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GLOW DISCHARGE PROCESSING VS BAKEOUT FOR ALUMINUM STORAGE RING VACUUM CHAMBERS*

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ABSTRACT

Experiments were carried out on laboratory and prototype scale systems in order to establish the feasibility of argon discharge processing the PEP† storage ring aluminum vacuum chambers. Electron-induced desorption rates showed significant reductions following bakeout and/or argon glow discharge treatment ($> 10^{19}$ ions cm^{-1}). Data are presented and discussed in relation to advantages and problems associated with: water removal, argon trapping and subsequent release, electron energy dependence, discharge distribution, and surface plasma chemical effects.

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†PEP, the Positron Electron Project, is a DOE-funded joint storage ring project of the Lawrence Berkeley Laboratory and the Stanford Linear Accelerator Center, presently under construction at SLAC.

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Introduction

In order to store electrons and positrons for experimentally useful times (hours) the pressure in the vacuum chamber must be maintained low enough to avoid excessive beam loss due to interaction with gas molecules.

The principal gas source during beam storage is due to synchrotron radiation striking the chamber walls and releasing adsorbed gases.[1] After extensive bakeout many hours of synchrotron radiation bombardment are necessary to "scrub" the intercepting areas and reduce the photodesorption effect to tolerable levels. Accelerator vacuum physicists are always looking for some method of treating the vacuum walls in order to reduce thermal, ion, electron, and photon desorption values. The success at CERN[2] with in-situ glow discharge cleaning of the proton Intersecting Storage Ring has prompted investigators at PETRA[3,4] and here at SLAC to examine the feasibility of using glow discharge cleaning on these large electron-positron colliding beam machines.

Measurements of simulated synchrotron desorption rates (using electrons) were made following various bakeout and glow discharge treatments in order to compare their applicability to the PEP machine.

Experimental

Two experimental chambers were used: an aluminum diode system was used to obtain quantitative data on electron-induced desorption rates as related to bakeout and argon glow discharge treatments, and a 3-meter prototype PEP chamber was used to check the discharge distribution and sputtering effects when using the distributed ion pump anode as the glow discharge electrode.

A schematic diagram of the diode arrangement is shown in Fig. 1. The 6061-T6 aluminum alloy chamber, ion gauge, and quadrupole mass spectrometer were separated from the 400 ℓ/sec ion pump by an orifice having a

conductance of 10 ℓ/sec for nitrogen. The mass spectrometer was calibrated for H_2, CH_4, CO, N_2, CO_2, and argon, using the CH_3^+ fraction for CH_4, the C^+ fraction for CO, and the N^+ fraction for N_2. The quadrupole sensitivities varied between 7 and 100 amps/torr for all of the gases measured. H_2O partial pressures were estimated using the N_2 sensitivity factor. In order to calibrate for neon and argon it was necessary to turn off the ion pump; otherwise hydrogen, helium, neon, and argon were released in perturbing quantities. A coaxial tungsten wire 0.25 mm in diameter and 660 mm long served as a source of electrons during electron bombardment and as anode during glow discharge argon bombardment. The chamber was water-cooled during both glow discharge treatment and electron bombardment.

The aluminum surface area under bombardment was ~ 1200 cm^2 and dose rates of 1.3×10^{15} ions $\cdot$ sec^{-1} $\cdot$ cm^{-2} and 5.2×10^{14} electrons $\cdot$ sec^{-1} $\cdot$ cm^{-2} were used.

Argon glow discharge processing of the chamber was accomplished by introducing pure argon and maintaining a chamber pressure of ~0.04 - 0.08 torr. Both dynamic (pumping with LN_2 trapped mechanical pump) and static discharge processing were tried. It was necessary to apply about 1000V to the anode to initiate a glow discharge, after which the voltage was steady at ~300V.

