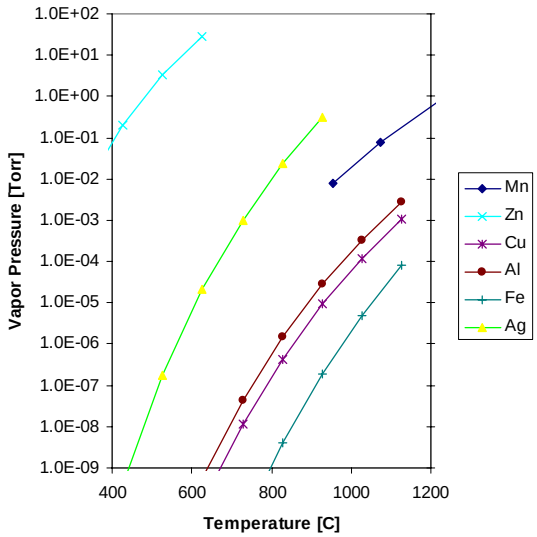
LBNL-61978

Comments on cathode contaminants and the LBNL test stand
F. Bieniosek, D. Baca, W. Greenway, M. Leitner, J.W. Kwan,
Nov. 13, 2006

This report collects information on cathode contaminants we have gathered in the process of operating the LBNL DARHT cathode test stand.

Information on contaminants is compiled from several sources. The attachment, "Practical Aspects of Modern Dispenser Cathodes", is from Heat Wave Corp. (TB-134) and was originally published in Microwave Journal, September 1979. Cathode contamination depends on both material choices and residual gases. Table 1 of TB-134 lists materials that can poison dispenser cathodes. These include reactive residual gases or vapors such as oxygen, water vapor, benzene, chlorine, fluorine, sulfur, silicon, and most metals other than molybdenum, rhenium, tungsten, and copper. The metals interact with the cathode surface through their vapor pressure. A paper by Nexsen and Turner, J. Appl. Phys. 68, 298-303 (1990) shows the threshold effects of some common residual gases or vapors on cathode performance. The book by Walter H. Kohl, Handbook of Materials and Techniques for Vacuum Devices, also contains useful information on cathodes and poisoning agents.

A plot of the vapor pressures and poisoning effect of certain metals (from Kohl) is shown below. Note that the vapor pressure of zinc is 1.1 x 10^{-8} Torr at 400 K = 127 C, and 2.7 x 10^{-5} at 500 K = 227 C. By contrast iron reaches a vapor pressure 1 x 10^{-8} between 800 and 900 C. Therefore it is important to eliminate any brass parts that could exceed a temperature of 100 C.



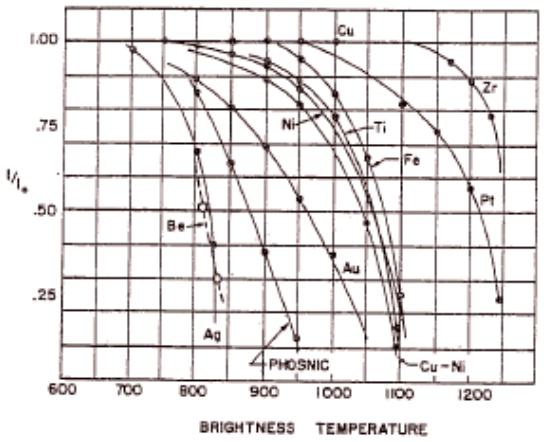


FIG. 16.23. Normalized short-time poisoning current vs. poisoning agent temperature (Cathode at 1100°C_{Br}). After Shaw *et al.*[176a] (*Courtesy Raytheon Co. and New York University*)

Many structural components of the cathode assembly contain steel. At 500-600 C in an oxygen atmosphere chromium oxide may outgas from the steel. [Cho, et.al., J. Vac. Sci. Technol. A 19, p. 998 (2001).] Steel may also contain silicon, and sulfur at low concentrations. Therefore use of steel should be limited or avoided at high temperature near the cathode.

