1. (20 pts maximum) Indicate T for true, F for false or X for no answer for each question. Correct answers earn 1 point, the X response earns 0 points and incorrect answers will earn -1 point. The maximum score for the question is 20 points and a minimum score is 0 points.

a) _T___ The slope of a plot of thickness remaining after development vs log dose defines the contrast of a negative resist.

b) _T___ Ellipsometry can be used to measure dissolution rates.

c) _F___ The process stability problem in chemically amplified resists was the result of airborne base contamination that occurred in the interval between the exposure and the post exposure bake steps.

d) _T___ In general, polymers do not form homogeneous blends or alloys.

e) _T___ Unlike high pressure mercury lamps, which emit light continuously, Excimer lasers and EUV sources provide high frequency pulses of radiation.

f) _F___   A dose of $100mJ/cm^2$ of 200nm radiation provides twice as many photons as $100mJ/cm^2$ of 400nm radiation.

g) _T___ "Shot Noise" describes the uncertainty of getting the mean or targeted dose in a given pixel and the shot noise problem becomes more serious as the number of photons in the targeted dose is reduced.

h) _F___ The ideal TARC would have the same refractive index as the resist over which it was to be coated.

i) _F___ The pattern in the image below has the characteristics of having been made by the SADP process.
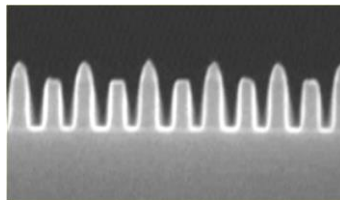
j) _F___ The dissolution rate of diazonaphthoquinone – novolac resists is directly proportional to the post apply bake temperature.

k) _F___   The famous KTFR resist is comprised of synthetic rubber and diazonaphthoquinone.

l) _F___   The letter A in BARC stands for the word Applied.

m) __T__ The period of a lamellar block copolymer is independent of orientation.

n) __F__ Novolac and poly(p-hydroxystyrene) are both soluble in water.

o) __T__ Diazonaphthoquinone dissolution inhibitors bleach when exposed to 365nm light

p) __F__ LFLE, LELE and SADP all require two exposure steps.

q) __T_ The final step in the dual damascene process is CMP.

r) __F_ The photoacid generators used in 248 and 193 nm resist formulations bleach upon exposure.

s) __F_ The G value of polymers that undergo random scission upon exposure to radiation is the slope of a plot of number average molecular weight of a sample (M_n) vs log dose.

t) __T_ Plasmas are employed in both RIE and EUV.

2. (10 Pts) An important principle was taught by the Hitachi negative tone, crosslinking, deep UV resist that was comprised of a bis-azido aromatic and p-hydroxy styrene.
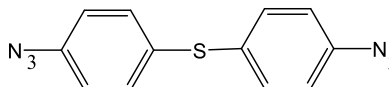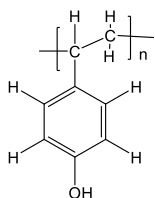
a. What was the important principle?

- Dissolution is achieved by a chemical reaction/etching
- Hence, even though this is a negative-tone resist and change in dissolution rate by increasing MW, the resist does not swell

b. Why did the material fail in the market place?

- The bis-azide was too strongly absorbing
- Resist is opaque

3. (10 pts) What are the implications of a negative G value for a polymer. Please explain your answer.

- Increase in MW as the polymer crosslinks upon exposure
- Negative-tone resist (optional)

4. (10 pts) End capped poly(phthalaldehyde) formulated with an appropriate onium salt provides a remarkably sensitive imaging system.

    a. List two important design principles taught by this resist.

- High resolution possible by chemical amplification/catalysis
- High sensitivity is also achieved by catalysis

    b. Why is this resist not used in manufacturing today?

- Not really a resist because it does not resist many etchants

5. (10 pts) The "swing curve" plot shown below depicts the relationship between the dose to clear under constant development conditions and the thickness of a film of diazonaphthoquinone / novolac resist.   The curve has two interesting characteristics. The first is the periodic variation in dose with thickness and the other is the monotonic increase in dose at the maxima (and the minima) as a function of thickness. Please explain the origin of both of these characteristics.
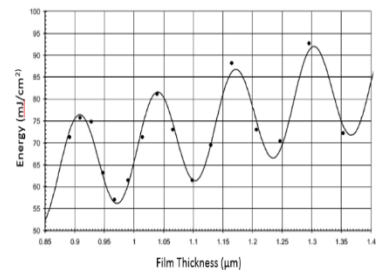
- The oscillation is due to constructive and destructive interference
- The monotonic increase is due to absorbance of the resist film as its thickness increases

6. (10 pts) Wet etching generally produces isotropic etching which limits the resolution of image transfer processes. Fortunately, Reactive Ion Etching can provide highly anisotropic etching and produce structures with very steep and vertical side walls. Please explain the basic principle that allows reactive ion etching to provide anisotropic etching.

- Anisotropy is achieved by formation of *boundary sheath* when a *confining potential* forms a thin wall that *repels electrons but accelerates ions* towards the substrate at *near normal incidence*
- *Activation energy* required to react with the substrate is provided by ion bombardment

7. (10 pts) List two applications of MEMS that ae found in modern automobiles.

a.

Accelerometers for air bags

b.

Pressure sensors for tires

8. (10 Pts) Accurate determination of the sensitivity and contrast of negative tone 193nm resists requires exposure at varying doses delivered to the bottom of a film cast on a transparent substrate. For electron beam resists, this experiment can be run on opaque, silicon substrates that are exposed from the top.   Please explain why this is true.

- For 193 nm photolithography, most of the light is absorbed at the top surface of the resist
- High dose at the top of the film and makes it insoluble
- Loss of contrast at varying doses
- For e-beam lithography, high dose at the bottom of the film due to electron backscattering