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MICROWAVE CAVITY FOR MEASUREMENT OF IONIZATION DUE TO MeV ELECTRON BEAM

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16. Abstract

A microwave cavity which can be penetrated by an electron beam in the MeV range and which can be evacuated to 10^{-8} torr and baked at 200° C is described. The electron beam is admitted through a titanium foil welded to one end of the copper body of the cavity; targets of a variety of materials may be brazed to the other end. The design permits all brazed joints to be thoroughly cleaned before the final seal, an electron-beam weld, is made.

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SUMMARY

This report describes the design and fabrication of a microwave cavity suitable for making measurements of the electron density and the probability of collision for momentum transfer in a gas which is partially ionized by an MeV electron beam. The microwave cavity measurement technique offers sufficient sensitivity and accuracy; a solution to some of the fabrication problems which arise is described.

The electron beam enters the cavity by passing through a titanium foil at one end and strikes a metal target at the other end. About 97 percent of the electron beam strikes the target, which can be made of a variety of materials, copper, aluminum, or tungsten being used here. The cavity is attached to a high-vacuum pumping and filling system which reaches a pressure of 10^{-8} torr after baking at 200° C. Both gas and gas pressure can be conveniently varied.

INTRODUCTION

The device described in this report is used in a study of the plasma produced in a gas when the walls of the gas container and the gas itself are bombarded by an electron beam in the MeV energy range.

The critical factors in the design of any piece of apparatus for the study of the interaction of electromagnetic waves with ionized gases are usually the problems which arise at the interfaces or windows between the test chamber and the rest of the system. Typically, the gas must be of a very high purity, which implies that the system must be baked and evacuated to a high vacuum before the test gas is introduced. The interaction chamber must, therefore, be separated from the rest of the system by a high-vacuum, bakable window which has the additional property that it is virtually transparent to electromagnetic waves at the frequencies of interest. The present apparatus has the additional requirement that a beam of MeV electrons must be permitted to enter the chamber.

Of the plasma diagnostic techniques available, the microwave cavity method (ref. 1) is most suitable for this application. The design and fabrication of the microwave cavity ionization chamber are described in the next section.

DESCRIPTION OF THE DEVICE

The cavity assembly shown in figure 1 is designed to resonate in the TE_{011} mode at about 27.7 gigahertz. Using a cylindrical microwave cavity allows the electron beam to pass through the titanium window on one end and strike the target on the other end. The problem of achieving a bakable seal between the titanium window and the oxygen-free high-conductivity (OFHC) copper cavity body is solved by an electron-beam weld. Only two-thirds of these copper, titanium electron-beam welds have been successful, but those that are successful have remained intact through repeated pressure and temperature cycling.

The electron density produced in this device generally has some gradients in the radial direction and may have gradients in the axial direction as well. The TE_{011} mode of resonance is chosen to avoid the problems associated with electron density gradients in the same direction as the electric field intensity within the cavity (ref. 2). The cavity diameter (1.524 cm), length (1.07 cm), and coupling aperture position are chosen to achieve this mode and resonant frequency. Because the resonant frequency of a cavity in this mode is a function of axial length, it is necessary to place the titanium window at the end of a short tunnel, 0.586 centimeter in diameter, which represents a segment of a circular waveguide beyond cutoff (ref. 3). Thus, no propagating fields exist in the beam tunnel, and fluctuations of the titanium window due to pressure changes have no effect on the resonant frequency. The electron beam is scattered as it passes through the titanium window, but approximately 97 percent of the beam is contained within a cone of 23° half-angle (unpublished data obtained from F. R. Stevenson). With the length of the electron-beam tunnel fixed at 0.254 centimeter, a beam having a diameter at the window as large as 0.369 centimeter may pass through the tunnel to the target without striking the wall. In practice a beam of this diameter has not been necessary to deliver the desired current to the target.

The WR(28) waveguide is made of OFHC copper and is furnace brazed to the cavity. The cavity is pumped out through an aperture having a nominal diameter of 0.254 centimeter in the cylindrical wall. A tuft of glass wool is placed inside the waveguide against the aperture. This does not impede the flow of gas in and out of the cavity and is essentially transparent to the microwaves, but provides a block to diffusion of plasma from the cavity into the waveguide because of its great surface area.

The waveguide vacuum seal is a metal, glass, mica sandwich purchased from a commercial supplier. The seal is indium (5 percent), lead (95 percent) soldered to an OFHC copper flange which is in turn silver soldered to the waveguide. The pumpout tube is 1.27-centimeter-outside-diameter 304 stainless steel and is squeezed into an oblong shape and ground flat before being silver soldered over the 0.635- by 0.079-centimeter slot in the center of the broad wall of the waveguide. The other end of the pumpout tube can be welded to any commercial high-vacuum 7-centimeter flange and attached to a suitable high-vacuum pumping and filling system.

