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A Sputtered-Ion Source for the Lintott Ion Accelerator

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A SPUTTERED-ION SOURCE FOR THE LINTOTT ION ACCELERATOR

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ABSTRACT

A sputtered ion source has been developed for use with the commercial Lintott ion accelerator. This source is readily interchanged with the existing commercial sources, and it requires no modifications to the Lintott accelerator. Sample currents in excess of 15 microamps have been produced for Al, Fe, Cu and the refractory metal Ta. Design considerations and operating characteristics will be discussed.

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A SPUTTERED-ION SOURCE FOR THE LINTOTT ION ACCELERATOR

I. Introduction

The Lintott 80 kV ion accelerator is well suited to implantation research because of its high flux, a design which facilitates rapid change of source materials, and a beam which may be defocussed magnetically to avoid sweeping. However, during extensive use of this machine at Sandia Laboratories over the past two years, it has been found impractical to heat source materials above $\approx 1000^{\circ}C$. At higher temperatures these materials often amalgamate destructively with metal source components. Also, problems arise with high-voltage breakdown inside the acceleration region of the vacuum chamber, presumably because of outgassing. These practical constraints on temperature exclude many elements, including most of the first transition series and all of the refractories. In some cases, this may be alleviated by use of the metal chloride which may have a sufficient vapor pressure when the pure metal does not. However, the chlorides tend to give less stable beams, are very corrosive and may be toxic.

Sputtering provides an alternative to thermal vaporization of source materials, and it has been used in several ion source designs.[1,2,3] The feasibility of modifying the commercial Lintott source for sputtering has been demonstrated by Mossman[4] who obtained an Au beam in this way while working at Texas Instruments Inc.

This report describes a simple modification of the commercial Lintott graphite source to incorporate source-material sputtering. The performance and operating characteristics are discussed for seven elements, including the refractories V and Ta.

II. System Description

The sputtering source retains the basic configuration of the Lintott graphite source, and it is therefore completely interchangeable (see Fig. 1). A 2.03 mm tungsten filament runs the full length of a cylindrical arc chamber of diameter 25.4 mm and length of 44.45 mm. A longitudinal extraction slit produces a line

beam of approximate dimensions of 40 mm by 1.5 mm. A low voltage DC power supply produces 130 amps at 3.5 volts which heats the filament. There is a potential of 170 volts DC between the filament and walls to maintain an arc discharge. When needed, a carrier gas can be introduced into the chamber through a capillary.

To incorporate the sputtering feature, an arc chamber is constructed out of grade ATJ graphite with a 38.1 mm OD hole in the back (Fig. 2). The edges of the hole are rounded (smoothed) to reduce arcing to the sputtering target. The negative (0-5 kV) biased target is then introduced to the discharge through this hole. Cylindrical targets up to 25.4 mm in diameter can be used. A 26.67 mm ID, 41.27 mm OD by 76.2 mm length ceramic insulator is used to position the target and aid in heat dissipation (as seen in Fig. 3 and 4). This insulator is held in place by two 304 stainless steel clamps. There is a distance of 6.35 mm between the arc chamber and the insulator to reduce electrical conduction paths to ground via sputtered material. Also, there is a 12.7 mm by 152.4 mm in length solid insulator attached to the rear of the target, which allows the target-arc chamber distance to be changed. Connected to the solid insulator is a 304 stainless steel rod which is tapped at both ends. This rod passes through a vacuum seal and is used to position the target externally. By using a calibrated threaded nut on the end of the stainless steel rod, the distance between the arc chamber and target is accurately known and can be repeated from implant to implant.

Argon and xenon have been used as carrier gases for the source. Although it is reported in the literature[5] that higher sputtering yields can be obtained by using the heavier gas xenon, the increase is less than a factor of two. Furthermore, the use of xenon produces certain problems. First, it does not strike an arc as well as argon. Also, the Lintott ion accelerator uses extensive liquid-nitrogen trapping to keep the system clean. Xenon is so readily trapped at liquid-nitrogen temperatures that it quickly saturates the traps and causes unstable operating pressures.

