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A novel ceramic chamber prototype

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ABSTRACT

A novel ceramic chamber prototype has been designed and fabricated which is described in this paper. The manufacture procedure of the ceramic test chamber is original. For the novel ceramic chamber, the uniformity of its inner deposited Ti film is improved to have a thickness variation of approximately 1%, and the average wall thickness error of the chamber (length 650 mm) is developed to be less than 55 μm. The manufacture procedure is explained below. The two halves of ceramic chambers were first cleaned, the metal films were then deposited on the inner surface by sputtering and, finally, the two halves were joined with a fixture to become a ceramic tube using glass powder colloid at ~250 °C. The glass powder colloid can be used for the vacuum-assembled parts because the outgassing rate is measured to be 4.8×10^{-9} Pa m s^{-1} after baking. For a novel ceramic chamber prototype, the ceramic tube was connected to the stainless steel flange by glass powder colloid and tungsten inert gas (TIG) welding. The ceramic chamber prototype was leak tight after the rapid temperature cycle test. Thus, it is feasible to fabricate the novel ceramic chamber prototype.

1. Introduction

For an accelerator, a ceramic vacuum chamber inside the kicker magnet is used to penetrate the fast-changing magnetic field into the beam pipe. A metallic chamber is not used due to the shielding effect of eddy currents from a fast-changing magnetic field. Therefore, a ceramic chamber was produced and then the metallic thin film was deposited on the inner surface. The ceramic powders were sintered at a high temperature to form a ceramic vacuum chamber with a compact shape. However, the ceramic chamber produced some deformation during cooling down.

The uniformity of the metallic thin film is one of the important issues because the image current of the electron beam passed through the chamber as well as shielding of the kicker field [1–4]. Due to limitation of the geometry of a ceramic chamber structure, the thickness error of inner deposited metal thin film is about 20% [5]. For our case, the optimum deposited thickness of Ti film is approximately 2 μm [6,7]. Although the disturbance to kicker magnetic field is of far more importance than for the image current, the novel-type ceramic chamber was focused on improving the deformation and uniformity of the inner metallic thin film. To improve deformation and uniformity of the Ti film thickness, a novel-type ceramic chamber was designed and fabricated recently. The ceramic chamber has a race-track cross-section, with an aperture of H × V = 68 × 20 mm. The cross-sectional view of one half of the novel-type ceramic chamber is shown in Fig. 1. Moreover, the small-size test ceramic chambers were also prepared to analyze the fabrication condition.

1.1. Experiments

The ceramic material, alumina 995, was fabricated by cold isostatic press (CIP) production. The ceramic chamber was composed of two halves. First, the two halves were cleaned by alkali solution and furnace annealing treatment. Second, the Ti films were deposited by the sputtering method with power of 200 W. The deposition pressure was approximately 0.4 Pa and the deposition rate was measured to be 0.79 nm s^{-1}. In order to improve the uniformity of Ti films, ceramic halves were moved at the constant speed in the longitudinal direction during the deposition process. The post-bonding interfaces for two halves were protected from deposition by using the design fixtures. Third, these two halves were sealed to become the ceramic tube with the glass powder colloid. Finally, the ceramic tube was connected to the stainless

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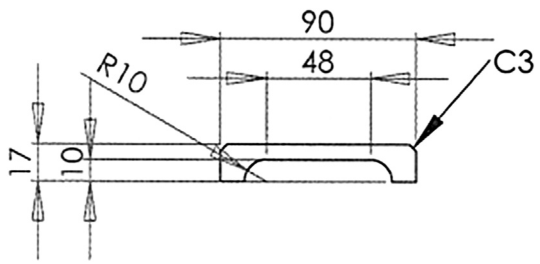

Fig. 1. The cross-sectional view of one half of the novel-type ceramic chamber. The units are mm.

flange with the aid of the glass powder colloid sealing and tungsten inert gas (TIG) welding.

Prior to the fabrication of the novel-type ceramic chamber, a series of measurements and experiments were carried out, including the wall thickness of a half ceramic chamber, uniformity of the inner deposited metal thin film, the outgassing rate of the glass powder colloid, and the leak checking test at all connection sites. For a half ceramic chamber, the height was measured by the coordinate measuring machine (CMM). The thickness of the metal thin film was observed by secondary electron microscopy (SEM). The outgassing rate per unit area (q) of the glass powder colloid was calculated and compared by measurement in a thermal outgassing rate system. In this paper, q_{72} means the outgassing rate per unit area after pumping time of 72 h, the q_{10} means the outgassing rate per unit area after pumping time of 10 h, and the q_{24} means the outgassing rate per unit area after pumping time of 24 h. The helium-leakage test was performed using a helium leak detector or the leak-detection mode of a residual gas analysis (RGA).

