BEAM TUBE COPPER PLATING SPECIFICATIONS DUE TO VACUUM REQUIREMENTS

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General: From the vacuum point of view the copper plating must meet the following requirements.

1) It should never peel, flake, or detach itself in any fashion from the stainless steel tubing.
2) It should not photodesorb excessively so as to cause beam lifetimes shorter than design requirements.
3) It should not statically outgas excessively so as to cause warm half cell pump down times to exceed 24 hours.
4) It should not introduce any contaminants into the vacuum system that might corrode or make inoperable valves, pumps, bellows or other vacuum components.

All other vacuum requirements are intended to insure that these four basic requirements are met. Requirements for RRR and thickness (from the electrical viewpoint) of the plating are contained in SSC-N-434.

1. Mechanical Requirements. The main plating requirement from a vacuum point of view is that the plating never peel, flake, or otherwise become detached from the stainless steel beam tube. Various tests have been performed at BNL on the strength and durability of the bond produced by the present PCK developed plating process. The results of these tests indicate that the bond

is excellent. The main reason for this, according to two BNL metallurgists, is that electroplating is started immediately after surface activation. A list of suggested mechanical requirements, provided by J. Skaritka, BNL, is given in Table I. A program to develop appropriate mechanical tests to insure adhesion of the copper plating for the lifetime of the SSC is necessary. The description of the requirement or test in Table I is not meant as a complete technical description.

Table I

Requirement/Test	Test Frequency
1. Visual delamination inspection	every tube
2. Plating shall not vary more than ± 10% of required thickness	every tube
3. ASTM 360° double back bent test to check for delamination	every tube
4. Scratch test for voids and flaking	every tube
5. Stress cycled at LHe temperature 1000 to 10,000 times and then test 3 and 4 performed	random tube per plating batch
6. Pull to failure test at LHe temperature	random tube per plating batch
7. Photomicrographs	random tube per plating batch

2. Photodesorption Requirements. The present PCK plating process produces copper plating that meets photodesorption requirements. The main protodesorption requirement is that the number of H_2 molecules desorbed per photon from LHe temperature copper plating be less than 0.05 for an accumulated photon dose of 10^{19} photons per meter of beam tube. It is

impractical to perform photodesorption tests on plating samples on a routine basis. Electrodesorption tests can be routinely performed on plating samples and have been performed on beam tube samples plated by the PCK process. Therefore, for the purpose of providing photodesorption requirements, it is assumed that photodesorption and electrodesorption are directly proportional, and it is recommended that the copper plating meet the following electrodesorption requirements. The incident electron energy shall be 1.5 keV. The number of molecules per incident electron after a 24 hour pumpdown should be less than the following:

Table II

Integrated Dose	H_2/e^-	Mass $28/e^-$	Mass $44/e^-$	Mass $18/e^-$	All Other/e^-
3×10^{-4} Coul/cm^2	5.0	1.2	1.2	1.2	0.05
4×10^{-3} Coul/cm^2	1.4	0.2	0.2	0.1	0.01
5×10^{-2} Coul/cm^2	0.2	.016	.016	0.006	0.002

3. Static Outgassing. To achieve an average pressure before cool-down of 10^{-4} Torr in a 114 m long half cell pumped at both ends requires an outgassing rate of 5×10^{-10} Torr·l/s/cm^2 if H_2O is the dominant gas and an outgassing rate of 1.5×10^{-9} Torr·l/s/cm^2 if H_2 is the dominant gas. The somewhat arbitrary before-cool-down pressure of 10^{-4} Torr is chosen to give a low surface coverage after cool-down and hence minimize photodesorption. A pressure of 10^{-4} Torr corresponds to a surface coverage of 3×10^{-3} monolayers in a 3.3 cm id pipe. This is a small coverage compared

to that existing on the tube surface before cool-down. Photodesorption measurements on unbaked beam tubes indicate that an additional coverage of $3x10^{-3}$, or even $3x10^{-2}$, should not significantly increase photodesorption.

Two measurements of static outgassing have been performed on copper plated beam tubes. A measurement at BNL gave a total outgassing rate after 24 hours of pumping of $1.3x10^{-9}$ Torr·l/s/cm^2. A measurement at CERN after 24 hours of pumping gave an outgassing rate for H_2 of $8x10^{-9}$ Torr·l/s/cm^2 and a rate for H_2O of $5x10^{-9}$ Torr·l/s/cm^2. The BNL measurement indicates the before-cool-down pressures of 10^{-4} Torr are achievable. The CERN measurement indicates before-cool-down-pressures of 10^{-3} Torr. More outgassing measurements are required since these two disagree. For the moment we will use the 10^{-4} Torr requirement for before-cool-down-pressure.

In writing outgassing specifications it is realized that H_2O outgassing rates are determined by the history of the tube and local humidity. Therefore we should require that both total outgassing and H_2 outgassing meet the following:

Table III

Component	Maximum Outgassing (unbaked)
Total (less H_2)	$1x10^{-9}$ Torr·l/s/cm^2
H_2	$1.5x10^{-9}$ Torr·l/s/cm^2

4. Plating Surface Preservation. It was noted at the January '87 workshop on photodesorption that the surface of the copper plating will oxidize after long exposure to air. This oxidation, it was suggested, will have deleterious effects on the conductivity of the plating and possibly on the photodesorption properties of the plating. To minimize oxidation the tubes should be

evacuated or filled with dry nitrogen and then sealed by the plater. However, there may be long periods during magnet construction and installation when beam tubes will be exposed to air. A "chromate pickle" of the copper plating surface has been suggested to retard oxidation. The effect of a "chromate pickle" on photodesorption properties is not known. Effects of such a surface preservation technique are being investigated; it is not recommended as a specification at this time.

5. Surface Roughness. The PCK plating procedure gives a surface roughness of 5 μm rms peak to valley. If it is necessary to reduce static outgassing, surface roughness or surface finish may have to be modified. At present no change to the surface given by the PCK process is recommended. SSC-N-285 also indicates that the surface roughness is acceptable from the electrical point of view.

6. Contaminants. The CERN outgassing measurement, at present, is the only test that detected the presence of a contaminant. The contaminant was chlorine. The chlorine disappeared after a 200°C bake for 24 hours. Chlorine was not detected in electrodesorption tests with sensitivities greater than that required by the CERN detection of chlorine. To insure that no contaminants are present we should require that no corrosives, heavy metals, or heavy hydrocarbons have a static outgassing rate greater than 1×10^{-12} Torr·l/s/cm^2 from an unbaked plating sample and that the total outgassing rate of all contaminants be no greater than 1×10^{-12} Torr·l/s/cm^2.

7. Hydrogen Removal. At present photodesorption measurements indicate that it is not necessary to require hydrogen removal from the copper plating. The measurements from KEK showing photodesorption to be decreased by an order of magnitude in the presence of a low (700 gauss) magnetic field further reduce the probability that hydrogen removal will be required.

8. Recommended Specifications. The vacuum specifications for copper plating are summarized as follows:

Mechanical Specifications. Suggested mechanical requirements are listed in Table I. A program to determine exact mechanical specification is needed.

Electrodesorption Specifications. The plating should meet the specifications of Table II.

Static Outgassing Specifications. The plating should meet the specifications of Table III.

Contaminants Specifications. No corrosives, heavy metals, or heavy hydrocarbons shall have a static outgassing rate greater than $1x10^{-12}$ Torr·l/s/cm^2 and the total outgassing rate of all contaminants, shall be no greater than $1x10^{-12}$ Torr·l/s/cm^2.

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