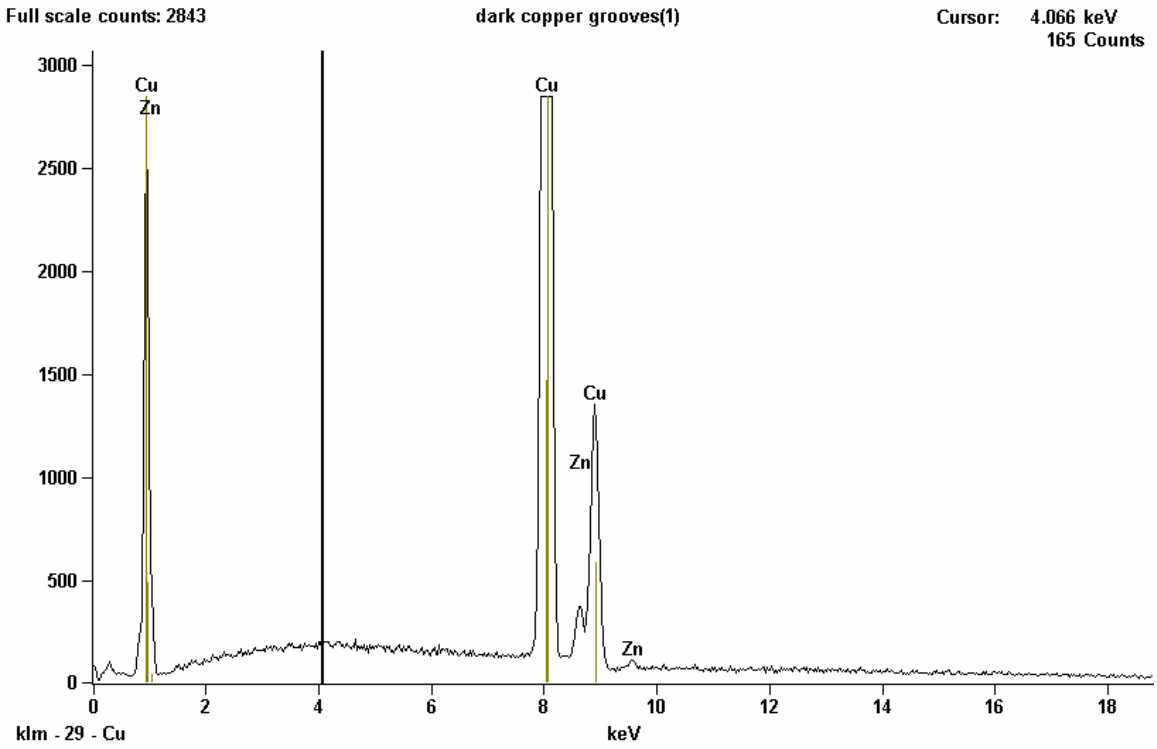
Materials that should be avoided in the vicinity of the cathode include brass, silver, zinc, non-OFHC copper, silicates, and sulfur-containing lubricants such molybdenum disulfide.
-Macor is an aluminosilicate-based insulator that is not stable at high temperature. Macor near the cathode should be replaced by a high-temperature insulator such as alumina ceramic.
-Other insulating materials that contain silicates, such as fiber insulating sleeves, should be avoided.
-Copper that is not OFHC contains oxygen and other impurities and should be avoided.
-Lubricating screw coatings should be chosen carefully to have no sulfur content.