Sputtering source materials such as Al and Cu which are readily obtained in cylindrical rods may be machined to fit directly into the source. Other materials are attached to the end of a 304 stainless steel sputtering probe.

Figure 5 shows an electrical diagram of the sputtering unit. Since the entire system floats at 80 keV, it is powered by an isolation transformer. The 240 V AC,

60 hertz output from the isolation transformer is connected to a variac, whose output (0-240 V AC) is adjusted from outside the high-voltage enclosure by a Lucite rod. The variac output controls the output of two 0-5 kV, 0-10 mA DC unregulated power supplies (Plastic Capacitors Inc., model HV50-130M) connected in parallel. The ouput from the DC supplies is fed to the sputtering target through a vacuum insulator. Two meters are used to monitor the electronic circuit; one measures the current drain on the variac and the other is calibrated to indicate the high voltage applied to the sputtering target. The variac and DC supplies are mounted on a single chassis using color-coded interconnections; this facilitates rapid removal when other sources are to be used.

III. Performance

At the present time Al, Si, V, Fe, Cu, Mo and Ta have been successfully sputtered. The beam current for singly-charged ions after magnetic mass analysis was measured on a sample holder which was surrounded by a suppression grid biased at - 150 V DC, and which collected a 9.53 mm section of the line source beam. Table 1 shows the sample current for the above ions for accelerated energies of 50 or 60 keV. Before the sputtering source was placed in use, it was not possible to produce substantial ion beams of Si, V, Mo and Ta with thermal vaporization. Also, there were severe problems with AlCl when aluminum implants were attempted. Above approximately 130°C the vapor pressure of AlCl rose so rapidly that the vacuum pumps became overloaded and terminated the implant.

Figure 6 shows the current for the refractory metal Ta as a function of distance from the arc chamber. High-melting-point materials such as Ta can actually be inserted into the arc chamber with significant improvements in current, as seen in the figure. It can also be observed from Fig. 6 that ion current is a strong function of the target voltage up to 5 kV. This dependence is qualitatively consistent with sputtering data in the literature.[5]

The principal constraint on ion beam current results from heat generation. The source currently generates up to $\simeq$ 1 kW which is dissipated primarily in water-cooled vacuum walls which surround the source on the ground side of the acceleration region. At this heat level sputtering targets such as Al and Cu may melt, and consequently they must be located at least 3.18 mm from the arc chamber and

not sputtered at the maximum rate. Furthermore, excessive outgassing of components and overheating of vacuum seals occur at $\simeq$ 1 kW. Hence, substantially higher beam currents would require water cooling of the source. Since the currents achieved in the present configuration more than satisfy most requirements, the additional complexity of water cooling was thought to be unwarranted.

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IONS	ACCELERATED ENERGY (keV)	PEAK SAMPLE CURRENT (μAMPS)	STABLE OPERATING CURRENT (μAMPS)
ALUMINUM*	50	17.0	10.0
VANADIUM+	50	3.0	3.0
IRON	50	30.0	12.5
COPPER*	50	45.0	12.5
MOLYBDENUM+	50	3.0	3.0
TANTALUM	60	35.0	20.0
SILICON*	50	8.0	4.0

*LIMITED BY HEATING OF THE SPUTTERING TARGET

+THE SPUTTERING TARGET HAD LESS THAN ONE HALF THE MAXIMUM AREA

Table 1. Sample current for various implanted ions.