2. Results and discussion

Fig. 2 shows that the height measurement for the outside plane and inside plane of two halves of ceramic chambers (650 mm-long). The error of the wall thickness was to be less than 55 μm for the two halves of the ceramic chambers. The measurement method is described below. Three datum points were selected on the designed support, placed on the granite table, to construct the datum plane. The height of the datum plane is defined as 0 mm. First, the outside plane was put on the datum plane. The height of the ceramic chamber was measured every 20 mm by a sensor tip of

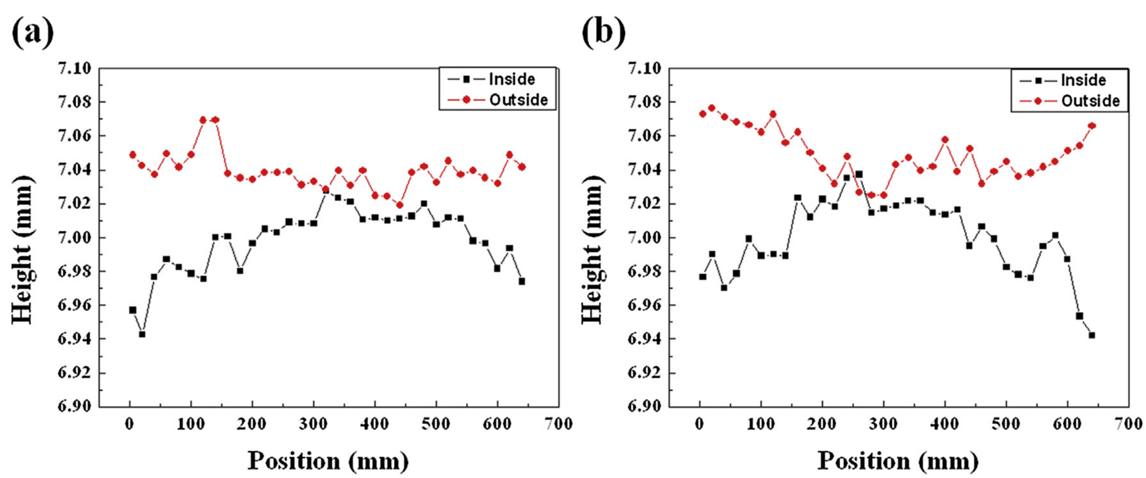

Fig. 2. The height values on the inside and outside plane of (a) one half and (b) the other half of ceramic chamber.

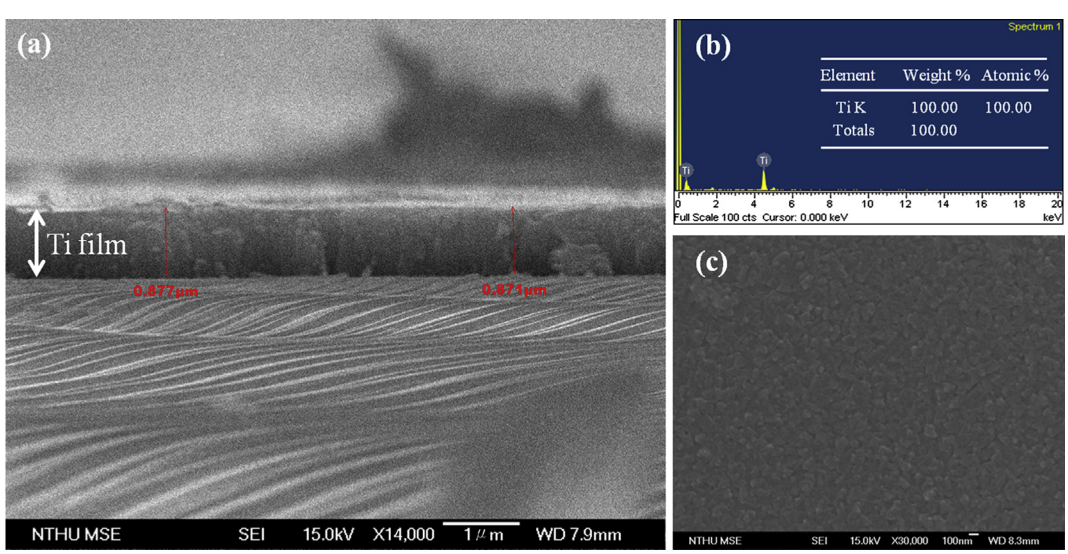

Fig. 3. (a) The cross-sectional, (b) the EDS analysis, and (c) the plane-view SEM images of the deposited Ti films.