

DESIGN AND FABRICATION OF THE NOVEL-TYPE CERAMIC CHAMBER

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Abstract

A ceramic chamber of novel type has been designed and fabricated. The uniformity of its inner thin film of deposited metal is improved to have a thickness error about 1 %. The average straightness error of the chamber (length 550 mm) is developed to be less than 55 μm . To fabricate the ceramic chamber of novel type, we first cleaned and joined the two halves; the metal films were deposited by sputtering. These two halves were next sealed with a glass powder colloid to become a ceramic tube. The rate of outgassing of this colloid is 3.57×10^{-12} Torr L s⁻¹ cm⁻² after baking. The ceramic tube was connected to a stainless-steel flange with the aid of a glass powder colloid and TIG welding. This ceramic test chamber will be installed in the experimental system to analyze the residual gas.

INTRODUCTION

For an accelerator system, a ceramic chamber serves as kicker. Ceramic powders were sintered to form a ceramic chamber of a compact shape, but some deformation occurred during cooling. After this chamber was produced, a metallic thin film was deposited on the inner surface because the electron beam passes through this chamber.^[1-4] Because of geometric limitations of the structure of the ceramic chamber, the thickness error of the inner deposited metal thin film is about 20 %.^[5] For the purpose of improvement of the deformation and the uniformity of the thickness, the ceramic chamber of novel type has been designed and fabricated.

EXPERIMENTS

The ceramic material, aluminium 995, was fabricated with a cold isostatic press (CIP). The ceramic chamber is composed of two halves that were first cleaned with an alkaline solution and annealed in a furnace. The Ti films were then deposited by sputtering; the rate of deposition was calibrated to be 0.79 nm s⁻¹. After these two halves were sealed with the glass powder colloid to form the ceramic tube, the ceramic tube was connected to a stainless-steel flange with the aid of the glass powder colloid and TIG welding.

Before this chamber was produced, measurements and tests were made to verify the straightness of a half ceramic chamber, the uniformity of the inner deposited metal thin film, the rate of outgassing of the glass powder colloid, and a leakage test at all connection sites. The straightness of a half chamber was measured with a coordinate-measuring machine (CMM). The thickness of the metal thin film was observed with a scanning electron microscope (SEM). The rate of outgassing of the glass powder colloid was measured with a home-made thermal

system. The leakage was tested with a helium leak detector or a residual-gas analyzer (Inficon, Transpector 2 Gas Analysis System H100M (100 u)).

RESULTS AND DISCUSSION

Figure 1 shows that the average error of the straightness of a ceramic chamber (length 550 mm) is improved to be less than 55 μm . The method of measurement is explained below. After a datum plane was established, the height was recorded per 2.5 mm with a sensor tip of the CMM along the middle axis on the outer and inner planes, individually. Three selected points defined the datum plane, which would affect the height value.

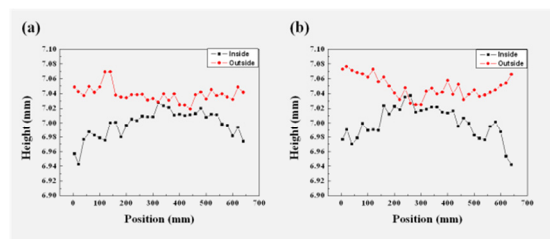


Figure 1: Heights of the inner and outer planes of (a) one half and (b) the other half of the ceramic chamber.

Figure 2 shows an SEM image and analysis of the deposited Ti films with an energy-dispersive X-ray analysis system (EDS). The thickness as measured with the tool is marked in Fig. 2(a); the thickness error of the deposited Ti film is about 1 %. The composition of the film is recognized as Ti, shown in Fig. 2(b). No clusters were obvious on the surface, shown in Fig. 2(c). Photographs of one half of the ceramic chamber before deposition are compared with that after deposition of the Ti film in Fig. 3. The post-bonding interfaces of the two halves of the ceramic chambers were protected from deposition using designed fixtures.

