STUDY ON THE METALLIC COATING OF THE CERAMIC CHAMBER FOR THE ATF DAMPING RING KICKER MAGNETS

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A ceramic chamber in the kicker magnet is used to penetrate the fast-changing magnetic field into the beam pipe. On the other hand, the metallic coating inside the ceramic chamber is important to pass the image currents of the beam. For the ATF Damping Ring, it is planed to study the multi-bunch-beam operation. The requested rise time of the kicker field is less than 60 nsec.

Studies to get a suitable metallic coatings inside a long-and-narrow ceramic chamber have been performed and continued. Tests of the sub-micron-thickness coating were carried out as the first stage of our studies.

I. INTRODUCTION

The construction of the 1.54 GeV damping ring in KEK Accelerator Test Facility (ATF) is in progress. The purpose of the ring is to study the multi-bunch-beam operation with a low emittance to realize the future linear collider. Under such operation, up to five-bunch trains, each of which contains up to 60 bunches, circulate in the ring. The repetition rate of the injection is 25 Hz. The kicker magnets are designed to operate with 60 nsec field rise time and with 4.6 mrad kick angle [1,2].

Ceramic chambers in kickers are used to avoid the shielding of a fast-changing magnetic field by a metallic beam pipe. On the other hand, a thin conductive coating must be provided on the inside of the chamber to carry the image currents of the beam and to avoid electrical discontinuities of the chamber wall. It is an important point for the ATF damping ring; the vacuum system is designed to achieve low-impedance chambers. However, this coating again has a shielding effect of the kicker field.

Therefore, the metallic coating should be optimized concerning the effects that related to the fast-changing kicker field and that related to the beam; that is the effects due to the image currents and the eddy currents.

II. CERAMIC CHAMBERS

The aperture for the ceramic chamber in the kicker magnets is long and narrow. The cross sectional view of the proposed ceramic chamber is shown in Figure 1. The length of the alumina ceramics is 500 mm long to avoid the electrical breakdown between the 40 kV conductor and the metallic joints brazed to the ceramic pipe.

Type-A is a circular one for injection kicker. Type-B is a racetrack shape for extraction kicker, extended to the outer side of the ring, is designed to protect the ceramic chamber from the unwanted synchrotron irradiation. Such irradiation will warp the brazing part of a ceramics and a metallic joint, and finally it will break the vacuum. The shielding of a kicker field due to the eddy current would be large for type-B.The radius of the beam pipe is 5 mm. If the load of SR is acceptably small, type-A is adopted for the extraction kicker.

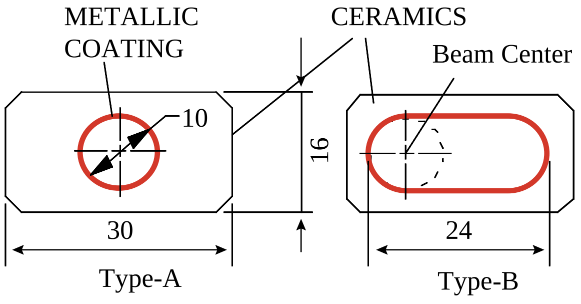

Figure 1: Proposed cross section of the ceramic chamber.

A. Required surface resistivity

Method of a metallic coating by longitudinal strips is applied for recent accelerators [3,4]. For the ATF, it is planned to use a continuous coating, because the forming method of strips in the circular area is seems to be very difficult for the long and narrow ceramic chamber. For the continuous case, the surface resistivity of a coating is evaluated concerning the effect of the eddy currents and that of the image currents [5,6].

