DEVELOPMENT OF RF INPUT COUPLER WITH A COAXIAL LINE TIN-COATED AGAINST MULTIPACTORING

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Abstract

In one of the normal-conducting RF cavities used in the KEKB operation, we observed an unexpected rise of the vacuum pressure at certain input-power levels with and without a beam current. From the simulation study, we identify the pressure rises as an effect of the multipactoring discharge in the coaxial line of the input coupler. According to the simulation results, we have decided to make TiN coating on the inner surface of the outer conductor to suppress the multipactoring. In this paper, the status of the development of the TiN-coated input coupler is reported including the recent results of the high-power tests.

INTRODUCTION

KEKB is a double-ring asymmetric-energy electron-positron (e^-e^+) collider [1], which has delivered world-highest luminosities, beyond its design, mainly for B physics [2].

The ARES[1] system [3], which is a normal-conducting RF accelerating cavity system for KEKB, stores high beam currents of e^- and e^+ stably to achieve the high luminosities. The stability is obtained by having the additional energy-storage cavity with a large cylindrical shape (S-cav), which is electromagnetically coupled to the HOM-damped accelerating cavity via the small coupling cavity.

The input coupler is an important key component for high-power RF cavities, which is attached to one of the ports of the S-cav in the ARES system. Figure 1 shows the ARES input coupler with a capacitive iris, a door-knob transformer, a ceramic window, a coaxial line (WX77D), and a coupling loop.

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[1] ARES stands for Accelerator Resonantly coupled with Energy Storage.

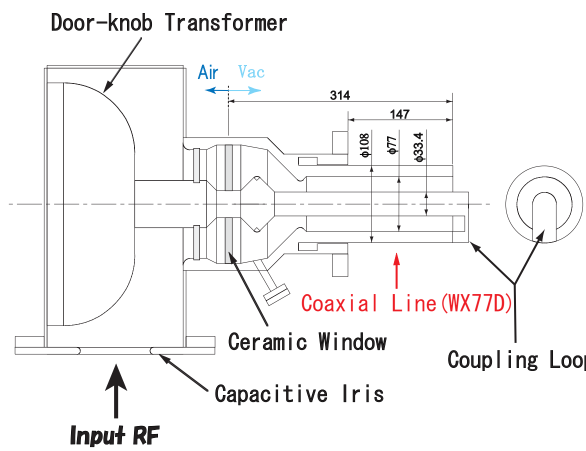

Figure 1: ARES input coupler.

TIN COATING ON THE COAXIAL PART

Apparatus

TiN coating is performed with a DC sputtering method in a vacuum chamber, where the vacuum pressure is about 3×10^{-4} Pa before coating. In the chamber, the coaxial part of the input coupler is hung vertically, and a bar made of titanium (Ti) to provide Ti molecules is put at the axis line of the coaxial part. During the coating, argon (Ar) and nitrogen (N_2) gases are injected. This apparatus has been used for TiN coating with a thickness of about 10 nm on RF ceramic windows for couplers of ARES and of the linacs for the J-Parc project.

Study for an Appropriate Condition

We have two important parameters on the TiN coating: thickness and secondary-electron yield (SEY) to be controlled. We measured them using disk-shape test pieces with a 15 mm diameter and a 3 mm thickness made of glass (for thickness measurements) and of copper (for SEY measurements), as shown in Figure 2. These test pieces were attached on a dummy conductor made of stainless steel, as seen in Figure 3. This dummy conductor has exactly the same shape as the real one to make the same boundary condition of the electric field during the TiN coating.

We initially made TiN coating with the same total pressure, 5 Pa, as in the coating for RF ceramic windows. However, there was not enough glow discharge, and almost no coating on the surface. Therefore, we increased the to-

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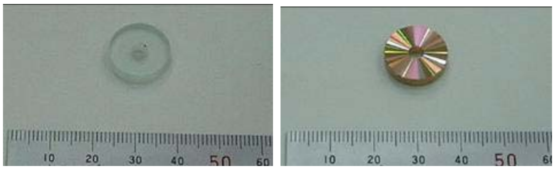

Figure 2: Glass (left) and copper (right) test pieces. A hole with a diameter of 3.5 mm is made at the center for the attachment on the dummy conductor with a M3 bolt.

Figure 3: Glass and copper test pieces are attached on the dummy conductor made of stainless steel. A hole was made to inspect the status of the TiN coating inside the conductor, as seen in the left picture.

tal pressure by decreasing the conductance of the vacuum pump[2]. Finally, we had enough amount of coating with a total pressure of 24 Pa. We made the gas mixture ratio of Ar:N_2 a free parameter to be adjusted in order to obtain an appropriate thickness and a minimum SEY.

The thickness was measured by a direct observation of a cross section of a cut test piece using a scanning electron microscope (SEM) with a magnification of 2×10^5. Figure 4 shows an example of the cross-section images by SEM. From our early study, it is found that 10 nm thickness is not enough because the SEY is increased after heat in brazing (820 °C for 5 min), so that we need at least 20 nm thickness. Figure 5 shows thickness measurements as a function of the gas mixture ratio. The ratio of Ar:N_2=1:2 is the best from a point of view of thickness. The azimuthal uniformity was also measured, and it was found to be enough.

SEY was measured using a modified SEM [5], where primary and secondary currents of electrons were measured with Faraday cups. SEY is defined as a ratio: a secondary current divided by a primary current, including elastically-scattered electrons. The vacuum pressure during the measurement was about 2×10^{-4} Pa. Figure 6 shows measured SEYs as a function of the gas mixture ratio. Since there is no significant dependence on the gas mixture ratio in this measurement, we adopted the ratio of Ar:N_2=1:2.