Electron bombardment was employed to measure the effects of bakeout and/or argon glow discharge treatment and to establish relative equilibrium electron-induced desorption values. It was possible to vary the bombarding electron energy from 0 to 12 keV; however, most of the measurements were made at 300 eV (near the maximum in the energy dependence curve).[5]

Electron-induced desorption rates were calculated (for each gas of interest) from mass spectra signals, correcting for quadrupole sensitivity and pumping

speed variations. The procedure was to allow the system to reach a base pressure following the surface treatment, measure the prompt electron-induced desorption rates, continue electron bombardment ($> 10^{19} e \cdot cm^{-2}$), and then measure the final (asymptotic) rates. The chamber was exposed to the atmosphere for at least one half hour between surface treatments.

Results and Discussion

Table I is a summary of the results obtained for the various surface treatments.

Upon electron impact, partial pressure increases were noted for H_2, CH_4, Ne, CO, Ar, and CO_2. It appears that the increase in CH_4 is generated in the ion pump in proportion to increases in hydrogen. This was confirmed by isolating the ion pump with a valve and noting the change in the H_2/CH_4 ratio on electron bombardment. Neon and argon are also released from the ion pump whenever other partial pressures are increased. We also observe that CO_2 production on electron impact seems in some way related to the amount of H_2O available. When the partial pressure of H_2O is very low, little CO_2 is measured. Earlier measurements[6] on the SPEAR storage ring with a stored beam showed decomposition of H_2O into H + OH + O with a consequent small increase in CO_2, probably from the $CO + O \rightarrow CO_2$ reaction.

Of some interest is the mechanism by which the partial pressure of water vapor is reduced three orders of magnitude or more in several hours during and following the glow discharge treatment. Before bakeout or glow discharge the quadrupole was valved off with an H_2O partial pressure of $\sim 10^{-7}$ Torr. Following glow discharge the valve was opened to the quadrupole and it was possible to observe the pumping action as the H_2O partial pressure dropped much more dramatically than under the effect of the ion pump alone. It is known that

aluminum forms a number of different hydrated oxides and it appears that the glow discharge activates the surface in some way to pump and strongly bind H_2O. Heating (> 100°C) the aluminum surface following discharge showed a slight increase (from 1.4×10^{-10} to 1.5×10^{-10} Torr) in H_2O partial pressure, whereas H_2 plus CO increased from 2 to 6×10^{-9} Torr.

It is apparent that in a simple coaxial aluminum chamber an argon discharge treatment reduces the electron-induced desorption rates to the very lowest values, a static discharge being nearly as effective as the dynamic situation, where argon was being introduced and pumped away. In an actual storage ring chamber a number of problems arise. Figure 2 sketches a cross section of the PEP aluminum vacuum chamber, showing the integral cooling channel, beam chamber, and distributed ion pump chamber.

We are not encouraged to install any kind of permanent electrode (that could be used as a discharge anode) in the beam chamber due to induced current effects and beam perturbations resulting from any such element or change in cross section.[7] The obvious thought is to use the distributed ion pump anode as the glow discharge electrode and try to fill the beam chamber with ions through the pumping slots. This scheme has been proposed at PETRA.[3] Our tests with a 3-meter prototype chamber showed that it was possible to fill the entire three meters with a discharge from a 0.5 meter ion pump element located at one end. After a total dose corresponding to 10^{19} ions/cm^2 for the entire chamber, examination of the pump elements showed considerable local sputtering. No evidence of breakdown of the shielded insulators resulted.

Of central concern with any argon glow discharge treatment is the subsequent release of argon into the residual gas atmosphere, where it is nearly three times as effective as carbon monoxide in reducing beam lifetime.[3] Ion

pumping of argon is slow even with special cathodes; in addition, any argon that enters the ion pump can be reemitted at any time other gases are being pumped. Vacuum bakeout ($\sim 600^{\circ}K$) is being used as a means of reducing the residual argon in the stainless steel ISR chambers.[2] However, it is doubtful that a $450^{\circ}K$ bakeout (maximum possible with present PEP design) would do much in our case with aluminum. We will measure the thermal treatment argon reduction, as well as any possible increase in argon partial pressure as related to the ion pump's argon history. However, our present thinking is to use argon glow discharge processing only if bakeout and beam cleanup proves inadequate, or in the event of a vacuum chamber catastrophe, such as heavy hydrocarbon contamination, etc.