The heating due to the ohmic loss of the image currents favors a low surface resistivity. The dissipated power density Pi in the coating is given by

$$Pi\,(W/cm^2) = \frac{Nq^2c^2}{2\sqrt{\pi}\sigma_Z(2\pi a)^2 C_R} R_{sq},$$

where N is the bunch number, q is the charge in a bunch, c is the velocity of light, σ_Z is a bunch length, C_R is a circumference and R_{sq} is the surface resistivity. For our case, it is simplified to $3.8R_{sq}$

On the other hand, the heating due to the eddy currents favors a high resistivity. In this case, the dissipated power density is

$$Pe\,(W/cm^2) = 2B_k^2 F 10^{-16} / t\, R_{sq},$$

where F is a repetition rate and t is the rise time of the kicker field B_k. For our case, the maximum power density becomes $0.1/R_{sq}$.

The total power dissipated in the coating is shown in Figure 2 as a function of the surface resistivity. For the left-hand side of the minimum, 0.16 ohms/square, it shows the rapid increase due to the eddy currents. On the other hand, right-hand part shows the steady increase and it is suitable for the handling of the coating resistivity.

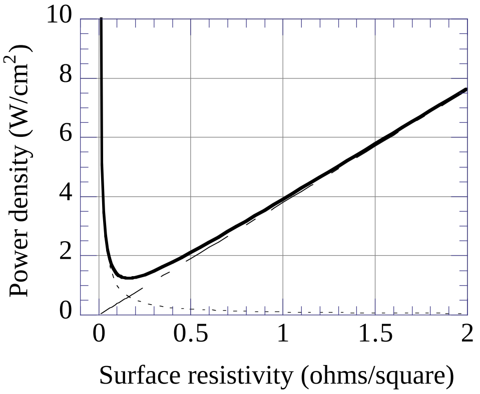

Figure 2: Dissipated power in the coating as a function of the surface resistivity. Solid line shows the sum from image currents (dot-dashed) and the eddy currents (dots).

The penetration time of the kicker field is a function of the surface resistivity. For a circular chamber with a radius a(cm), the time constant due to the eddy currents is $2\pi a/R_{sq}$ nsec. Figure 3 shows the penetration pattern of the kicker field where the rise time of the external kicker field is assumed to be 50 nsec. The acceptable one is greater than 1 ohms/square for the multi-bunch-beam operation.

If the surface resistivity of the metallic coating is 1 ohms/square, the total dissipated power becomes 300 watts. This power must be removed by a forced air cooling.

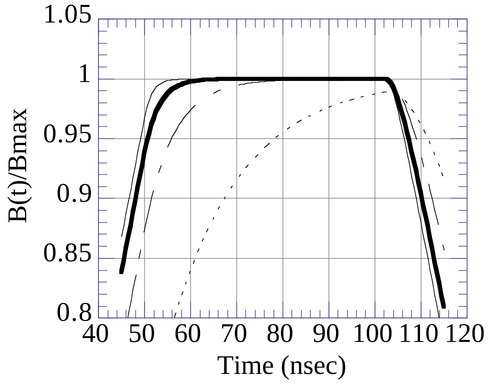

Figure 3: Penetration patterns of the kicker field evaluated with various surface resistivity (ohms/square) of 0.2(dots), 0.5(dot-dashed), 1.0(wide-solid) and 2.0(solid).

III. TEST OF THE METALLIC COATING

If a coating material has a specific resistivity $\rho(\Omega\text{cm})$ and thickness d(cm), the surface resistivity is given by ρ/d. Materials which have a bigger ρ and a smaller d is better for the coating.

There are some formation methods of a thin film such as an evaporation and a chemical vapor deposition (CVD). The evaporation by a metal wire seems to be realistic for our chamber. While it need more time for R & D, because we have no experience to do it. As a first stage of studies, we decided to check the condition of a coated material by using TiN which was a well-known material of a coating on the ceramics and was easily obtained. The method is a thermal CVD.

Tests of the TiN coated on ceramic plates were performed by changing the coating thickness. If we use the TiN as a coating material, the thickness should be 0.2 micron.

