Ultra Low Work Function Coating for Combined Passive Electron Emission and Collection for Spacecraft Charging Neutralization and Electrodynamnic Tether Applications

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12CaO-7Al₂O₃

[Ca₂₄Al₂₈O₆₄]⁴⁺ 2O²⁻

[Ca$_{24}$Al$_{28}$O$_{64}$]$^{4+}$ 4e$^-$

Cathode Flange

Cathode Tube

Bottom Crucible with one half insert located one half insert located over the C12A7 load

Two Insert

One Half of Insert

Crucibles

Cathode Tube

Two Insert

Halves Enclosed

Keeper

Cathode Tube Mounted to Cathode Flange

Enclosed Keeper

Enclosed

Keeper Mounted to Cathode Flange
Plasma Electron Emitters are Nice, but are there Other Applications for Electride Electron Emitters?
Plasma Contactor

- DC-DC Converters & Electronics
- Solenoid Valve
- Pressure Regulator
- Xenon Tank
- Hollow Cathode with Keeper
- Fill & Drain Valve
- Pressure Transducer
• Why not use electride to coat a tether and passively EMIT and COLLECT electrons?

• One question to answer is where the floating point will end up.
  – How long is the negatively biased section relative to the positively biased section?
Electron Collection

Space Plasma

Sheath

+V

0 V

$\eta_{eo}$

$T_{eo}$

Positively Biased Tether
Thermionic Emission

\[ j = AST^2 \exp\left(\frac{-e\Phi}{kT}\right) \]

\[ S = \exp\left(\sqrt{\frac{e^3V}{4\pi d\varepsilon_o kT}} \cdot \frac{1}{kT}\right) \]
Space Charge Limited Current

\[ j = \frac{2}{9\pi} \sqrt{\frac{e}{2m}} \frac{V^2}{d^2} \]

\[ j = (2.25 \times 10^{-6}) \frac{V^2}{d^2} \]
\[ j_{TE} > j_{SCLC} \] ?

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\[ j_{SCLC} > j_{TE} \] ?

\[ j = AST^2 \exp\left(\frac{-e\Phi}{kT}\right) \]
Some typical high current density emitters

<table>
<thead>
<tr>
<th>Compound</th>
<th>$\Phi$ (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LaB$_6$</td>
<td>2.66</td>
</tr>
<tr>
<td>CeB$_6$</td>
<td>2.43</td>
</tr>
<tr>
<td>Ba-W</td>
<td>2.14</td>
</tr>
<tr>
<td>C12A7</td>
<td>0.6</td>
</tr>
<tr>
<td>Material</td>
<td>$T$ (K)</td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
</tr>
<tr>
<td>LaB$_6$</td>
<td>1900</td>
</tr>
<tr>
<td>CeB$_6$</td>
<td>1750</td>
</tr>
<tr>
<td>Ba-W</td>
<td>1350</td>
</tr>
<tr>
<td>C12A7</td>
<td>440</td>
</tr>
</tbody>
</table>

**Questions:**

- Same Geometry?
- Same Applied Voltage?
- Same Emission Current!
The graph shows the relationship between current density (A/m²) and tether potential (V). The red line represents the OML, and the blue circles represent the OOPIC Pro. The y-axis represents current density ranging from 0.00 to 0.10 A/m², and the x-axis represents tether potential ranging from 0 to 1000 V.
The graph illustrates the relationship between current density (A/m²) and tether potential (V). It shows three distinct emission processes:

1. **OML Electron Collection**: The red line represents this process, which shows a gradual increase in current density as the tether potential increases.
2. **SCL Electron Emission**: The black line indicates this process, characterized by a sharp increase in current density at a specific tether potential.
3. **TL Electron Emission**: The blue line denotes this process, which remains relatively constant at a lower current density.

Key points:
- **Preliminary Calculation**: This refers to the initial predictions made for the electron collection efficiency.
- **270 K, 0.6 eV**: This notation indicates the temperature and energy level at which electron emission occurs.
- **n_{eo} = 10^{11} m^{-3}**: This represents the electron density at the emission site.

The graph also highlights a **5X Higher** emission rate at a certain point, indicating a significant increase in electron density or efficiency under specific conditions.
Conclusion

• A new material may be available soon that has a very low work function that is stable under high emission current
• Preliminary calculations suggest that electron emission length of a bare tether might be ~1/5 of the positively biased section
• Ohmic heating might reduce negative bias section length even more
• Configuration of electride into gun geometry might be an alternative to coating tether