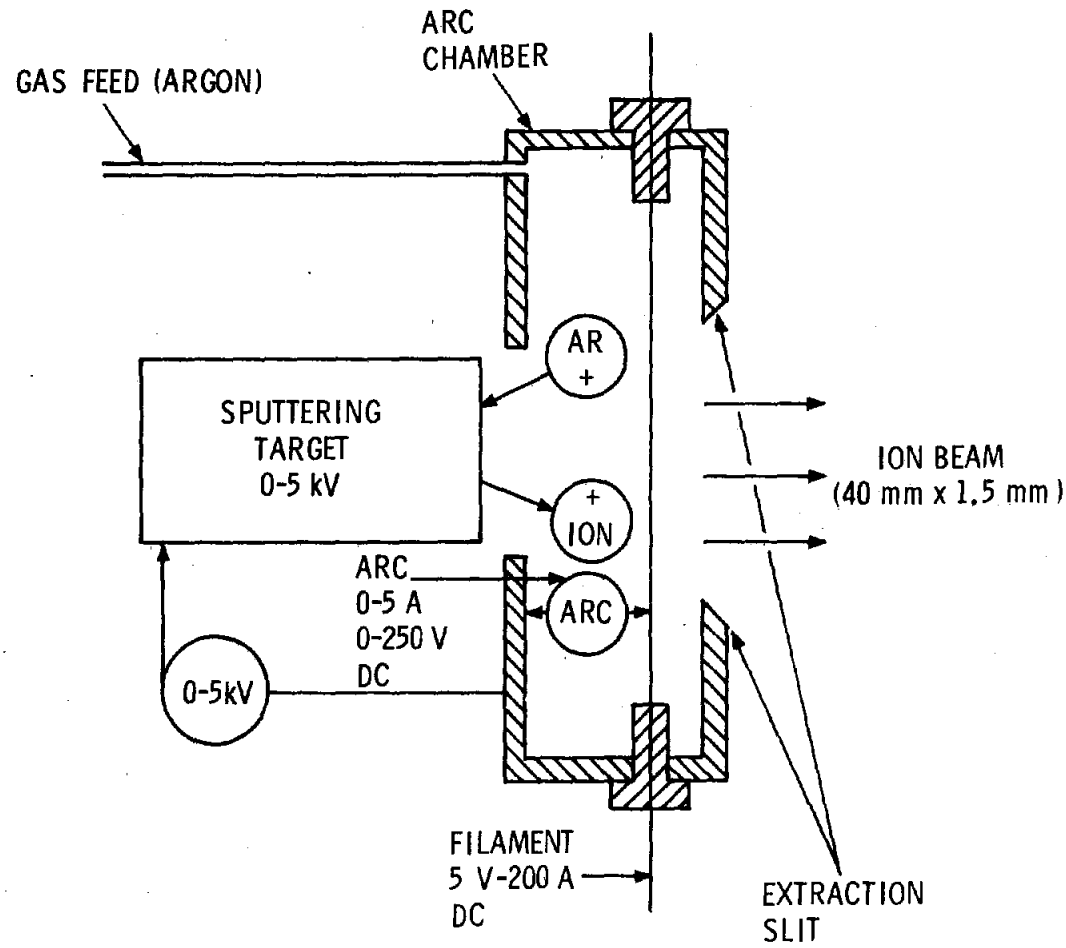

Figure 1. Schematic of arc chamber and sputtering process.