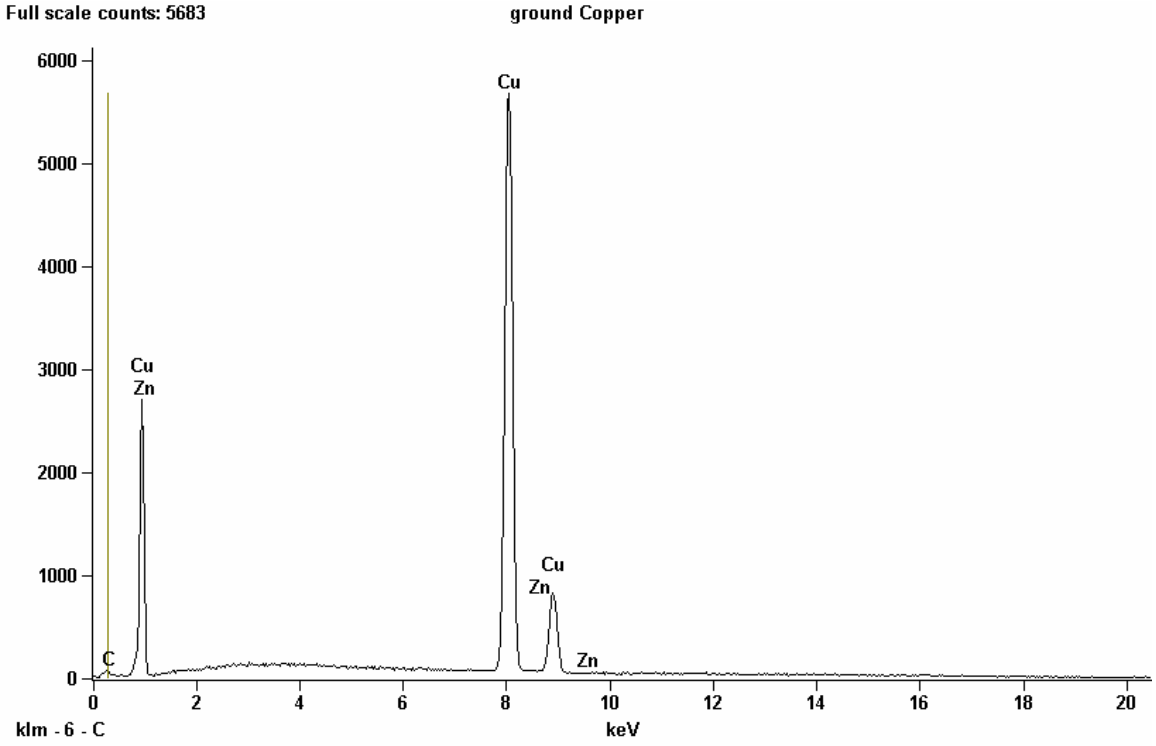
Common sources of contamination that can cause low emission include water, saliva, silicates such as glass dust, etc. Cathodes should be handled in near clean-room conditions to minimize the amount of water vapor on the cathode surface from breathing, etc. Cathodes should also be stored in such as a way as to avoid contact with materials such as glass dust and water vapor.

