HIGH CURRENT TARGET FOR POSITIVE ION ACCELERATORS

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Target development work has led to a design which has been tested with beam power densities near 10 kW/cm^2. Use of this design with hydrogen isotopes for targets provides stable, long-lived neutron sources.

Introduction

Modern high-power accelerators have resulted in the necessity for targets with high power dissipation capabilities. The data presented here resulted from work carried out at The Boeing Company in Seattle, Washington, to develop targets for use with a Dynamitron accelerator. The design aim of the target is to provide power dissipation of a few kW/cm^2.[1]

The basic target is a scaled up version of one developed previously for use with cyclotron beams.[2] A necked-down section of tubing results in a high velocity water flow in the vicinity of the target that keeps the laminar layer next to the wall as thin as possible. The high velocity flow sweeps out steam bubbles as soon as they are formed, which may also help to maintain the necessary cooling.

The target assembly is shown in Figure 1.* The basic target is a flattened 2.5 cm diameter OFHC copper tube with a 0.8 mm wall thickness. The tube is annealed and then flattened in a forming jig to provide flat parallel surfaces with a spacing of 0.6 to 0.8 mm.

A copper insert (B), attached to the flange (A) supports the target and provides a face vacuum seal between the beam pipe and target. The insert is constructed to provide a water channel around a conical collimator hole to cool the insert and associated "O" rings. The target is easily changed by removing the rear support bracket (D) from the insert and unscrewing the knurled nuts which connect the target to the water connections. Quick and simple removal is necessary because of the high neutron induced activity of the copper target (typically 10-20 R/h). The rear support bracket is necessary to keep the thin flattened section of the target from ballooning out of shape from internal water pressure.

Power Capability Tests

The first active targets were prepared by deuterium beam loading a thin film of titanium which had been vapor deposited in a 22 mm spot on the copper backing. A Hurst counter was located 1 m from the target. It was used to detect neutrons from the D(d,n)He^3 reaction and monitor target performance. Initially 200 to 400 A of molecular deuterium were focused by a quadrupole triplet located roughly 100 cm upstream from the target to cover most of the titanium spot on the target blank. When the neutron yield from the target stabilized (typically 10-15 minutes) the beam current was increased to the order of 1 mA and the spot size decreased by the quadrupole triplet. Spot size was determined by melting holes through thin stainless steel foils located about 30 cm upstream from the targets. Minimum spot size was about 6 mm. Some of the targets with poorly bonded titanium films failed under these focused high current conditions. Good targets maintained stable neutron yields from periods of 20-30 hours. A water flow of 0.22 l/s was used as the starting flow rate for these power capability tests. It was gradually decreased until the targets failed from apparent heating. These failures occured near 0.05 l/s and happened rapidly. The neutron yield from the target dropped suddenly when the required cooling was not maintained.

The maximum power density achieved during these tests was obtained with 1.2 mA of molecular deuterium ions with energies of 2.4 MeV focused into a 6 mm diameter spot. This corresponds to a beam power density of about 10 kW/cm^2.

T(d,n)He^4 Experiments

A number of copper targets blanks were sent to the International Engineering Services Co. in Vienna, Austria, for application of the titanium films and tritium loading. Sixteen targets were obtained ranging in titanium thickness from 0.4 mg/cm^2 to 3.0 mg/cm^2. Eight of these targets have been used to date. They have been exposed to molecular deuterium beams ranging in current from 0.4 to 1.2 mA. The accelerator operating voltage was between 0.8 and 1.8 MeV. The neutron yields were measured by

* Detailed drawings available (R.F. Seiler, The Boeing Company, Seattle, Washington)

determining the activity induced in sulfur and aluminum foils.