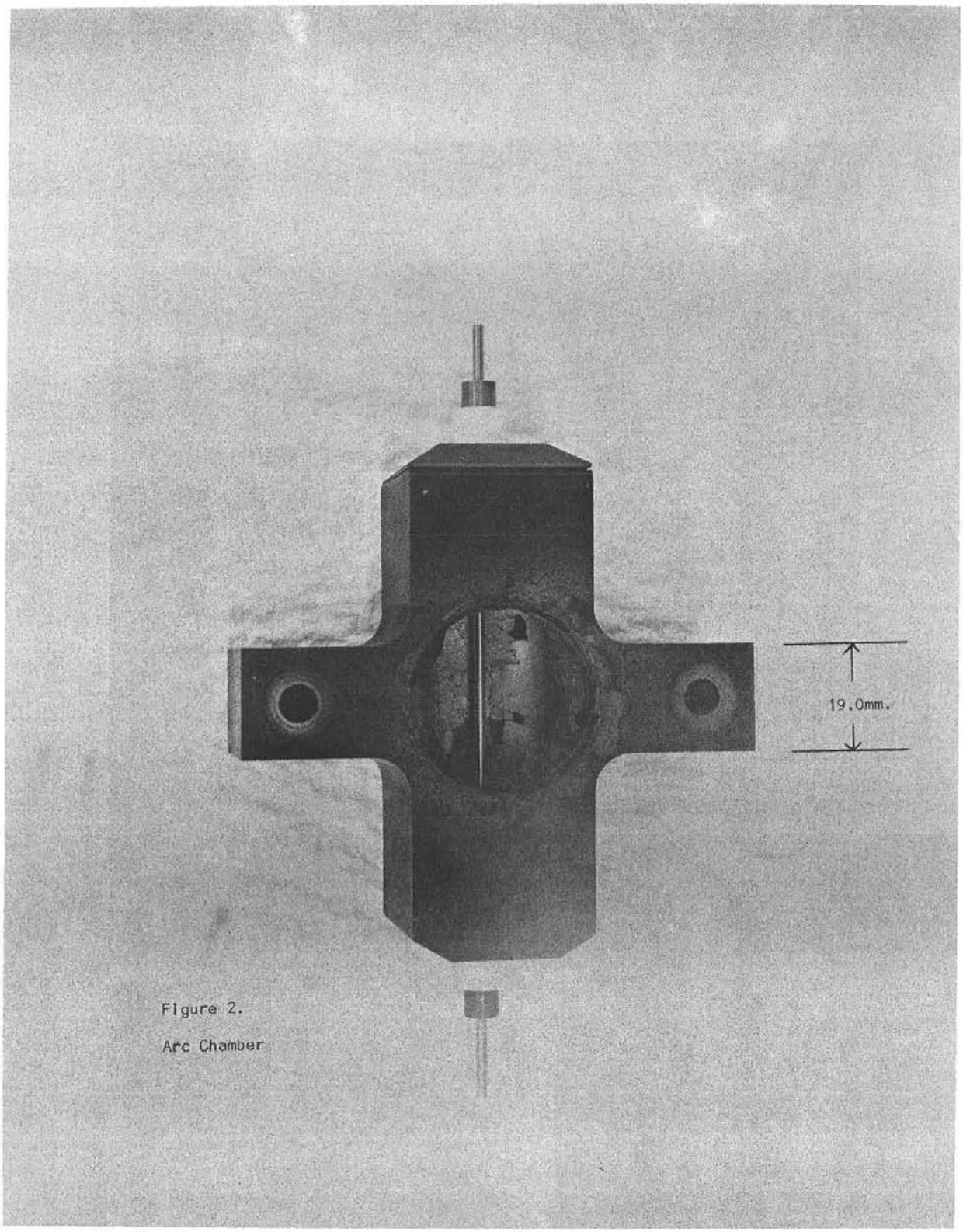

Figure 2.

