A. $E_0=20\text{keV}$

principles: 1) since det. on rt, we will always
get shadows in areas away from detector
2) the range of the incident and backscattered
electrons will determine how signal
is enhanced near edge
3) at vertical boundaries, the secondary
signal is enhanced since more can escape.
4) if Range $>\text{overlay thickness}$, then
backscattering from substrate will be important

at 20keV, range $R(20\text{keV}) = \frac{11.32 \times 10^{-4} E_0^2}{n^2\gamma^3} \ln\left(\frac{2.5E_0}{\sqrt{E_0}}\right)$ in $\mu$m

$R(20\text{keV}) = \frac{11.32 \times 10^{-4} (20)^2}{n^2\gamma^3} \ln\left(\frac{2.5(20)}{\sqrt{20}}\right)$

so lets look at range in high $Z$ overlay

say $Z=79$ (Au).

$R(20\text{keV}) = \frac{11.32 \times 10^{-4} E_0^2}{n^2\gamma^3 \ln(0.37E_0)}$

$R(20\text{keV}) = 7\text{nm}$

$R(5\text{keV}) = \frac{345\text{nm}}{2.34\text{nm}} = 150\text{nm}$

$R(5\text{keV}) = 22.4\text{nm} \approx \text{10x less.}$

for $Z=47$ (Ag) we would get

$R(20\text{keV}) = 680\text{nm}$, $R(5\text{keV}) = 52\text{nm}$
In both Ag and Au, at $E_0 = 20\text{ keV}$ the range $>\text{overlayer thicknesses}$ and similarly at $E_0 = 5\text{ keV}$. The difference in the range between 20 keV and 5 keV is that $R_{20} \approx 10R_5$.

Thus we expect a sharper “band” at the edges due to diffusion of backscattered electrons out the side for the 5 keV beam.

In addition, since the range of the primaries (and BSE) is $\approx 10$ times greater than the 40 nm overlayer for 20 keV electrons but the same order of magnitude for the 5 keV, we expect a slighter higher signal for the 40 nm layer at 5 keV.

**NOTE:** Slips at edges due to fract that secondary escape depth is the order of the beam diameter.
(3) with EE 213. Homework #1. 5/6/69 (Due)

1. Unit

2) $E_0 = 5$ keV

3) Material is uniform composition, the thickness (depth)
of structures is greater or comparable to range.

- principle: 1) None shadowing on the side away from the detector
  2) aborption in the layers
  3) enhanced signal at the peak
  4) none signal at the sloped edges due to the scattering instead of surface not normal to beam.
  (i.e. SPE effect)
  5) Broad diffusion effects due to BSE somewhat masked due to signal enhancement at sloped edges
one will get roughly the same effects at 5kev as at 20kev. except gain signal will be higher due to gain increase of secondary electron yield at 5kev vs 20kev
- the structures are large, so diffusion broadened produce broadenings are not as prominent.
principles:

1) enhanced x-radiation at the edges of the step and the large particle.

2) if range of primary and BSE of order of particle radius then particle will appear uniform, no edge effects since x-radiation produced equally at all sides.

3) secondary absorption at inner even though inner faces detect some some x-radiation so will strike back into the inner unless you have very high voltage pulling them into detector.

4) broad bands of intensity near edges due to escaping BSE, primary x-radiation will be more prominent at 5kev, since the range is 10x smaller than at 20kev.

5) Range (in µm):
   - 20keV: Au 0.345µm 0.027µm, Al 3.29µm 0.25µm.
   - 5keV: Au 0.690µm 0.054µm, Al 6.58µm 0.50µm.
At $E_0 = 20$ keV:

- Absorption at the detector.
- Secondary BSE signal from Al away from edge.
- Edge effects - more secondary particles produced.
- Small sphere has almost uniform signal appearance since the BSE range is 7 μm.
- Signal enhancement also at edges.

Sample with smaller particles is less than larger one, some might of the electrons go through the particles so it appears as a thin overlay. At 20 keV there is a lower X-ray excitation produced some most electrons go right through it.

At $E_0 = 5$ keV:

- Lower X-ray excitation produces lower edge effect since range in Au is less than particle size.
- But yield higher at 5 keV than 20 keV.
2. The detector position will result in a shadow on regions facing away from detector.

the image (secondary electron) shown is an inverted image of the signal (ie, darker is more signal).

Looking at line scan, we see for all the double peaks, the one on the left is always brighter.

The detector is at the left of the page.

\[ \text{Image} \]

\[ K = 50 \text{ nm} \]

the separation of the double line peaks is about 50 nm.