Conclusions

Argon glow discharge processing of aluminum was found to be superior to bakeout ($480^{\circ}K$) in reducing surface electron-induced desorption rates. Glow discharges could be propagated and easily filled the prototype storage ring test chamber without continuous electrodes. On the negative side, argon processing gives rise to an increase in argon partial pressure with its associated pumping reemission problems and its greater beam scattering effect.

Acknowledgements

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TABLE I

300V Electron-induced Desorption Measurements Following Various Surface Treatments

Surface Treatment	Gas Desorbed	Prompt Rate (mol/e)	Final Rate (mol/e)	Dose (e/cm^2)	Final H_2O Partial Press (Torr)
Chemical Cleaning and Pumpdown	H_2	6.8×10^{-3}	1.0×10^{-4}	1.8×10^{20}	1.0×10^{-7}
	CO	3.5×10^{-2}	8.2×10^{-5}		
	N_2	6.7×10^{-3}	4.4×10^{-6}		
	CO_2	2.2×10^{-3}	3.9×10^{-7}		
	CH_4	2.3×10^{-4}	1.2×10^{-6}		
Air Exposure and Pumpdown	H_2	3.5×10^{-3}			1.2×10^{-7}
	CO	8.4×10^{-3}			
	N_2	4.4×10^{-5}			
	CO_2	6.2×10^{-6}			
	CH_4	6.1×10^{-5}			
	Ar	$< 10^{-8}$			
Bakeout 140 hrs at 200°C	H_2	2.6×10^{-5}	4.7×10^{-6}	1.4×10^{19}	2.0×10^{-10}
	CO	1.5×10^{-3}	4.3×10^{-6}		
	N_2	2.6×10^{-4}	1.1×10^{-6}		
	CO_2	2.4×10^{-6}	$< 10^{-8}$		
	CH_4	8.1×10^{-5}	2.2×10^{-7}		
	Ar	7.2×10^{-8}	1.6×10^{-9}		
Air Exposure Pumpdown and Dynamic Argon Glow Discharge (0.04 Torr) 10^{19} ions/cm^2	H_2	1.5×10^{-4}	7.1×10^{-6}	4.9×10^{19}	2.2×10^{-10}
	CO	2.2×10^{-6}	2.0×10^{-7}		
	N_2	1.3×10^{-6}	4.5×10^{-8}		
	CO_2	$< 10^{-8}$	$< 10^{-8}$		
	CH_4	1.1×10^{-6}	3.3×10^{-9}		
	Ar	7.7×10^{-7}	2.0×10^{-9}		
Air Exposure Pumpdown and Static Argon Discharge (0.06 Torr) 1.1×10^{19} ions/cm^2	H_2	3.7×10^{-4}	9.9×10^{-6}	1.1×10^{19}	1.4×10^{-10}
	CO	9.7×10^{-6}	1.4×10^{-7}		
	N_2	5.6×10^{-6}	4.4×10^{-8}		
	CO_2	$< 10^{-8}$	$< 10^{-8}$		
	CH_4	3.2×10^{-6}	1.5×10^{-8}		
	Ar	1.4×10^{-5}	2.3×10^{-9}		

