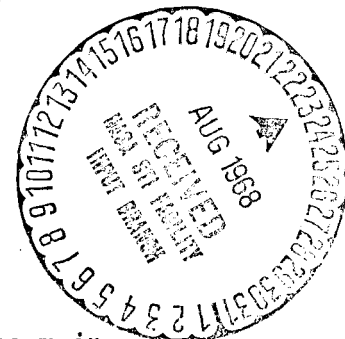N68-32187

Differential Ion Pumping for Vacuum Deposition*

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It is desirable to reduce the ultimate pressure that can be main-
tained during vacuum deposition to obtain films with low impurity content.
The major contributions to the total pressure during vacuum deposition
are outgasing from interior surfaces, leaks, permeation through gaskets,
back-streaming from the pump and the release of occluded gases from the
deposition material and holder. In a bakeable ultra high vacuum (UHV)
ion pump system evolution from all sources, except from the deposition
material and its holder, may be reduced to a low level. The pressure in
the substrate region may be reduced by reducing the conductance between
the source and substrate regions. In our preparation of thin films for
transport studies, the concept of differential pumping[1] has been utilized
in a bakeable UHV ion pump system to achieve lower pressures in the vicinity
of the substrate.

The differentially pumped evaporator is shown in figure 1. The basic
system consists of two bakeable chambers - a substrate chamber and a source
chamber - connected by a plate with a small conductance tube which allows the
vapor to traverse to the substrate. This arrangement confines the gases
generated by the source to the source chamber during evaporation and main-
tains a large differential pressure. Thus, deposition can be made at lower
pressures because only a small portion of the source gas load exists in the
substrate chamber. Both chambers are electronically pumped (140 liter/sec
Vac Ion pumps) and have ultimate pressures of 5×10^{-11} Torr. Each chamber

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(1) Schuetze, H. J. and Henning, K. E., Res./Dev., 64 (May 1965).

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was assembled from 15.24 cm stainless steel fittings which were modified by the addition of 3.81 cm ports to accommodate sources, substrates, crystal oscillators, etc. All flanges are sealed by the use of copper gaskets, and heater strips are attached directly to the chamber walls to provide bakeout temperatures up to 400°C.

The deposition source is a 2 KW self accelerated electron beam gun and is located 2.54 cm below the conductance tube and 28 cm from the substrate. The conductance tube used has the dimensions shown in the insert of figure 2. The calculated conductance for this configuration is 0.46 liters/sec for air.