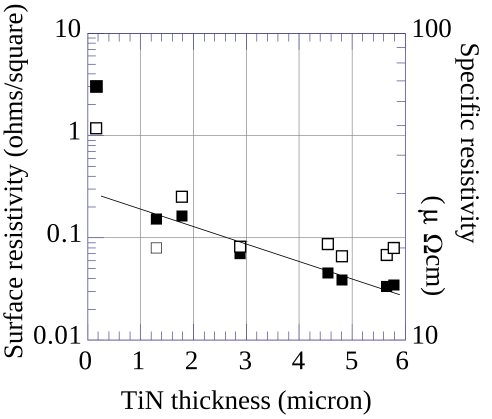

Figure 4: Surface resistivity (black) and specific resistivity (white) for TiN samples. Surfaces of ceramic plates were not polished.

Figure 4 shows the variation of the surface resistivity and the specific resistivity. The surface resistivity increases with a decrease of the thickness and steeply increases below one micron. These results are due to a difference of a uniformity of TiN film. After a sintering of a ceramic pipe formed by alumina powders, grains of the ceramics grow a few microns in size. Thus, the coating below one micron has a tendency to finish under insufficient formation. Figure 5 illustrates the close up view of such TiN sample, 0.3 μm.

On the other hand, to make a comparative study, same measurements were carried out for samples which surfaces were polished. The condition of a coating was uniform even if its thickness is 0.2 μm, see Figure 6.

The polishing of the ceramic surface is very difficult because of the long-and-narrow-kicker chamber. Further, it is difficult to handle the thickness of the sub-micron coating. Therefore, the TiN coating will not be adopted to our ceramic chamber.

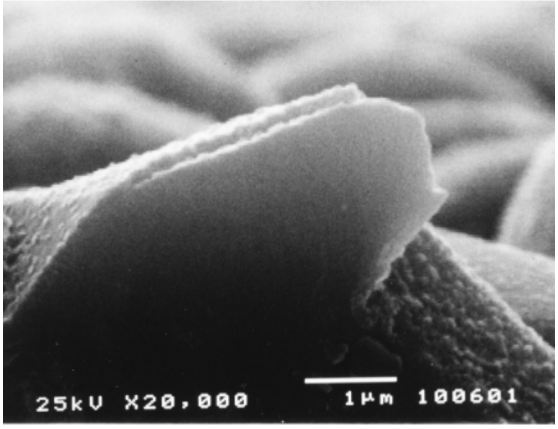

Figure 5: Cross section of the surface. The thickness of the TiN is 0.3 μm and the base ceramics is not polished.

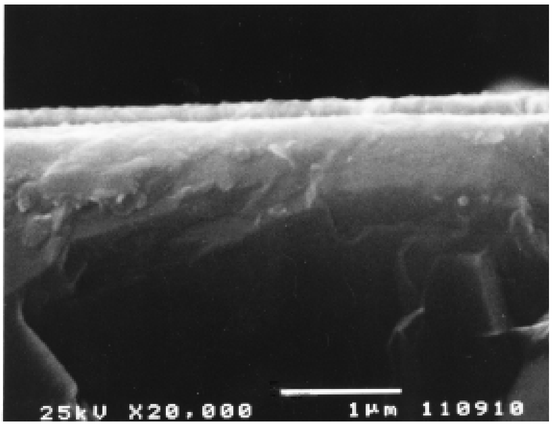

Figure 6: Cross section of the surface. The thickness of the TiN is 0.2 μm and the base ceramics is polished.

IV. CONCLUSIONS

To form a suitable metallic coating on the inside of the ceramic chamber, the thickness of the coating is needed to be more than one micron; the material must have higher specific resistivity more than 100 μΩcm.

There are some materials which specific resistivity is more than 100 μΩcm. Most of them are ferro-magnetic metals, thus effects due to the skin depth must be considered. Moreover, methods that make a small surface roughness of a ceramic pipe should be studied.

The injection and extraction system of the damping ring, including ceramic chambers, is planning to install in the fall of 1996.

V. REFERENCES

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