Electron Beam Photocathode Cleaning

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Benefits of an ultra-clean photocathode:

• Enhanced Quantum Efficiency
• Increased transverse beam uniformity.
Progression of Cu Cathodes in the 1.6 Cell Photoinjector at UCLA

First Cathode:
Standard OFC copper with residual contamination and amorphous crystal structure. Surface contamination impedes photoemission in a non-uniform way which reduces total charge and adds transverse structure to the beam. The presence of multiple crystal domains exacerbates these problems since domain structure is on the order of the laser spot size and different domains and have slightly different work functions due to the details of crystal type and orientation.
Progression of Cu Cathodes in the 1.6 Cell Photoinjector at UCLA

Current Cathode:

In order to eliminate the problems of amorphous copper our collaborator D.T. Palmer (SLAC) has built a gun back plane with a 1 cm diameter single crystal copper insert in the center. We are currently evaluating this new type of cathode without any post-installation cleaning other than a mild (150-200 °C) bake.
Progression of Cu Cathodes in the 1.6 Cell Photoinjector at UCLA

Cleaned Single Crystal Cu

Future Cathode:
In the near future we plan to conduct in situ cleaning of the cathode using the electron beam cleaning system we are developing.
Advantages of cleaning with an electron beam:

- Moderate energy electrons interacting with a surface readily induce desorption of contaminants and produce surfaces much cleaner than conventional baking.
- Cleaning times on the order of minutes are expected.
- Cleaning can be done in situ and on the fly.
• E-beam cleaning has been used successfully in electron-cooling devices:

  S. Nagaitsev - Fermilab

  A.N. Sharapa, A.V. Shemyakin - Novosibirsk

**Typical Cleaning Parameters:**

  - Electron Energy: 3 keV
  - Electron Current: 250 mA
  - Specific Dose: 2 mA h / cm²
## Cleaning Results

<table>
<thead>
<tr>
<th>Before Electron Cleaning:</th>
<th>After Electron Cleaning:</th>
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</thead>
<tbody>
<tr>
<td>$K_d \sim 1$</td>
<td>$K_d &lt; 10^{-3}$</td>
</tr>
<tr>
<td>Outgassing: $10^{-11}$ Torr-l/(s cm²)</td>
<td>Outgassing: $10^{-14}$ Torr-l/(s cm²)</td>
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- $K_d = \text{(molecules)} / \text{(electron)}$

**Optimum Baking Outgassing Rates:** $10^{-12} - 10^{-13}$ Torr-l/(s cm²)


All numbers cited are typical for clean stainless steel parts.
Implementation of Electron Beam Cleaning

The Mini-Gun:

1 cm² dispenser cathode mounted on 2 3/4” CFF

Max Output: 300W

(60 mA at 5 keV)

Time to achieve 2 mA h / cm² specific dose on 1 cm² of photocathode: ~5 min
Mini-Gun Beam Simulation Plot Showing Cathode / Anode Structure

Beam Diameter at Cathode ~ 5 mm

Large spot size should greatly reduce or eliminate the need for time consuming rastering during cleaning.
Current Test Stand Configuration

Testing Goals:

• Establish acceptable mini-gun operating parameters.
• Use electrically isolated copper target to develop optical diagnostics for electron beam position.
• Verify that materials which are sometimes emitted from dispenser cathodes have not contaminated the test target.
In Situ Cleaning Configuration
Using Existing Laser Port