Final exam: take-home part

- List five things that can be done to improve this class. Be specific; give much detail.
- (You will be penalized only for insulating comments made for no benefit; you will not be penalized for any insulting comments which have merit.)
- Number of points per response will be based on the value of the comment.
- Alternative: rewrite one of the labs. Include at least 5 significant changes.
- Due by email to Matt by 11 December at 1700.

Lab final

- Chamber will be open with samples mounted at correct height
- You get to choose detector(s) to insert
- “Three samples” to image
  - Au/C
  - Polystyrene balls on glass
  - Three microscope slides (Choose one for EDS)
    - Uncoated
    - Carbon coated
    - Gold coated
- High resolution image of Au/C (500kX).
- Image 0.5 micron polystyrene balls at 50kX
- Determine chemical composition of microscope slide.
- All machine parameters will be set to the same value
- NovaNano
- Schedule 1.5 hours with Matt. (All but 3 in regular class time)
Sample locations on multi-sample holder
SEM class final exam

- Everhard-Thornley Detector
  \((X, Y)\)

<table>
<thead>
<tr>
<th></th>
<th>CCD Camera</th>
<th>Au/C</th>
<th>Polystyrene On glass</th>
<th>Carbon-coated Microscope slide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Un-coated Microscope slide</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gold-coated Microscope slide</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Last lab report (ESEM)

- 1-page summary of how to use the ESEM (new stuff) and what you learned from using the ESEM
- Attach and reference images and lab notes, as usual
- Due when you take the lab final.
Final exam format
- Bluebook (supplied)
- 8.5x11 sheet of notes permitted (NOT open book)
- Questions from lecture, text, quiz
- Calculator not needed...
- Sample questions follow for discussion\n- Monday Dec 15th 1pm room EMCB 103

Nanotubes on AFM tip

Describe the problem here, and approaches to avoid it.
A very large file full of “junk”…

“streaks” indicate what?

The squared marks here are from what?

Dirty or charge-sensitive samples: How do you avoid this?
(Au nanoparticles on Si; oxide field)
These are “spheres”. Where are the shadows?
Simple two-level CMOS...

Passivation (oxide on nitride)

Intermetal oxide

Field oxide

Source/drain

P-well ("lub")

P-type substrate

Liquid Crystal Hot Spot

Deprocessed to Metal-2 layer (RIE depassivation)

Not all defects are so easy...
Continue Chemical Deprocessing...

M2 removed chemically
IMO removed by BOE

Deprocessing...

M1 removed / BPSG remains
BPSG removed, poly+ contacts
Defect location (finally!)

Removal of poly gate...

Wright etch of Si (decorates stacking faults)

Cause of square artifact

SE Emission (topography-sensitive)

("bright" contrast)
Secondary electron escapes

Secondary electron reabsorbed (Dark contrast)
(A) Identify six physical processes that simultaneously occur when an energetic electron beam impacts a material, giving rise to imaging opportunities.
(B) Explain what is meant by “Interaction Volume”

(D) Define Secondary Electron Yield
**Schematic use of S.E. Yield (δ)**

(E) Draw the representative shape of a typical insulating material.

(F) Identify the conditions under which the sample can be imaged without charging effects taking place. Why?

\[ \text{S.E. Yield} = f(\text{material, Vacc}) \]

**S.E. Yield = f(material, Vacc)**

As-cleaved samples (no chemical decoration or coating) can be quickly imaged with high resolution.

(A) Use the SE Yield concept to explain the contrast-forming mechanism for this image:
1.5keV imaging during via etch inspect

(patterned oxide over patterned metal)

Holes over dielectric

Holes over metal

(uncharged)

holes over ungrounded metal where metal has been previously subjected to extended beam dwell

(D) Contrast mechanism?

From the case study on IC damage...

(E) “ring” Contrast mechanism?
What technique should you use?

F) You have been asked for a recommendation how to image the crystal orientation of a nanowire (~10-80 nm diameter; 1-3 microns in length) in a cluster. Explain briefly.

2 Pts.

Explain the physical principle: why can EDX spectra be acquired at much higher spatial resolution in (S)TEM versus SEM? (assume same e-beam spot size)

2 Pts.
Sample: Packaged (de-lidded) IC with all pins grounded.

Explain the depth of beam penetration for the following images and ID relative charge state:
Question 9 - SEM contrast mechanisms, cont’d
Question 9 - SEM contrast mechanisms, cont’d

(F)

(j) FIB SE image of Blanket thin Al film

Final Exam review
The secret to the amazing resolving power of the helium ion beam starts with the source tip. A finely sharpened needle is made even sharper through a proprietary process that took years to develop. Individual atoms are stripped away from the source until an atomic pyramid is created with just three atoms at the very end of the source tip - a configuration called the "trimer". This repeatable process can be accomplished in-situ. Once the trimer is formed, the tip is maintained under high vacuum and cryogenic temperatures with helium gas flowing over it. A high voltage is applied to the needle to produce an extremely high electric field at its apex. The helium gas is attracted to the energized tip where it is ionized. With ionization happening in the vicinity of a single atom, the resulting ion beam appears to be emanating from a region that is less than an angstrom in size. This produces an extremely bright beam that can be focused to an extraordinarily small probe size.