Next, in order to form the ceramic tube, two halves of the ceramic chambers were sealed at the baking temperature about 250 °C, and they were pressed with a fixture simultaneously.

As the nano-scaled glass powders were dissolved in the glass powder colloid, its outgassing was measured for consideration for its application in an ultra-high vacuum system.^[6] Thus, we measure the outgassing rate of the glass powder colloid in our system, shown below.

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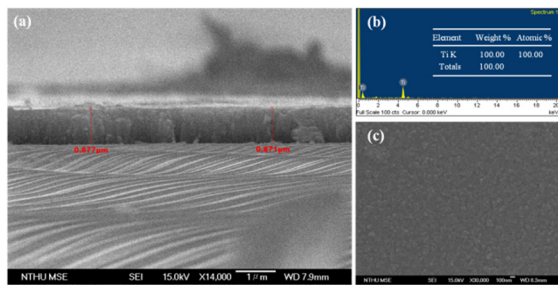


Figure 2: (a) Cross section, (b) EDS analysis, and (c) plane-view SEM images of deposited Ti films.

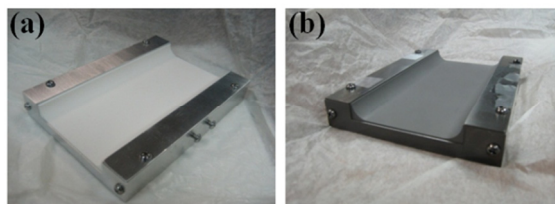


Figure 3: Half ceramic chamber (a) before and (b) after deposition of a Ti film.

The system to measure the rate of thermal outgassing is home-made. The orifice has diameter 6 mm; the area of the inner surface of the main chamber is about 2350 cm². The surface area of the ceramic test samples covered with the glass powder colloid is 1852 cm². Figure 4 presents the temporal variation of pressure during baking of ceramic test samples covered with glass powder colloid. After pumping for 10 h, P₁ showed 1.16×10⁻⁶ Torr and P₂ showed 4.63×10⁻⁸ Torr. The rate of thermal outgassing per unit area (q₁₀) is estimated to be 8.72×10⁻¹⁰ Torr L s⁻¹ cm⁻². After pumping for 24 h, P₁ showed 3.68×10⁻⁷ Torr and P₂ showed 1.54×10⁻⁸ Torr. The rate of thermal outgassing per unit area (q₂₄) is estimated to be 2.75×10⁻¹⁰ Torr L s⁻¹ cm⁻². The slope of P₁ vs. time is -1.32 Torr h⁻¹ and that of P₂ vs. time is -1.25 Torr h⁻¹ for a pumping period near 1 h. After baking and pumping for 72 h, P₁ showed 5.02×10⁻⁹ Torr and P₂ showed 4.47×10⁻¹⁰ Torr. The rate of thermal outgassing per unit area (q₇₂) is estimated to be 3.57×10⁻¹² Torr L s⁻¹ cm⁻². From the rate of outgassing of the ceramic test samples covered with the glass powder colloid, we thus judged that the glass powder colloid should be allowed to be applicable to the vacuum-assembled parts. Figures 5(a) shows the analysis of the residual gas of the blank ceramic samples and 5(b) shows the ceramic test samples covered with glass powder colloid. Comparison of Figures 5(a) and 5(b) indicates that the spectra are similar. The glass powder colloid hence produces no special residual gas.

The small ceramic test chamber was fabricated and sealed with the glass powder colloid, shown in Figure 6. For all connection sites, the rate of leakage was less than 1×10⁻⁹ Torr L s⁻¹, measured with a helium leak detector.

The small ceramic test chamber was fabricated with the glass powder colloid and TIG welding. Figure 7(a) shows the stainless-steel parts and a small ceramic chamber. The parts were assembled to become a small ceramic test chamber with a stainless-steel flange on one side, shown

in Figure 7(b). For all connection sites, the leakage rate was less than 1×10⁻⁹ Torr L s⁻¹. In the next experimental step, the small ceramic test chamber with a stainless steel flange on one side will proceed to the thermal test to confirm the limiting high temperature and to analyze the residual gas.