Figure Captions

1. Test chamber.

2. Cross section of PEP storage ring vacuum chamber.

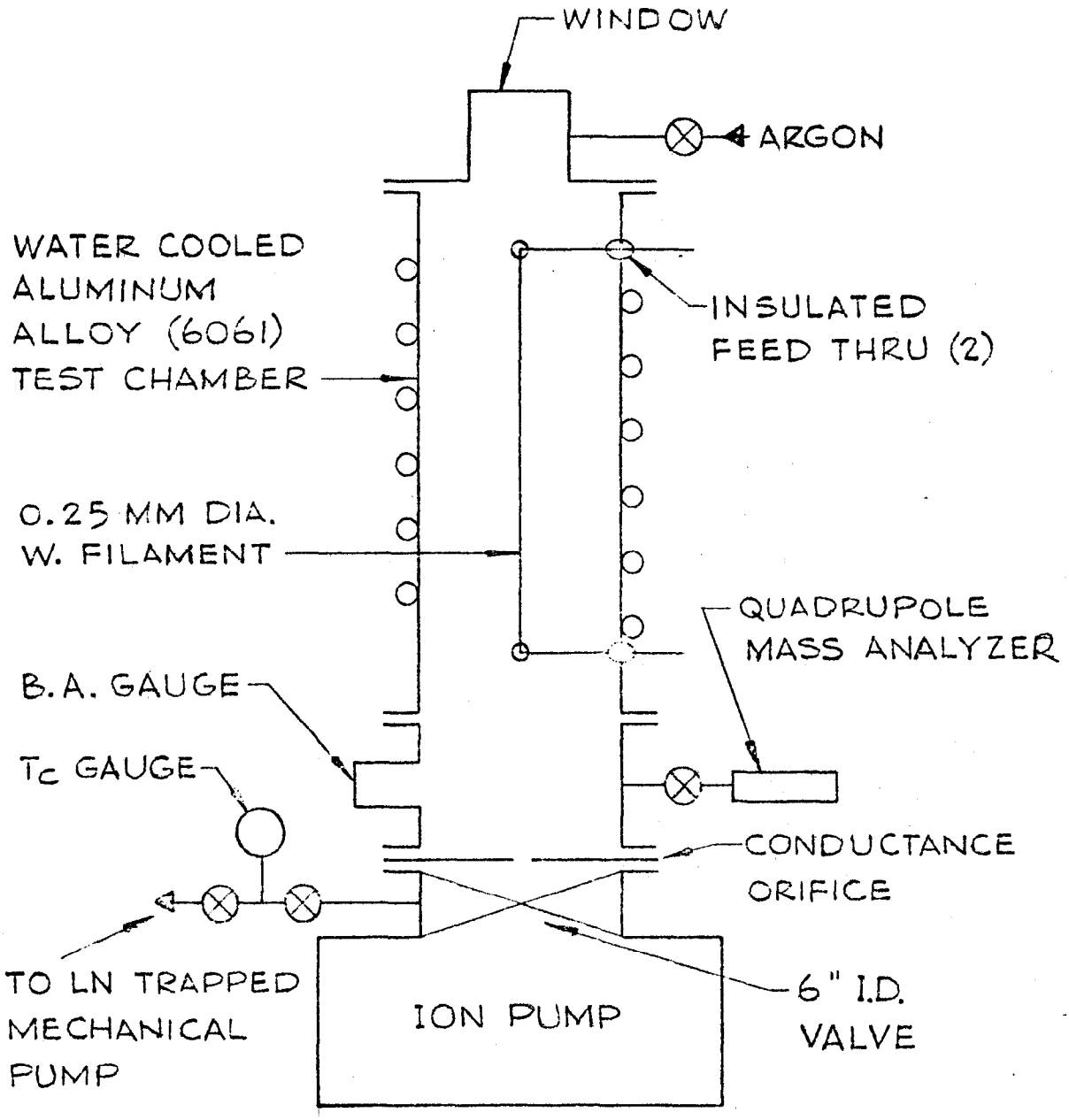
WINDOW
ARGON
WATER COOLED
ALUMINUM
ALLOY (6061)
TEST CHAMBER
INSULATED
FEED THRU (2)
0.25 MM DIA.
W. FILAMENT
QUADRUPOLE
MASS ANALYZER
B.A. GAUGE
Tc GAUGE
CONDUCTANCE
ORIFICE
TO LN TRAPPED
MECHANICAL
PUMP
ION PUMP
6" I.D.
VALVE

