Secondary Electron Emmission:

Reading 25 Mar 2020

By ion bombardment

SEY - secondary electron yield $\frac{\text{electron}}{\text{incident electron}}$

By electron bombardment

Dec 13 1987

Source NRL: High-Current Density, High-Brightness Electron Beams from Large-Area Lanthanum Hexaboride Cathodes

LaB_6 10-50 A/cm^2 pulses with high repetition rate on the order of 10^{-5} torr

Gallagher reports LaB_6 @ 1400°C is resistant to poisoning at air pressure as high as 5E-5 Torr

Thermionic limited electron current density is determined by the Richardson-Dushman equation

$$J\,[A/cm^2] = AT^2 \exp(-11600\,\text{Ø}/T)$$

A and Ø are constants, T is cathode temp in [K]

Lafferty reports the values $A = 29 \frac{A}{cm^2\text{-}K^2}$ and Ø = 2.66 eV

Field assisted Thermionic Emission

$$J\,[A/cm^2] = AT^2 \exp\left((139\,\mathcal{E}^{1/2}/T) - (11600\,\text{Ø}/T)\right)$$

- The Schottky equation

$\mathcal{E}$ - electric field at cathode surface in [kV/cm]

work function of 2.6 eV

CFR Experience (Tom during his 23 Mar 2020 Meeting)

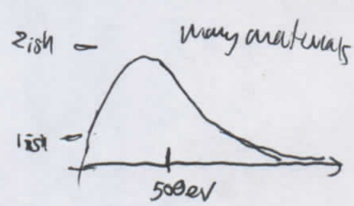
Practical limit for our LaB_6 crystal current: 10 A/cm^2

If we run driving a larger current, we evaporate LaB_6 material from the crystal

Ion energy and sputtering yield?

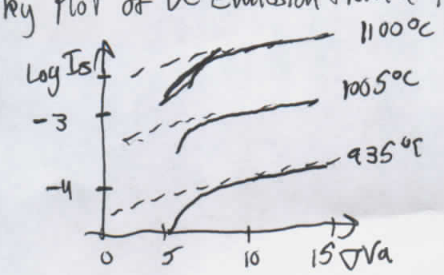
CERN: Secondary Electron Yield of Technical Materials and Its Variation w Surface Treatments

→ This is for electron bombardment of metals



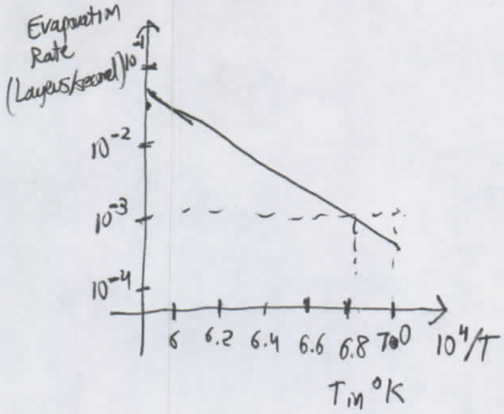
Lots of references in the literature to Lafferty

Schottky Plot of DC Emission from a typical diode → Learn about Schottky plots



Thermionic Emission Properties of a LaB6 Cathode/Rhenium Cathode

J.D. Buckingham 1965



$$\log(R) = \log(A) - 5040\,\phi\,\frac{1}{T}$$

R - evaporation rate

A - a constant

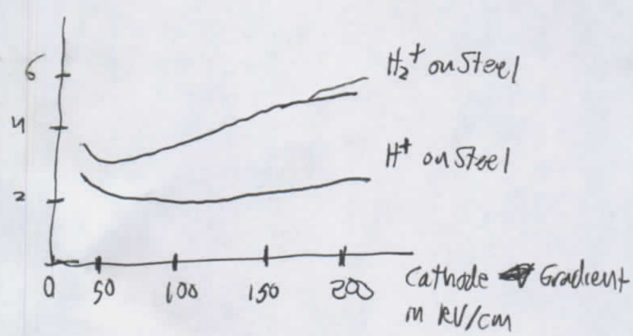
ϕ - the activation energy in V

The slope gives $\phi \simeq 3.25\,eV$

Lafferty J.M 1951 J. Appl Phys, 22, 299-309 → General Electric Research Lab Schenectady NY