Arc Chamber

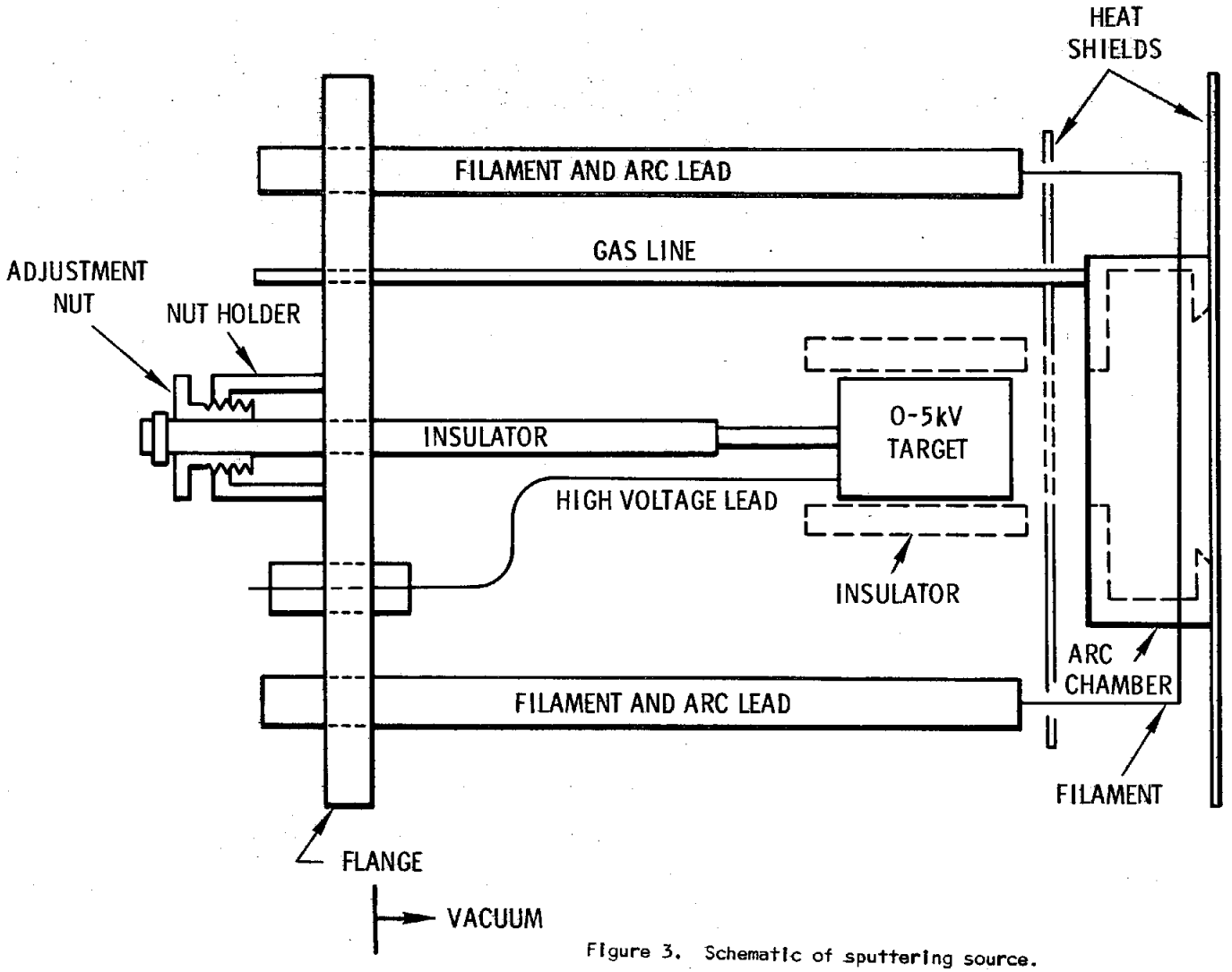

Figure 3. Schematic of sputtering source.