Fig. 1

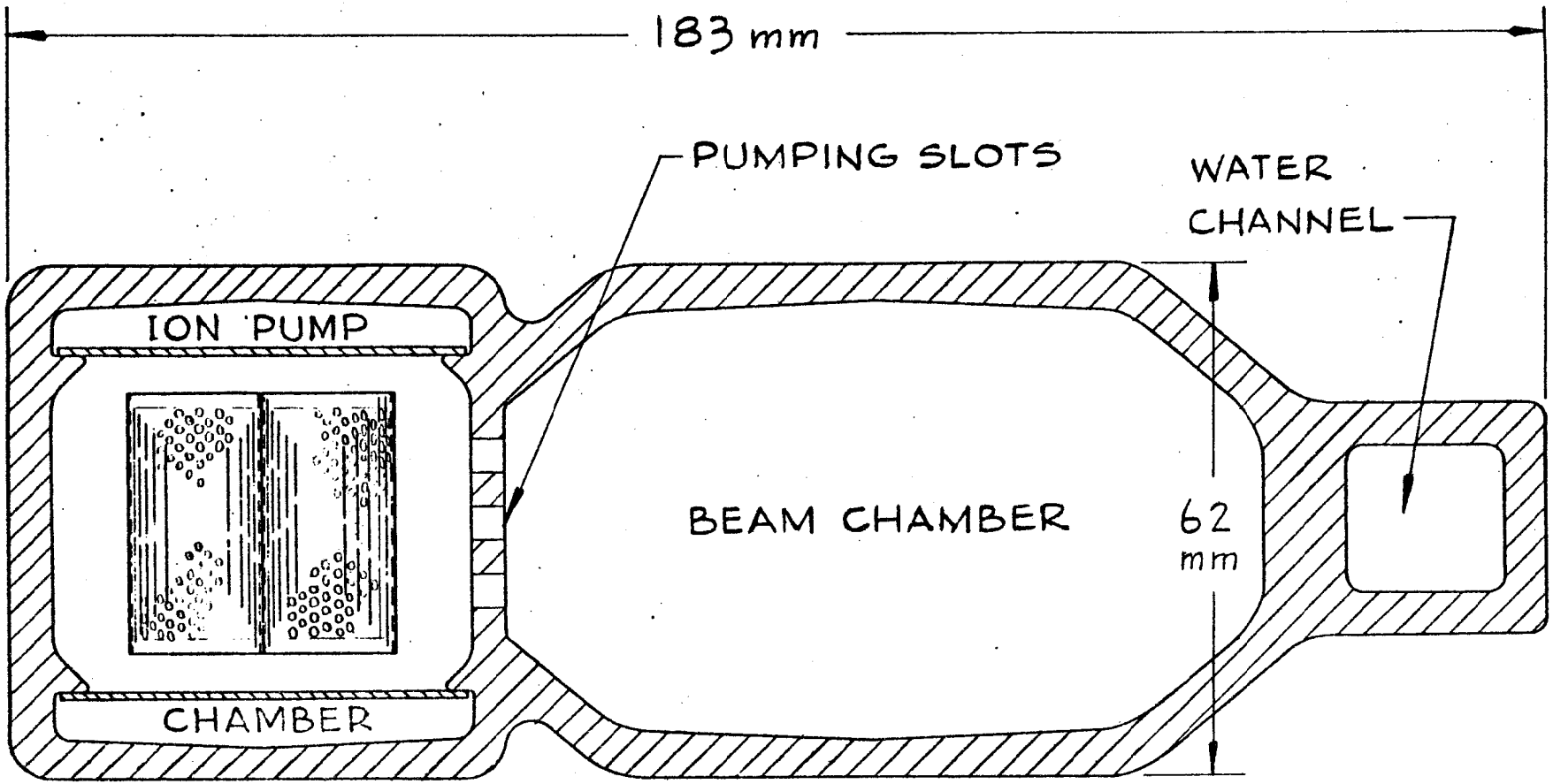
183 mm
PUMPING SLOTS
WATER
CHANNEL
ION PUMP
BEAM CHAMBER
62
mm
CHAMBER

Fig. 2