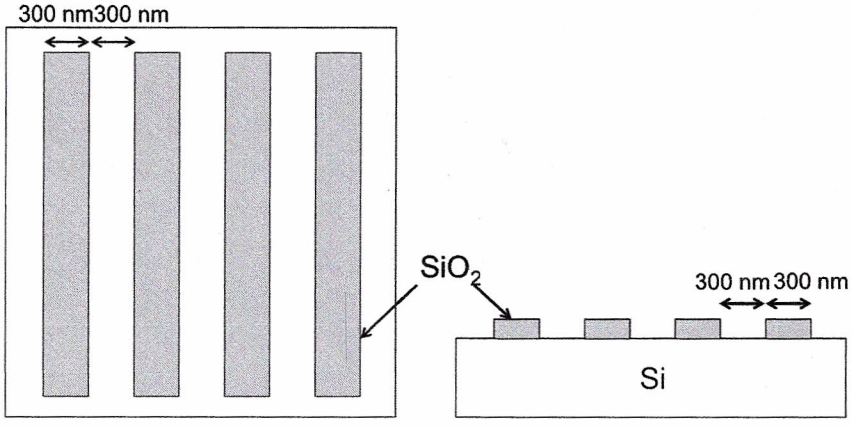
OPC involoe adding auxiliary feature on the mask to compensate for the lack of perfect fidelity in the photoresist image of the mask

after adding OPC



2. Choosing Stepper and Designing Mask (25 points)

A 100 nm thick layer of SiO2 is to be processed using photolithography. The final structure that is desired is shown in the figure below. You need to choose a stepper and design a mask for this structure. Assume you will use a 300-nm-thick layer of positive photoresist for lithography, followed by anisotropic plasma etching to etch the SiO_2.



Three optical steppers are available with following specifications:

Stepper	Photon Source (Wavelength)	Resolution Coefficient (k_1)	Depth of Focus Coefficient (k_2)	Numerical Aperture (NA)	Reduction Rate
Stepper A	I-line (365 nm)	0.8	0.5	0.6	4x
Stepper B	KrF Excimer Laser (248 nm)	0.7	0.6	0.7	5x
Stepper C	ArF Excimer Laser (193 nm)	0.7	0.4	0.8	5x

a. Calculate the resolution and the depth of focus for each stepper. (6 points)

stepper A $R = k_1 \frac{\lambda}{NA} = 487\ nm$

$DOF = k_2 \frac{\lambda}{NA^2} = 507\ nm$

stepper B $R = 248\ nm$

$DOF = 804\ nm$

stepper C $R = 169\ nm$

$DOF = 120\ nm$

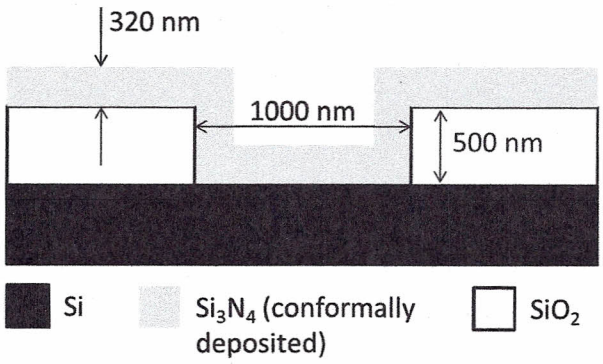
b. Which stepper will you choose for your process? Why? (9 points)

Stepper B.

Stepper A cannot resolve the features
The DOF of Stepper C is smaller
than the photoresist thickness

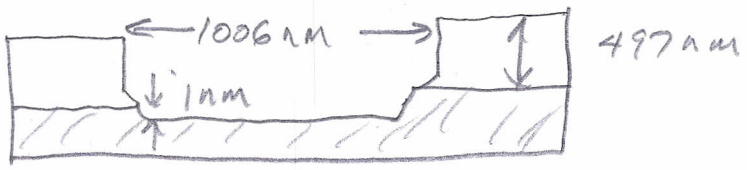
c. Draw the mask layout to fabricate the given structure. (Specify dark and clear areas and dimensions.) (10 points)

3. Etching (15 points)
Consider the cross-section below.



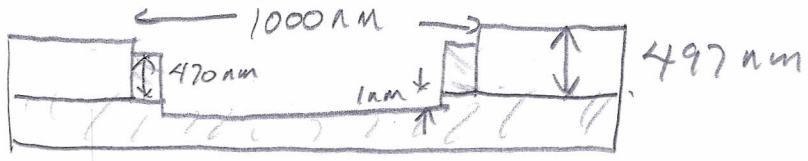
a. We etch the Si_3N_4 with hot phosphoric acid, which etches isotropically at 10 nm/min. Selectivity to SiO_2 is 10:1 and to Si is 30:1. Sketch the cross section after 35 min. (5 points)