One target which was 0.4 mg/cm^2 thick failed in 5 minutes when bombarded with 1.2 mA of beam. Four other targets with thicknesses less than 1.0 mg/cm^2 have been used for periods from 6 to 36 hours. The 14 MeV neutron yields from these targets varied from 6 x 10^{10} to 1.6 x 10^{11} neutrons/s/mA. Three thicker targets were used with a view toward establishing the effect of beam penetration of the titanium film. A target 3 mg/cm^2 was destroyed in less than 1 hour of operation at 1.1 MeV with 850 A of beam. Under the same conditions, a target 1.5 mg/cm^2 thick was used for a period of 9 hours. The 14 MeV neutron yield decreased 10% from its initial value over this time period for this target. A second 3.0 mg/cm^2 thick target was then used with 1.0 mA of 1.7 MeV molecular deuterium ions. The 14 MeV neutron yield from this target initially was 7 x 10^{11} neutrons/s. The yield decreased to 6 x 10^{11} neutrons/s over a 2 hour time period, then stayed essentially constant for an additional 8.5 hours. The performance of the two 3.0 mg/cm^2 targets indicates that penetration into the copper target backing with the incident beam is an important factor in target performance and lifetime.

Buildup of deuterium in the target was checked for just one of the targets. This target was 0.9 mg/cm^2 thick and a comparison of the D-d and 14 MeV yields was made by comparison of the neutron induced activities in sulfur and aluminum foils. The results indicate that the D-d fraction was less than 3% of the total yield which is near the accuracy limit of the technique used.

$D(He^3,p)He^4$ Measurements

Thick deuterium targets were prepared in the laboratory using a conventional vacuum system and loading procedure. These targets were mounted on a fixture inside a large vacuum tank in such a way that the plane of the target was held at an angle of 18° with respect to the incident beam. In this geometry, protons produced at angles between 20° and 30° have energies near 17 MeV. These protons were used to study proton radiation damage in various types of transistors.

The proton yield was monitored by a 6 mm thick pilot-B scintillation counter mounted behind a 1.5 mm diameter aperture located 65 cm from the target and was essentially constant for a total operational time of 54 hours with an average current of 1.5 mA of 2.0 MeV He^3 ions. The proton yield was isotropic to about 35% and amounted to 10^{10} protons/s for a target 0.3 mm thick.

These preliminary measurements indicate that this target design provides an effectively cooled substrate upon which various types of target materials can be bonded in the form of thin films. If the films are properly bonded so that good heat transfer can be provided, the operation of the target is apparently stable and long lived. When the films are thin enough so that the impinging ion beam can penetrate them and stop in the cool substrate rather than the active target area, the buildup of contaminant reactions seems to be minimal. Further measurements are necessary in order to determine the maximum power capability of this design as well as the optimum parameters necessary for the various types of target coatings that are used.

References

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2. C.O. Muehlhause, S.D. Bloom, H.E. Wegner, and G.N. Glasoe, Phys. Rev. 103, 720 (1956).

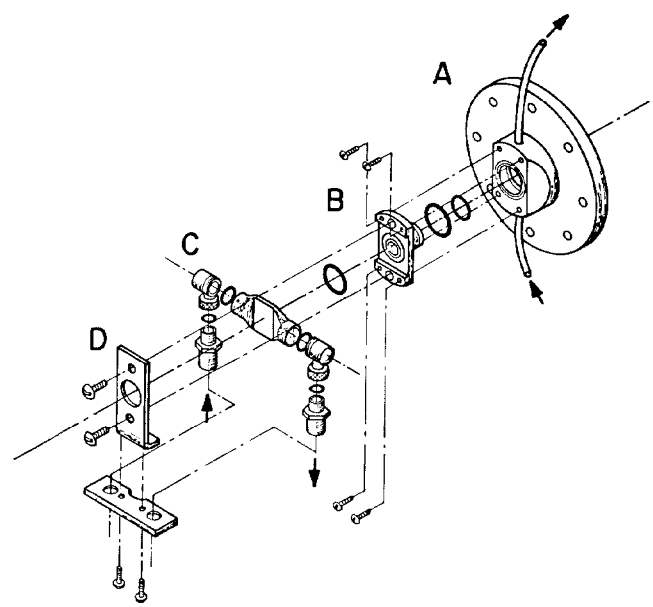

Fig. 1. Exploded View of Target Assembly
A. Mounting Flange
B. Cooled Collimating Insert
C. Target with Water Connections
D. Rear Support Bracket
Water flow is indicated by the arrows.