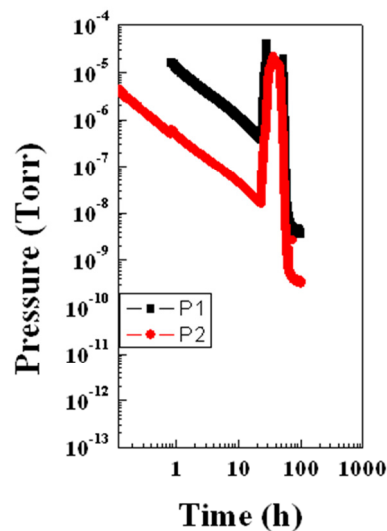


Figure 4: Temporal variation of pressure during baking of ceramic test samples covered with a glass powder colloid.

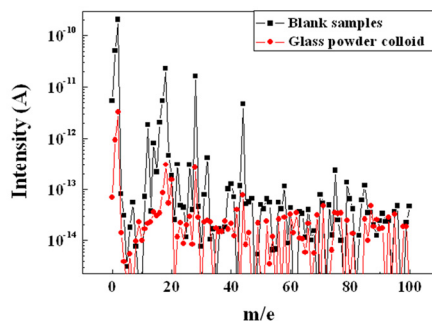


Figure 5: Residual gas analysis of (a) blank ceramic samples and (b) ceramic test samples covered with the glass powder colloid.

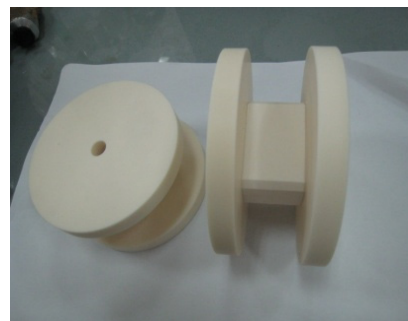


Figure 6: The small ceramic test chamber is sealed with the glass powder colloid.

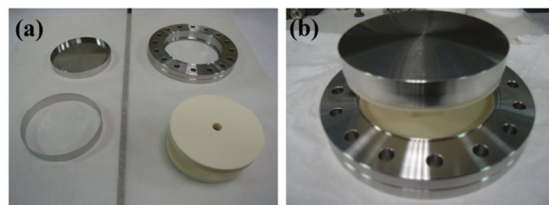


Figure 7: (a) Assembled parts and (b) small ceramic test chamber with a stainless-steel flange on one side.

CONCLUSION

For a ceramic chamber of novel type, the average straightness error of a chamber of length 550 mm is developed to be less than 55 μm ; the uniformity of the inner deposited Ti film is improved to have a thickness error about 1 %. Two halves of the ceramic chambers and the stainless-steel parts were joined to fabricate a small ceramic test chamber using sealing with a glass powder colloid and TIG welding. The rate of outgassing per unit area of the glass powder colloid is about 3.5×10^{-12} Torr L s^{-1} cm^2 after baking. The ceramic test chamber will be installed in the experimental system to confirm the limiting high temperature and to analyze the residual gas.

REFERENCES

- [1] V. C. Kempson, J. A. Dobbing, G. M. A. Duller, N. Hauge, G. Hilleke, C. Hansen, EPAC 2006, p. 3341 (2006).
- [2] S. Milton and D. Warner, EPAC 1994, p. 2494 (1994).
- [3] Y. H. Chin, S. Lee, K. Takata, and T. Toyama, Proceedings of HB 2006, p. 125 (2006).
- [4] T. Mattison, R. Cassel, A. Donaldson, G. Gross, and A. Harvey, IEEE Particle Accelerator Conference, p. 1 (1991).
- [5] P. He, H. C. Hseuh, and R.J. Todd, Inter. Conference on Metallurgical Coatings and Thin Films, p. 22 (2002).
- [6] Y. J. Pei, D. M. Jiang, W. M. Li, X. Q. Wang, Vacuum 41, p. 1870 (1990).