Thermal Degradation of Alkali Antimonide Cathodes

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APEX Photoinjector


<table>
<thead>
<tr>
<th>Frequency (7th sub-harmonic of 1.3 GHz)</th>
<th>186 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation mode</td>
<td>CW</td>
</tr>
<tr>
<td>Gap voltage</td>
<td>750 kV</td>
</tr>
<tr>
<td>Field at the cathode</td>
<td>19.47 MV/m</td>
</tr>
<tr>
<td>$Q_0$ (ideal copper)</td>
<td>30887</td>
</tr>
<tr>
<td>Shunt impedance</td>
<td>6.5 MΩ</td>
</tr>
<tr>
<td>RF Power @ $Q_0$</td>
<td>87.5 kW</td>
</tr>
<tr>
<td>Stored energy</td>
<td>2.3 J</td>
</tr>
<tr>
<td>Peak surface field</td>
<td>24.1 MV/m</td>
</tr>
<tr>
<td>Peak wall power density</td>
<td>25.0 W/cm²</td>
</tr>
<tr>
<td>Accelerating gap</td>
<td>4 cm</td>
</tr>
<tr>
<td>Diameter/Length</td>
<td>69.4/35.0 cm</td>
</tr>
<tr>
<td>Operating pressure</td>
<td>$\sim 10^{10}$-10⁻⁹ Torr</td>
</tr>
</tbody>
</table>
APEX Photoinjector
APEX Nosecone Heating


Maximum temperature under full power $\sim 52^\circ$C
Simultaneous deposition of Sb, K, Cs (90°C)

- 4 parameter initial search for correct conditions

- Very robust and repeatable method

- 7% QE is routinely achieved @ 532 nm

K$_2$CsSb yield growth curve

K$_2$CsSb QE(energy)

distinctive purple color cathodes

Near atomically smooth alkali antimonide photocathode thin films

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Questions

- How is cathode lifetime affected by operating temperature
- What is the mechanism of thermal damage
- Can the QE be recovered in some way

Method

- Prepare many cathodes by co-deposition ($K_2CsSb$, $Cs_3Sb$)
  - measure QE (wavelength)
  - refine method to make cathodes as close to identical as possible
- Measure QE (time) at defined temperature
- Repeat for range of temperatures
  - 1 cathode for each temperature....a tedious measurement
QE decay curves of $K_2\text{CsSb}$ at 532 nm

Initial QE in range 4.5 – 5.5% and normalized to 5%
Lifetime of $K_2CsSb$ at 532 nm
$K_2$CsSb: Full recovery of yield by re-cesiation: 100°C for 1 hr

100°C for 1 hour

- Factor of 2.7 loss in QE @ 575 nm, 1.4 @ 350nm
- Re-cesiation recovers ~100% of QE
$K_2\text{CsSb}$: Partial recovery of yield by re-cesiation: $100^\circ\text{C}$ for 12 hrs

100$^\circ\text{C}$ for 12 hrs

- Factor of 7 loss @ 575 nm, 3 @ 350 nm
- Re-cesiation recovers only a fraction of initial QE
  - 40% at 575 nm and 53% at 350 nm
K$_2$CsSb: 100° C and 1.5 hrs induces structural changes

- (111) reflection not allowed
- (111) indicates strain or disorder
- Large (111) intensity after heating indicates disorder
- Crystal symmetry remains the same after heating
- Thickness reduced by 5% after heating
- Out of plane roughness similar after heating
- X-ray induced x-ray fluorescence
- Indicates loss of Cs
- No loss of K or Sb
Summary: Thermal decomposition studies

- Safe operating range with $K_2CsSb$ up to around 55°C
  - Slightly higher than APEX cathode when under full power
- Decomposition via loss of Cs, and partial recovery possible
- $Cs_3Sb$ much less stable, NaKSB much more stable
Workfunction Imaging using LEEM

S. Karkare*, S. Emanian, G. Gevorkian*, H. A. Padmore (ALS, LBNL: * now ASU)

A. Galdi (Cornell)

A. Schmid (Molecular Foundry, LBNL)

- Emittance depend on physical and chemical roughness
  - Physical roughness UHV AFM
  - Chemical roughness KPFM, LEEM and PEEM
Work function variation for $K_2CsSb$ and $Cs_3Sb$

- KPFM measurements difficult and somewhat unreliable

- Use LEEM to measure work function
Spin Polarized Low Energy Electron Microscopy (SPLEEM)

A flange-on type low energy electron microscope

K. Grzelakowski and E. Bauer
Physikalisches Institut, Technische Universität Clausthal, D 38678 Clausthal-Zellerfeld, Germany


Unlocking Bloch-type chirality in ultrathin magnets through uniaxial strain

Gong Chen, Alpha T. N'Diaye, Sang Pyo Kang, Hee Young Kwon, Changyeon Won, Yizheng Wu, Z. Q. Qiu & Andreas K. Schmid

Nature Communications 6, Article number: 6598 (2015) | Download Citation
(SP)LEEM measurements of work function
LEEM measurement of work function of Cs$_3$Sb

Sequential deposition

Co-deposition @ 90°C

Co-deposition @ 70°C

Same amplitude, much lower spatial frequencies at 70°C (lower transverse fields)
Summary: work function imaging using LEEM

- 20 nm spatial resolution (2 nm)
- 5 meV work function ‘noise’
- Chemical potential roughness causes strong lateral potential gradients that degrade emittance
- Strong dependence of gradients on deposition temperature
- More work to be done on Cs3Sb at different growth temperatures, rates, and other antimonides

The best probe should be PEEM (photon energy).....1st attempt not successful due to low flux

New coherent supercontinuum source being tested.....a Fowler plot / pixel at few nm resolution!
QUESTIONS