Thus the peaks are sharp due to the enhanced secondary production at edges.

since the secondary electron escape depth is of the order of several 10 nm, then the signal between the edges never quite makes it back to the "far away" level.

\[ \text{Diagram} \]

the topography is as shown. Posts (rectangular) about 10-12 nm wide, separated by 50 nm.
EE 213, Spring 2012
homework #1, prob. #3.

KL2L3 transition in Aluminum

\[ E_{KL2L3} \approx E_k - (E_{L2} + E_{L3}) \approx 1560 - 74 - 73 = 1413 \text{ eV} \]

better approx.

\[ E_{KL2L3} (Z=13) \approx E_k (13) - \frac{1}{2} [E_{KL_2(13)} + E_{KL_2(14)}] \]
\[ - \frac{1}{2} [E_{L_2(13)} + E_{L_2(14)}] \]

A) \[ \approx 1387 \text{ eV} \]

For the X-ray (KL is L2 \rightarrow k)

\[ E_x \approx E_k - E_{L2} = 14.86 \text{ eV} \]

B) or better approx

\[ E_{x(13)} = E_{x(13)} - \frac{1}{2} [E_{L_2(13)} + E_{L_2(14)}] \]
\[ \approx 1473 \text{ eV} \]

C. Probability of KL2L3 Auger \( \frac{\text{KL2L3 Auger}}{\text{KL X-ray}} \)

\[ W_k = \frac{Z^4}{1.1 \times 10^4 + Z^4} \] probability of K-shell ionization resulting in X-ray

\[ 1 - W_k \] is probability of K-shell ionization giving Auger

But not all K-shell ionizations give KL X-ray,
and not all K-shell ionizations which result in
Auger elections give KL2L3 Auger \( \rightarrow \) NOTE

\[ \frac{KL2L3}{KL} \approx 38.2 (30.6) \]
In this problem, the error will occur in extracting the value from the graph. I should have given you a table instead.

In addition, if you use the Anger sensitivity table given on the class website, the spectrum shown does not give all the information needed to be sure those tables are valid. But the n.e. ele. energy is the type of analyzer used are the same, so we can assume that works.

to assign the peaks, keep in mind that the Anger energies are always less than the binding energy of the target shell.

Also, you need to be consistent in defining the "signal", that is, if you use peak to peak hits, do so for all peaks. Only consider the major peak.

Having said that, are illustrate the following table:

<table>
<thead>
<tr>
<th>Peak</th>
<th>S (peak)</th>
<th>~E_A (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>281</td>
</tr>
<tr>
<td>1</td>
<td>49</td>
<td>500</td>
</tr>
<tr>
<td>2</td>
<td>39</td>
<td>656</td>
</tr>
<tr>
<td>4</td>
<td>28</td>
<td>1440</td>
</tr>
</tbody>
</table>

to a 1st approx, the Anger peak is given as:

\[ E_A \propto (E_k - E_l) - E_l^2 \]

for an interaction event resulting in a K shell ionization.
Using that simple approx we would get:

<table>
<thead>
<tr>
<th></th>
<th>E_k(ev)</th>
<th>E_{k'}(ev)</th>
<th>~E_p(ev)</th>
<th>peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>carbon</td>
<td>6</td>
<td>284</td>
<td>7</td>
<td>277</td>
</tr>
<tr>
<td>oxygen</td>
<td>8</td>
<td>532</td>
<td>7</td>
<td>525</td>
</tr>
<tr>
<td>fluorine</td>
<td>9</td>
<td>686</td>
<td>18</td>
<td>668</td>
</tr>
<tr>
<td>Al</td>
<td>13</td>
<td>1586</td>
<td>146</td>
<td>1440</td>
</tr>
</tbody>
</table>

so we could calculate the sensitivity factors or just use the info in the table.

1e \[ S = N \times J \times F \Rightarrow S = N \times k_i \]

\[
\therefore \frac{N_i}{N_j} = \frac{S_i}{S_j} \cdot \frac{k_i}{k_j} \rightarrow \text{our relative sensitivity factor}
\]

the graphs in the notes have the k's relative to Ag but that doesn't matter since,

\[
\frac{K_i}{K_j} = \frac{K_i}{K_{Ag}} \cdot \frac{K_{Ag}}{K_j} = \frac{K_i}{K_j} \frac{K_{Ag}}{K_{Ag}} \frac{K_{Ag}}{K_j} \]

from the Ep=5 keV table, we get:

\[
\frac{K_i}{K_{Ag}}
\]

C    .14
O    .40
F    .48
Al   .075

and so the same way we did the X-ray quantitations the uncertainties are:

\[
C_i = \frac{N_i}{\sum_j N_j} = \frac{1}{\sum_j \frac{S_j \cdot K_i}{S_i \cdot k_j}}
\]