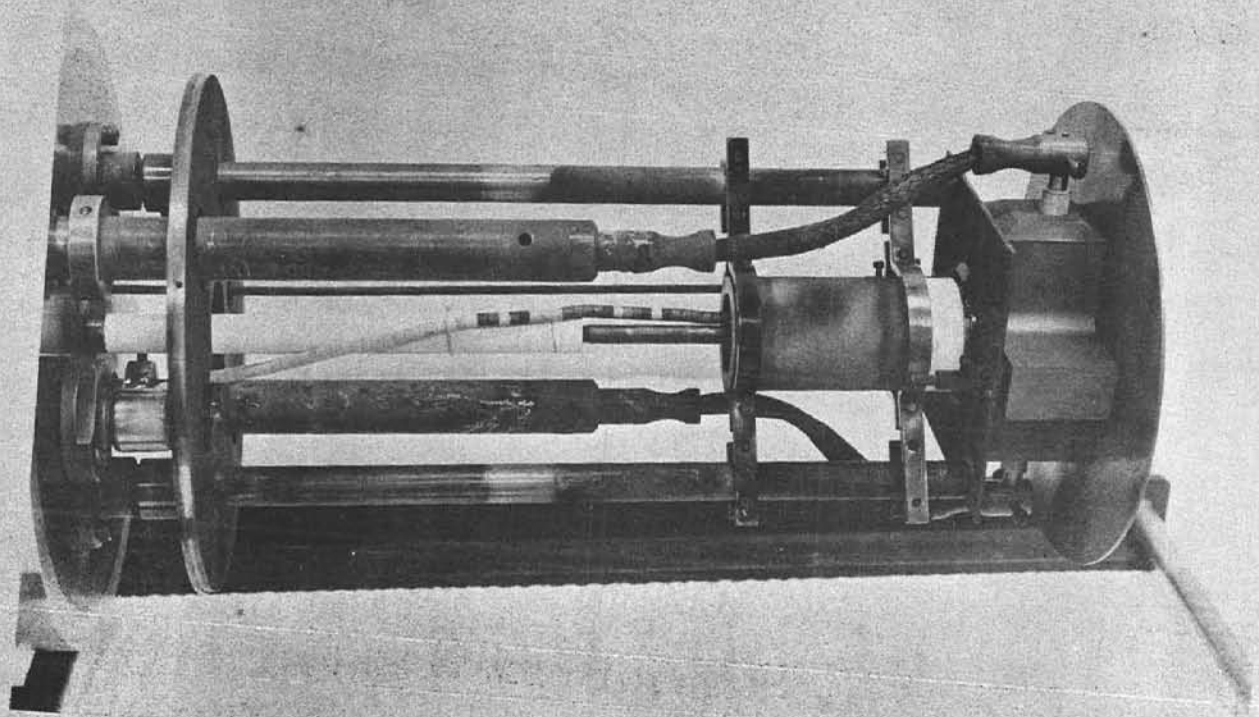

Figure 4. Photograph of sputtering source.

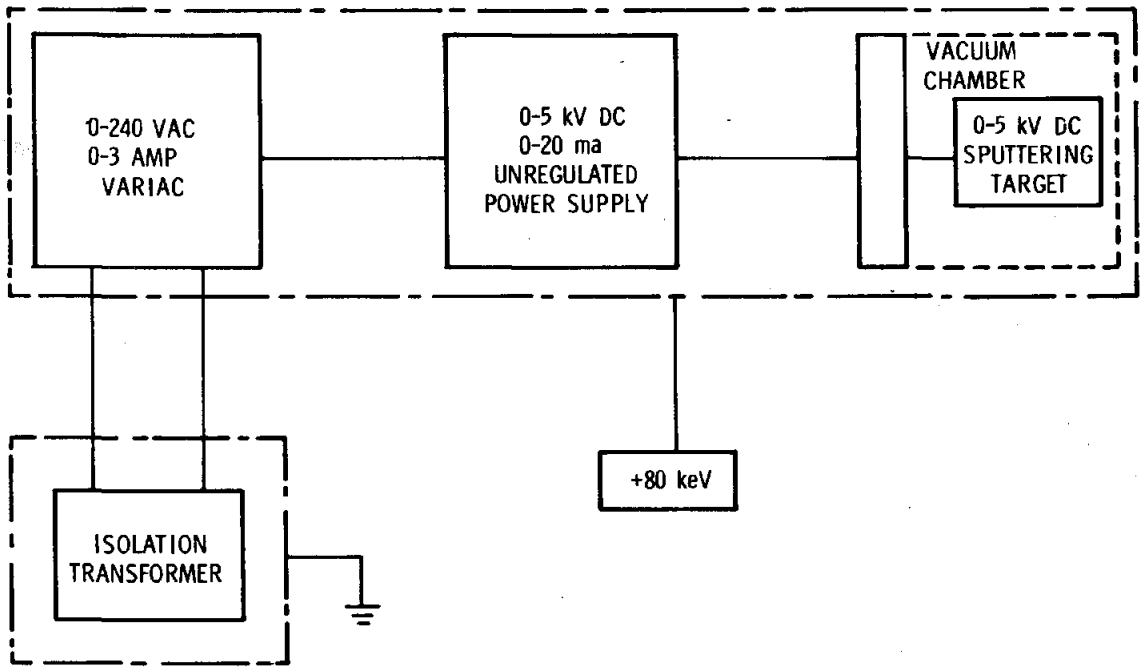

Figure 5. Electrical schematic of sputtering system.