Pressure variations in the substrate chamber were measured with a Varian partial pressure ionization gauge (PPG) which has a mass range of 1-70AMU and in the source chamber a Bayard-Alpert type ionization gauge was used.
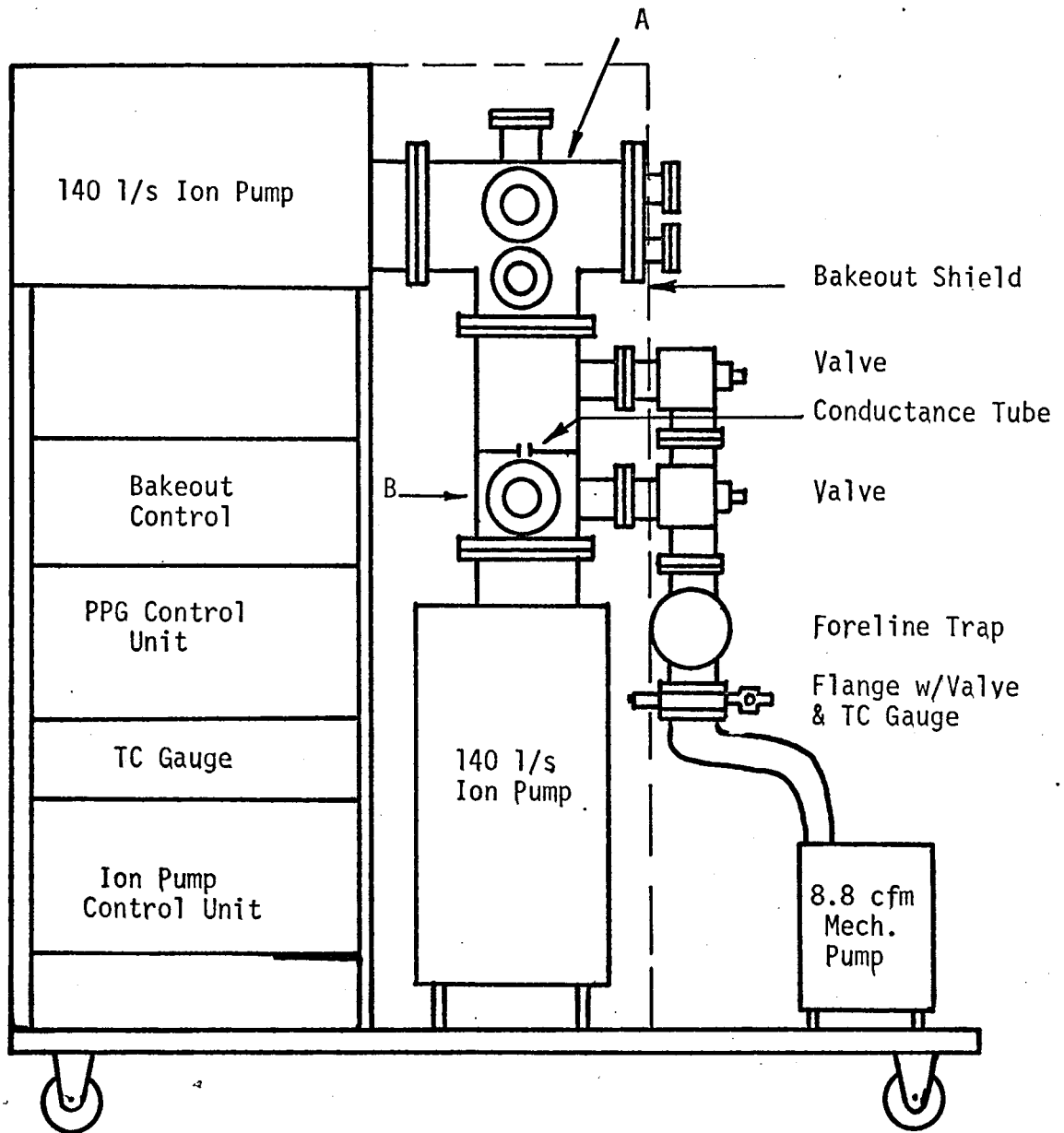
The characteristics of the conductance tube were determined by substituting a variable leak valve as a gas load in place of the electron beam gun. With a nitrogen leak the substrate chamber remained in the $10^{-10} - 10^{-9}$ Torr region for pressures ranging up to 2.5×10^{-6} Torr in the source chamber. Figure 2 is a plot of the actual performance of the conductance tube with the nitrogen leak. The PPG was taken as the pressure reference and was used to calibrate the Bayard-Alpert gauge. During actual deposition with copper as a source material, the pressure in the substrate chamber remained below 7.5×10^{-8} Torr for deposition rates between 10-20 $\overset{\circ}{A}$/sec. Attempts to increase the deposition rate have been hindered because the conductance tube, which is at ground potential, perturbs the electric field of the electron beam gun at large powers.