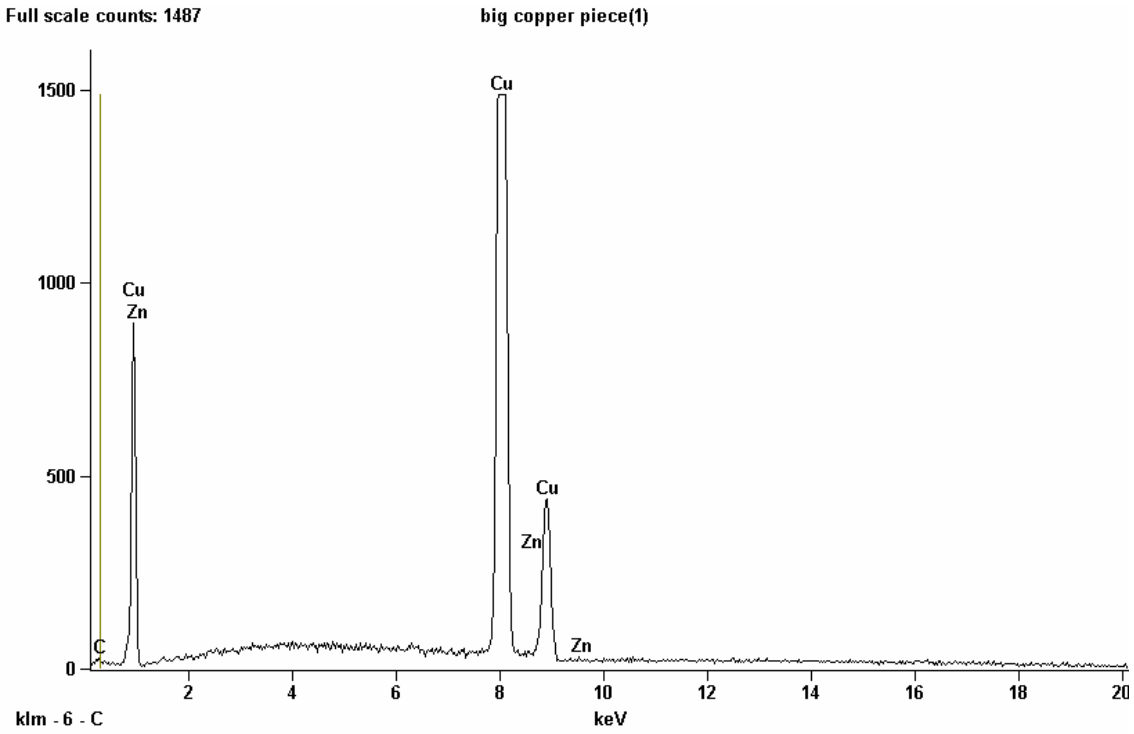
Attached are plots of SEM data for several test pieces that were taken from the LBNL test stand after activation of the 311x scandate DARHT cathode. Several copper pieces in the anode region were tested, showing the presence of zinc. Two stainless steel nuts coated with a contaminant were also tested. The SEM data indicates the presence of zinc and some sulfur. The zinc has been traced to a brass piece, and the sulfur to the possible use of molybdenum disulfide lubricant on a nut in the system. Finally a swipe of contaminant on the vacuum vessel wall analyzed by a commercial testing laboratory shows again the presence of zinc.

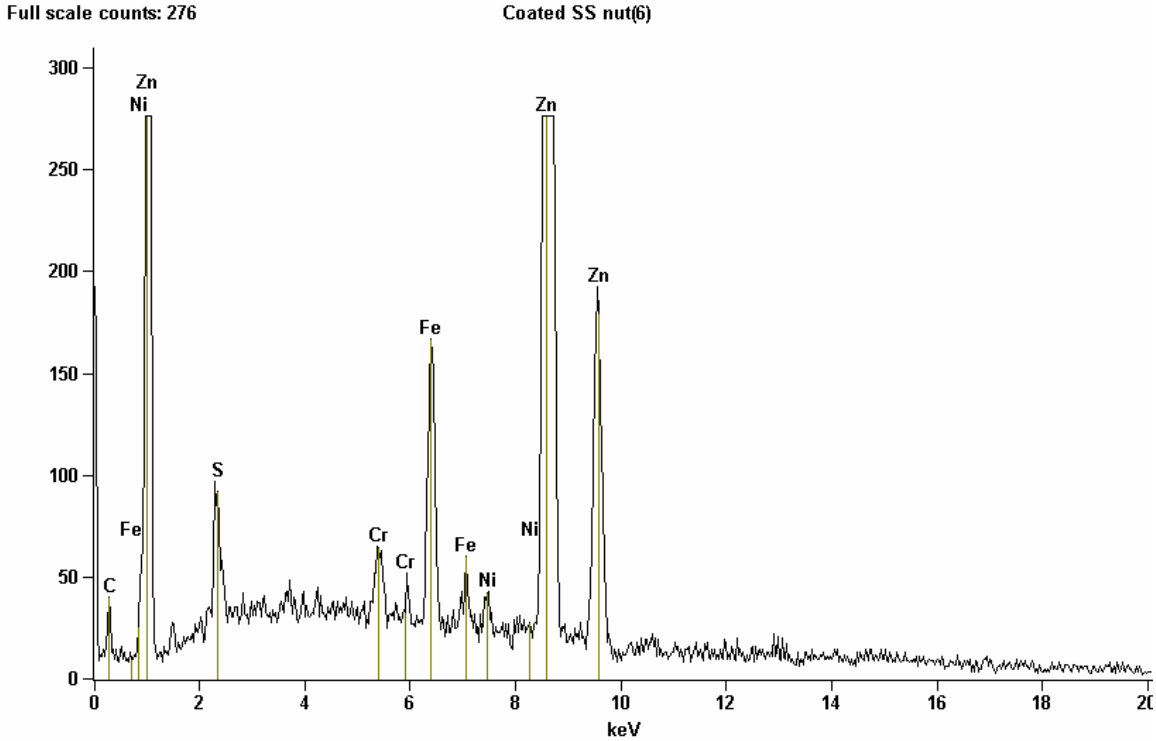
In order to improve system cleanliness, we have implemented the following modifications to the test stand:
- replaced the brass piece with copper-tungsten
- replaced Macor insulators with alumina ceramic
- used boron nitride lubricant
- replaced copper beam stop with OFHC copper
- replaced steel pieces near the cathode where possible with copper or copper-tungsten