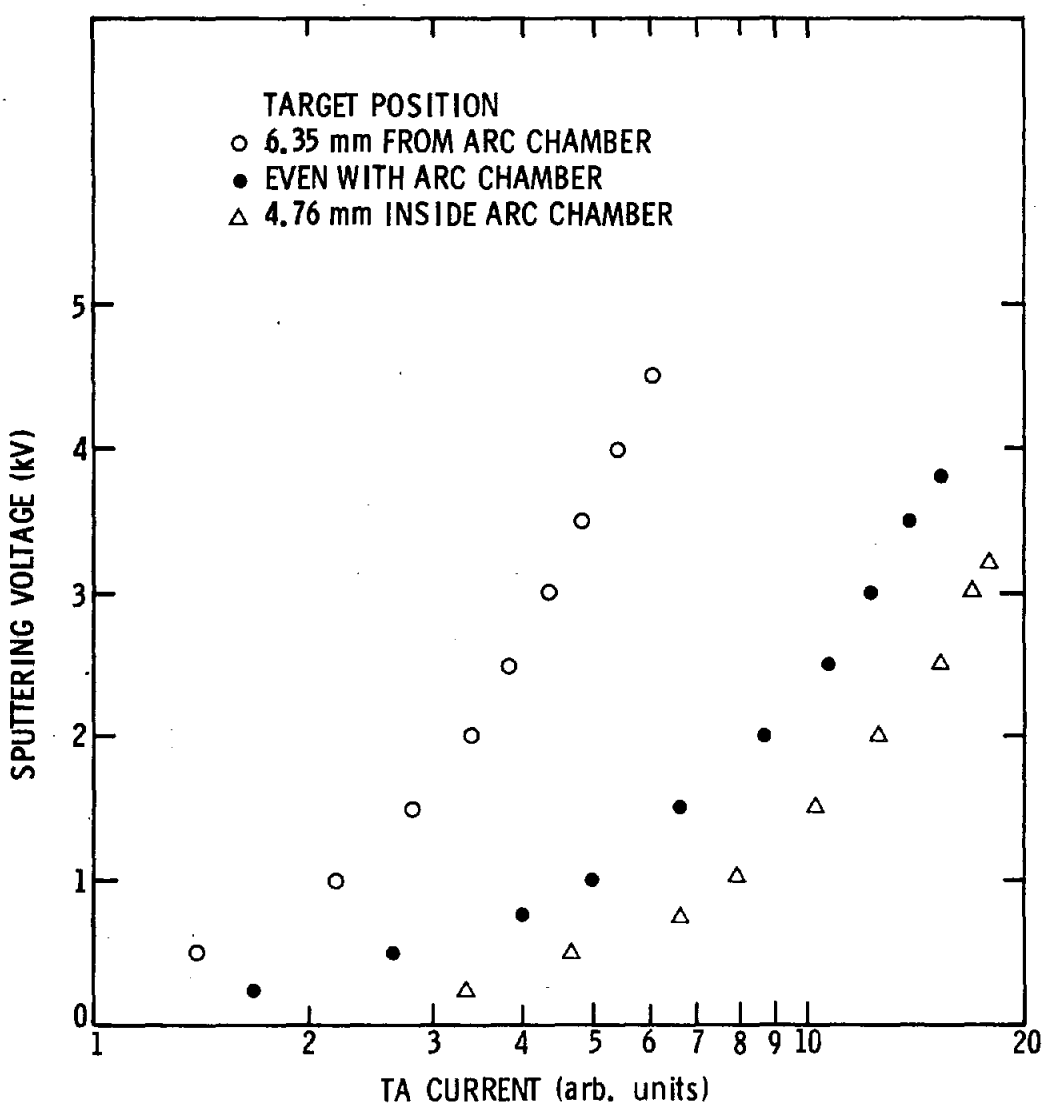

Figure 6. Tantalum sample current vs distance from arc chamber and sputtering voltage.

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