Partial pressures were also measured before and during deposition of copper with the PPG system. The predominate peaks in both cases were H_2, H_2O, and N_2 with traces of CO_2. During deposition, a proportionally larger increase of H_2 and CO_2 from the source material and gun occured.
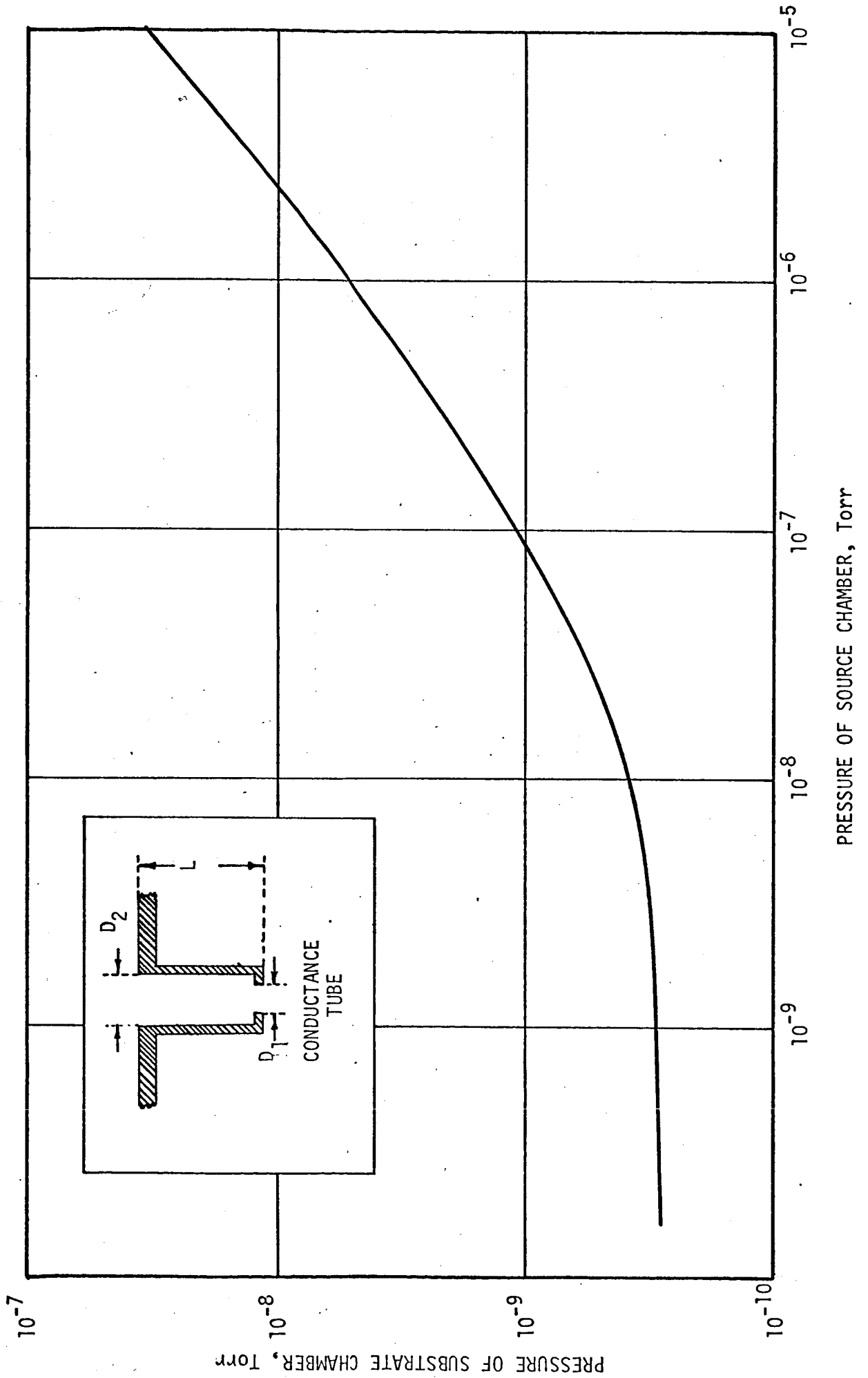
Various techniques not yet incorporated in the system exist to further reduce the gases in the substrate chamber during deposition. For example, a shutter may be placed at the aperature of the conductance tube to allow initial degasing of the source material without affecting the pressure in the substrate chamber. Also, since water vapor is a predominant peak, the conductance tube could be cooled to liquid nitrogen temperature in order to cut down the conductance for water vapor. Even without these improvements the system performance is attractive since differential pressures of 200/1 or better were easily obtained under heavy gas loads in the source chamber.

Figure 1. Differentially pumped vacuum system for thin film evaporation:
A - substrate chamber and B - source chamber.

Figure 2. Variation of pressure in substrate chamber with a variable
nitrogen leak in source chamber. The conductance tube is shown in the
insert (D_1 = 3.18 mm, D_2 = 6.35 mm, and L = 25.4 mm).

140 1/s Ion Pump

A

Bakeout Shield

Valve

Conductance Tube

Valve

Bakeout
Control

PPG Control
Unit

B

TC Gauge

Foreline Trap

Flange w/Valve
& TC Gauge

Ion Pump
Control Unit

140 1/s
Ion Pump

8.8 cfm
Mech.
Pump

PRESSURE OF SOURCE CHAMBER, Torr

PRESSURE OF SUBSTRATE CHAMBER, Torr