Figure 7 is a picture of the TiN coating on the coaxial part of the real coupler (not a dummy conductor).

[2]We could not increase the flow rate of the injected gases due to a technical reason

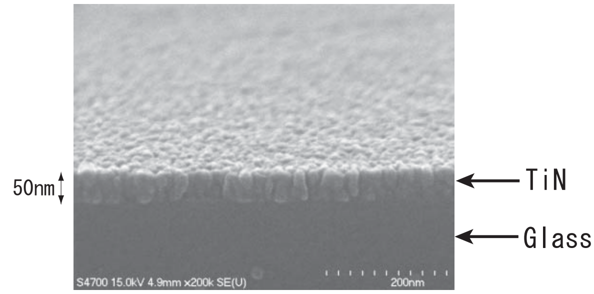

Figure 4: Example of the SEM images of the cross sections of the TiN coating, used for the TiN thickness measurement. Glass test pieces were polished with an average roughness of about 0.5 nm.

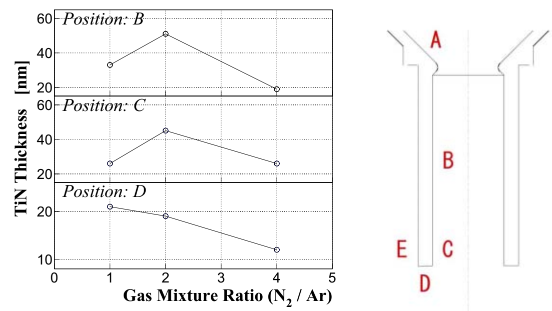

Figure 5: Thicknesses measurements (left) and the measurement positions (A-E) along the axis of the coaxial part (right). Each value is an average of twelve measurements at different points on a test piece.

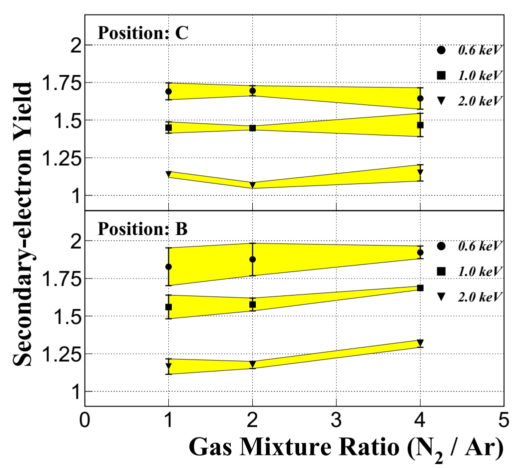

Figure 6: SEYs as a function of the gas mixture ratio. The positions of C and B are defined in Figure 5. Each value is an average of four measurements at different points on a test piece, and the bands indicate root-mean-square.

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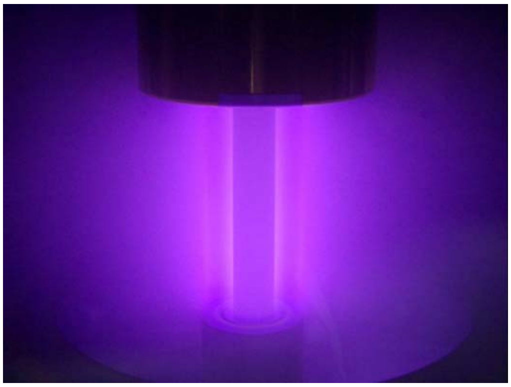

Figure 7: TiN coating on the coaxial part of the real coupler.

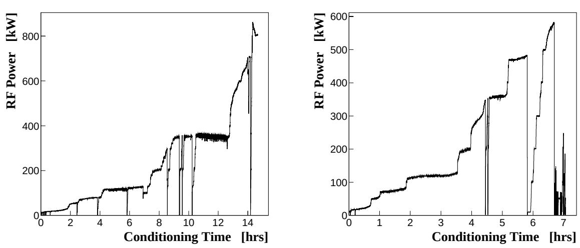

Figure 8: Power histories for the first-tested TiN-coated coupler (left) and the secondly-tested one (right). Only the periods when the aging program was executed are included, so that the horizontal axis does not indicate the elapsed time but the net conditioning time. The second test was interrupted below 800 kW due to some troubles in the low-level control system of the test stand.

HIGH-POWER TESTS

The TiN-coated couplers have been tested in the upgraded coupler test stand [6]. The power capability is over 800 kW, twice as much as the nominal power in KEKB. Figure 8 shows power histories from the high power tests, which can be compared with the power history for the non-TiN-coated coupler as shown in Figure 6 of [6]. At present, there is no significant improvement on the TiN coating seen in the conditioning time.

SUMMARY AND CONCLUSION

We have developed TiN-coated couplers toward SuperKEKB. The TiN coating is applied on the inner surface of the outer conductor according to the simulation result. We made a study with various coating conditions, and have found an appropriate condition for the TiN coating. The TiN-coated couplers have been tested in the upgraded coupler test stand. Although the statistics is not enough, no significant improvement can be seen in the conditioning time. Further tests are to be done, and alternatives are to be considered, e.g. to modify the shape to avoid multipactoring.

ACKNOWLEDGMENT

We are thankful to S. Michizono for the help in the SEY measurement.

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