A clean fire of high-temperature components and a high-current filament test have shown no evidence to date for contaminants since the modifications.


Full scale counts: 2843
dark copper grooves(1)
Cursor: 4.066 keV
165 Counts
3000
2500
2000
1500
1000
500
0
Cu
Zn
Cu
Cu
Zn
Zn
0
2
4
6
8
10
12
14
16
18
klm - 29 - Cu
keV


Full scale counts: 5683
ground Copper
6000
5000
4000
3000
2000
1000
0
Cu
Cu
Zn
Cu
Zn
C
Zn
0
2
4
6
8
10
12
14
16
18
20
klm - 6 - C
keV





Results for Coated SS Nut2

MICRO ANALYTICAL LABORATORIES, INC.

METALS-WIPE

1049
Lawrence Berkeley Laboratory
One Cyclotron Road - MS - 48 - 102
Berkeley, CA 94720

PROJECT:
DARHT
CATNODE TEST STAND
JOB NO. Z2D120

Micro Log In **88137**
Total Samples 1
Date Sampled 10/17/2006
Date Received 10/17/2006
Date Analyzed 10/20/2006

SAMPLE ID / DESCRIPTION

Micro Sample No.	Client Sample No.
88137-01	1

12" X 12" WIPE SAMPLE
DARHT CATNODE TEST STAND

ANALYTE	Analysis Results ug / sq. ft	Reporting Limit ug / sq. ft	Comments
Silver (Ag)			
Aluminum (Al)	**39**	1	
Arsenic (As)			
Barium (Ba)			
Beryllium (Be)			
Calcium (Ca)			
Cadmium (Cd)			
Cobalt (Co)			
Chromium (Cr)			
Copper (Cu)			
Iron (Fe)			
Magnesium (Mg)	**160**	5	
Manganese (Mn)			
Molybdenum (Mo)			
Nickel (Ni)			
Lead (Pb)			
Antimony (Sb)			
Selenium (Se)			
Tin (Sn)			
Titanium (Tl)			
Thallium (Tl)			
Vanadium (V)			
Zinc (Zn)	**3700**	100	
Mercury (Hg)*			

Technical Supervisor: _____ 10/17/2006
Farid Ramezanzadeh, Metals Supervisor — Date Reported

Analyst: FR

Preparation Method NIOSH 7300, 1994 (MODIFIED) **Test Method** EPA 6010B

NA = Not Applicable. ND = Not Detected (below detection limit). Unless otherwise indicated on this report, all required Quality Control samples have been determined to be in control prior to releasing these analytical results. Unless otherwise stated in this report, all samples were received in acceptable condition for analysis. This report must not be reproduced except in full, with the approval of Micro Analytical Laboratories, Inc., and pertains only to the samples analyzed.