Boride Cathodes

[E.W. Webster Secondary Electron Emission from Metals under Positive Ion Bombardment in High Extractive Fields 1951



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[Low Temperature Plasma Processing Environment Mattox Handbook of Physical Vapor Deposition 2010

Metals generally have a secondary electron emission coefficient of less than 0.1 under ion bombardment while the secondary electron emission coefficients of oxide surfaces are higher. SEE from e bombardment much higher than from ion bombardment]

{ If I had to guess, it is a velocity thing - relative velocity of electron clouds/nuclei

$$V = \sqrt{\frac{2E}{M}}$$

$E = \frac{1}{2} mV^2$

$E/m = \frac{1}{2}V^2$

These cross sections and yields are given in terms of keV/amu

1 $\frac{keV}{amu}$ for Hydrogen is 1 keV

for Deuterium is 2 keV

for Argon is 40 keV }

LaB_6 Mechanical Properties

$M = 203.78 \frac{kg}{kmol}$

$\rho = 4.72 \frac{g}{cm^3}$

$T_{melting}$ 2210°C (2480°K)

α_{CTE} 5.6E-6 $\frac{m/m}{°K}$

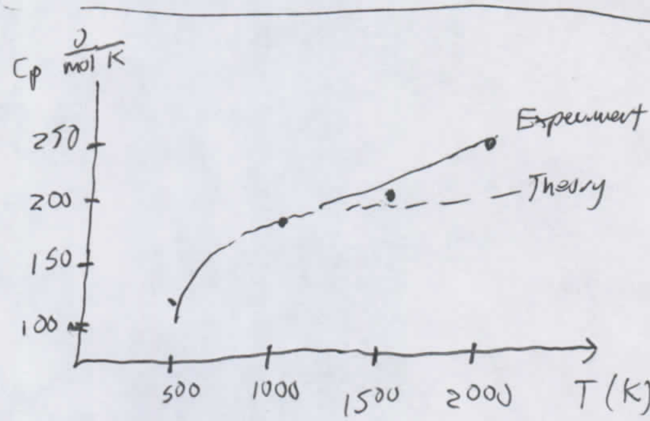
Resistivity μΩ-cm ~50

Emissivity 0.765

Evaporation Rate @ 1800K 2.2E-9 $\frac{g}{cm^2\text{-}sec}$

.emsdiasum.com/microscopy/technical/datasheet/80920.aspx

Comparing LaB_6 to Cerium Hexaboride Cathodes



$C_p \approx 200 \frac{J}{mol\text{-}K}$

$981 \frac{J}{kg\text{-}K}$

Source: S.P. Gordienko 1981
Specific Heat of Lanthanum Hexaboride
Soviet Powder Metallurgy and Ceramics
20(1), 66-68, doi:10.1007/bf00791914

Specific Heat Capacity:

Temperature Ranges 2-12 K
25-298 K
518-1483K
1341-2018
1100-2200K

(20°C) Thermal Conductivity 47 $\frac{W}{m\text{-}K}$ Source: Edgetech Industries LLC
www.edge-techind.com/Products/Functional-Materials/Grinding-Media/Lanthanum Hexaboride-751-1.html

Thermal Expansion 6.2E-6 $\frac{m/m}{°K}$ (20-900°C)

Current Density 150A/cm² @ 1950°C

Electrical Resistance 15 μΩ-cm (20°C)

Lafferty 1950 Boride Cathodes J Appl Phys 22 (3) pg 299

$$\log_{10}\left(\frac{I}{T^2}\right) = \log_{10}(A) - \frac{11600\,\phi}{2.303\,T}$$

$$\frac{I}{T^2} = A \cdot 10^{\wedge}\left(\frac{-11600\,\phi}{2.303\,T}\right)$$

$$I = AT^2 \cdot 10^{\wedge}\left(\frac{-11600\,\phi}{2.303\,T}\right)$$

Table II · Hexaboride Emission Constants

Boride	$A\ \left(\frac{A}{cm^2 - K^2}\right)$	ϕ (Volts)
CaB_6	2.6	2.86
SrB_6	0.14	2.67
BaB_6	16	3.45
LaB_6	29	2.66
Mischmetal Boride	14	2.64
ThB_6	0.5	2.92
CeB_6	3.6	2.59

He has a resistivity plot also