After 32 min, the nitride is etched through.
After 3 more min, 3nm of oxide and 1nm of Si is etched

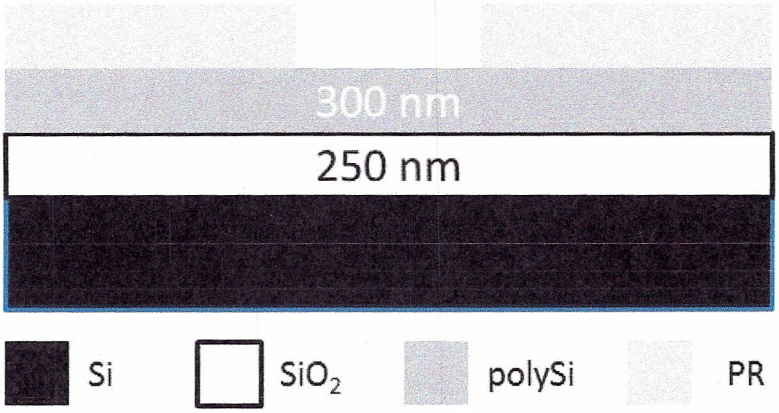


b. Instead of using hot phosphoric acid, we etch the Si_3N_4 using a perfectly anisotropic RIE, which has an etch rate of 10 nm/min. Selectivity to SiO_2 is 10:1 and to Si is 30:1. Sketch the cross section after 35 min. (5 points)

After 32 min, nitride is etched vertically through
After 3 more min, 3nm oxide and 1nm Si is etched vertically and 30nm nitride is removed from the top of the stringer



c. Consider the following cross section.

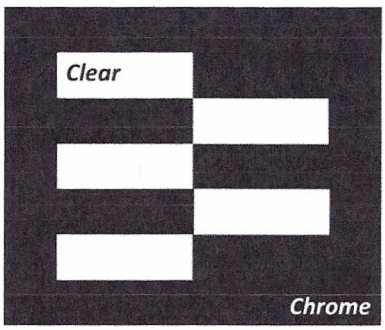


The poly thickness of 300 nm varies by ±20% over the wafer surface. If the average RIE etch rate is 25 nm/min but varies by ±4% across the wafer, what etch time should you use to be sure to clear the poly layer across the entire wafer? (5 points)

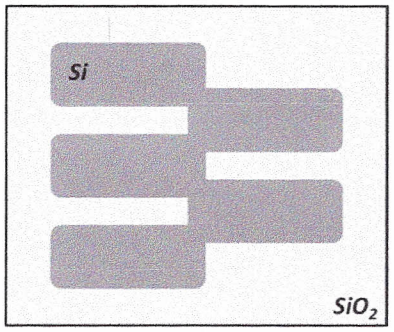
Worst case poly thickness is $300 \times 1.2 = 360$ nm
Worst case etch rate is $25 \times 0.96 = 24$ nm/min
time = $\frac{360}{24} =$ 15 min

4. Lab related (35 points)

a. Here is a drawing of part of the mask we use in the EE143 lab.



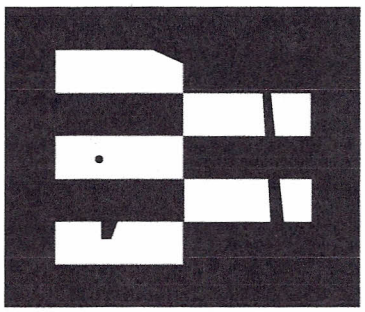
After exposing this mask on your wafer and etching your field oxide with HF, this pattern looks like this:



What went wrong with your etch, assuming the exposure of the photoresist was correct? (5 points)

HF etch was too long.

b. Now suppose that at the end of active region lithography step, you observe the following pattern in the resist. What might have caused this? What precaution would you take to avoid this? (10 points)



There is contamination on the mask.
Use acetone and IPA to clean the mask before exposure.

c. List three items of personal protective equipment that you should wear when you are handling corrosive chemicals. (6 points)

1. Chemical gloves
2. Chemical apron
3. Face shield

d. Do you use pyrex or plastic beakers for HF? Why? (4 points)

plastic.
HF etches pyrex

e. While wet etching the field oxide on your wafer using HF, you accidentally splash some of the acid. Some of it splashes onto your shoes, and you are not sure if it penetrates to your skin. You do not feel any burning sensation. What should you do? (10 points)

1. remove shoes. go to safety shower and wash, rinse feet for 15 mins at least
2. apply calcium gluconate to affected area