The Electron Cloud

- Fermilab and the intensity frontier
  - Accelerators are approaching a new regime in intensity
  - Many difficulties are associated with increased intensity

- Increased intensity results in electron cloud instabilities
  - Very hard problem to solve analytically
  - Not well understood
The Electron Cloud

• A secondary effect of accelerating particles

  – Primary electrons collide with beam pipe and components and generate secondary electrons
    • In proton/antiproton accelerators, primary electrons are formed mostly from residual gas ionization
    • In electron/positron machines, primary electrons are generated by the photoelectric effect

  – Secondary electron yield greater than unity for most materials => AMPLIFICATION!
Secondary Electron Yield

• Combat electron cloud formation by reducing secondary electron yield

• Commission a test stand to examine different materials for use in a beam line
  – Must be vacuum compatible
  – Durable
  – Have a low SEY
The Setup

- HV Supply
- Electron Gun
- Sample
- Picoammeter
- Sample Bias
- HV Supply
SEY Measurement Technique

- Bias the sample to +500 volts and measure beam current
- Bias sample to -50 volts and measure current
- SEY current is the difference between the -50 V bias reading and the +500 V bias reading
- SEY is then given as the ratio of SEY current to beam current
In Practice

• Sample is stationary and electrically isolated (mounted to SHV feedthrough)

• Pumped with Varian TPS-Compact pumping station (turbo pump backed with oil-less scroll pump)

• Inverted Magnetron Pirani vacuum gauge

-> Electron beam indicated by red arrow
SEY Measurement Technique

• Why -50 volts?
  • Convention suggests -20 volts
Initial Results

- Copper sample
- Qualitatively good data
Initial Results

- Copper sample
- Proof of conditioning
Refining the Technique

• Stray magnetic fields from gauge and ion pump had an unknown effect on low energy beams
  • *Mu-metal shielding*

• SEY measurements appeared to be sensitive to gun parameters
  • Spot size changes as parameters change
  • Measurement drift due to self-conditioning
    • *Perform beam studies*
    • *Speed up measurements by automating process with LabView*

• SEY current from residual gas ionization (i.e. not all of the measured current was necessarily from sample)
  • *Improve vacuum*
Refinements

• Shielded gauge using AD-MU-80; a high nickel alloy with a very large $\mu$
  – Magnetic field reduced to a maximum of 3 gauss outside the chamber and $\sim$ 1 gauss in the chamber

• Installed an ion pump
  – Vacuum improved to $4.1 \times 10^{-7}$
    -> Dirty sample (typical monolayer formation time $\sim$ 25 seconds according to *Building Scientific Apparatus* by Moore, Davis and Coplan)

• Performed basic beam study; spot size measured through beam extinction technique
Mystery Magnetics

• Vacuum gauge produces a field of roughly 30 gauss at the KF flange
• After removal, 8-9 gauss still measured inside the chamber!
• Supports for the test stand were magnetic; fields on the order of 42 gauss!

• SOLUTION: Build degausser using a half torroid ferrite and a variac.
Degaussing a Wrench
Improved Test Stand

- Sample electrically isolated and stationary
- Aperture mounted on mechanical feedthrough for extinction measurements
- Ion pump installed
Mu-Metal shielding for gauge

Electron Gun

Mechanical feedthrough for aperture
Initial Results

SEY as a Function of Beam Energy
(new copper sample; beam current < 50 nA)
Conditioning

• Made a critical mistake; first hour of conditioning the emission current indicated on the EGPS increased

• Estimated dose: \(~ 137.63 \, \mu A\text{-hr}^*\)
Questions About Conditioning (Future Work)

• How does the conditioning beam energy effect sample conditioning?
  – Produce SEY comparisons of conditioned and unconditioned samples for several different conditioning energies

• How does sample bias effect conditioning?
  – Conditioning current measured from EGPS “emission current”, which does not always match actual beam current
  – Can the sample be effectively conditioned with a large positive bias (allowing more accurate dose measurements)?
Results After Conditioning

SEY as a Function of Beam Energy
(conditioned copper sample; beam current < 70 nA)

Average of Run 1 and Run 2
Investigate Spot Size

• Installed an aperture
• Measurement technique:
  – Feed aperture into beam; record position when beam current is reduced to 99% of the unobstructed beam current
  – Continue feeding until beam current drops to 1% of unobstructed beam current and record position
• Double edge aperture used to gain a rough beam profile
  – Raster aperture back and forth, recording the current as a function of position
Spot Size Measurements
Spot Size

**Good Measurements**

1000 eV Beam

**Bad Measurements**

400 eV Beam
Spot Size

**Conditioning Beam**

- Current (μA) vs. Aperture Displacement (mm)

**Bad Measurements**

- 350 eV Beam
  - Current (μA) vs. Aperture Displacement (mm)
What’s Going On?

Three Cases

- ~400 eV to 200 eV range => artificially high SEY from overlap condition
- ~600 eV to 400 eV range => appears as a plateau
- ~2000 eV to 600 eV range => qualitatively looks fine but still suffering from slight overlap

Ideal Case
## New Parameters

### Conditioning Beam:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Energy</td>
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<tr>
<td>Grid</td>
<td>1 V</td>
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<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; Anode</td>
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### SOURCE

<table>
<thead>
<tr>
<th>Parameter</th>
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<tbody>
<tr>
<td>Voltage</td>
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<tr>
<td>Current</td>
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<tr>
<td>Emission</td>
<td>30.99 μA</td>
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</tbody>
</table>
Double Sided Aperture Measurement

Conditioning Beam Measured with double sided aperture

Single Sided Aperture Comparison

Conditioning Beam Comparison

- Conditioning Beam (old parameters)
- Conditioning Beam (new parameters)
Conditioning Current

Dose approximately 0.041 C/cm^2
Initial Results with new Parameters

**SEY as a Function of Beam Energy**
(conditioned copper sample; beam current < 40 nA)

-1.6 -1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2 0

-1.6 -1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2 0

Beam Energy (eV)
Useful Comparison

• New conditioning beam and new measurement beam (E=150 eV and F = 310 V in this example)

New conditioning beam and old measurement beam (E=150 eV and F = 150 V in this example)
CONCLUSION

• Successful proof of technique
  – Setup for biasing the sample is robust and easily controlled, either manually or via computer
  – Low noise
  – Reasonable results
• Need to develop a solid set of gun parameters for future measurements
  – Raster the beam for a larger, more uniform conditioning?
• Future work should also include a formal study of conditioning
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