Targets of copper and tungsten may be furnace brazed to the cavity body at the same time as the waveguide. However, the tungsten target is designed to encircle the copper cavity body to reduce the stress on the braze during cooling. An aluminum target may be indium, lead soldered to the cavity body after the sealing surface is copper plated.

The device is assembled in two pieces, the cavity end and the waveguide end, and then joined by an electron-beam butt weld for the final seal. The solder joints in the waveguide assembly can then be thoroughly cleaned before the final seal is made.

SUMMARY OF RESULTS

Microwave cavities suitable for measurement of ionization due to an MeV electron beam have been designed and fabricated. The completed cavity assemblies were repeatedly baked out at 200° C and achieved a vacuum of 1.0×10^{-8} torr.

Lewis Research Center,

National Aeronautics and Space Administration,

Cleveland, Ohio, February 3, 1971,

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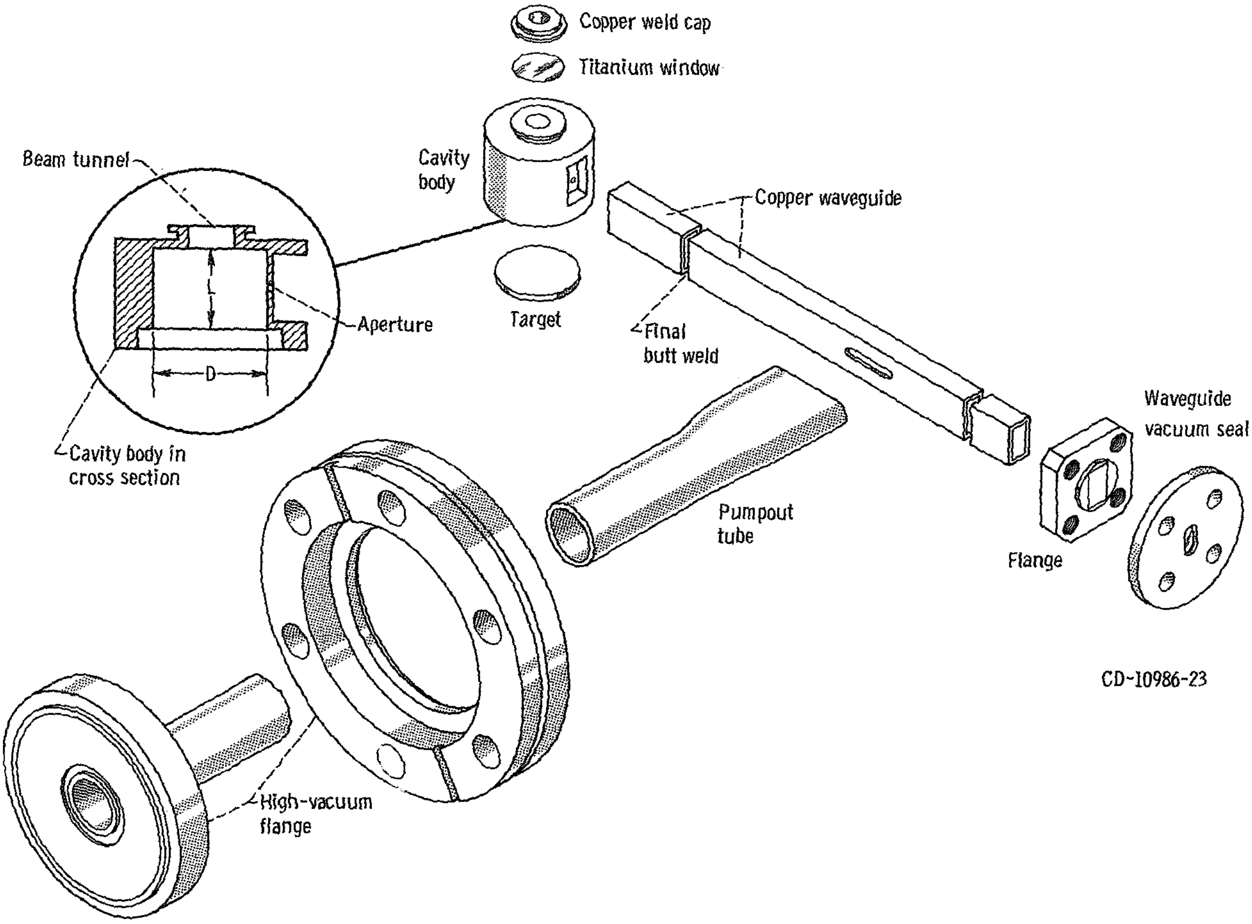

Figure 1. - Cavity assembly.

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