RESIDUAL GAS ANALYSIS AND ELECTRON CLOUD MEASUREMENT OF DLC AND TiN COATED CHAMBERS AT KEKB LER

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Abstract

For future high-intensity positron or proton accelerators, beam instability caused by electron cloud is one of the most important problems. Some coatings on inner surface of beam chambers with materials having low secondary emission yields such as titanium nitride (TiN), non-evaporable getter and so on have represented good effects against the electron cloud instability. In this study, diamond like carbon (DLC) and TiN coated chambers, and a copper chamber without coating were installed to an arc section of KEKB LER to make comparisons of total pressure, residual gas components and electron cloud activity during the beam operation under the same condition. Residual gas observation for the DLC coating revealed much higher hydrogen gas desorption because a process gas including hydrogen was used for the film growth. No remarkable hydrocarbon gas desorption was found. On the other hand, a mass peak of amu = 14, that is N^+ was prominent in the TiN coating. The electron cloud activity in the DLC coating was lower than the TiN coating and the copper chamber.

INTRODUCTION

In high intensity positron or proton accelerators, to obtain an inner surface of beam chamber with a low electron emission coefficient is one of the most effective solutions to avoid electron cloud instability. Several coatings, such as titanium nitride (TiN) and non-evaporable getter, having low secondary electron yield (SEY) for the inner surface of chamber have been examined to reduce the electron cloud density in major accelerators including the KEK B-factory (KEKB) [1-4]. And those coatings have been found to be effective in reducing the electron cloud density.

We reported that carbon materials have low SEY and might be effective for reduction of electron cloud instability in the past studies [5,6]. In CERN, an amorphous carbon coating method has been developed for SPS to correspond LHC upgrade [7].

In this report, authors will propose diamond like carbon (DLC) coating on the inner surface of beam chamber. We prepared a DLC coated aluminum chamber, a TiN coated copper chamber and copper chamber without coating. Each test chamber with and without coating was installed to an arc section of KEKB LER (positron ring) to compare the residual gas component and the electron cloud density during beam operation. We will report the results of the observation of gas species with a residual gas analyzer and the measurement of electron cloud with an electron monitor during beam operation.

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EXPERIMENTAL

Coating

DLC coating on the aluminum chamber has been carried out by plasma-CVD method with acetylene gas. The coated film has a layered structure to fix on the aluminum substrate. Fig. 1 shows SEM image of a cross section of DLC film on aluminum substrate. The total film thickness was around 3.5 μm. The DLC film was only the top surface layer of which thickness was around 0.2 μm. The temperature of the aluminum chamber was less than 110 degrees C during coating.

TiN coating on the copper chamber has been carried out by magnetron sputtering method in the KEK coating facility. The thickness of TiN film was around 0.2 μm. The temperature of the copper chamber was 130 – 150 degrees C by heating during coating.

The test chambers were baked for 24 h before installation to KEKB.

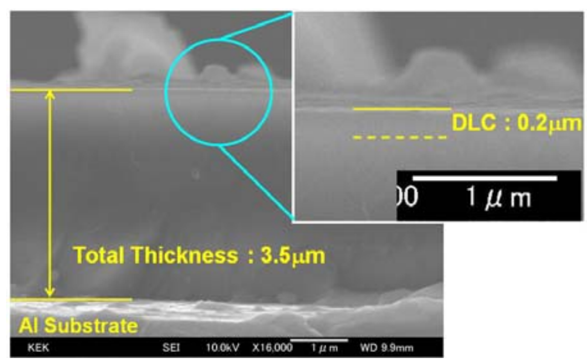

Figure 1: SEM image of DLC layered film on aluminum substrate. The total thickness was around 3.5 μm and DLC film thickness was 0.2 μm.

Test Chamber Installation to KEKB LER

The test chambers with DLC and TiN coatings and without coating were installed to the same position of the arc section of KEKB LER. Fig. 2 shows an outline of the aluminum test chamber with DLC coating. The test chambers are equipped with the electron monitor and the residual gas analyzer (RGA). Only the copper chamber without coating had no RGA. A cold cathode gauge (CCG) and an ion pump are located at 1.5 m from the test chamber.

RESULTS AND DISCUSSIONS

The observation of total pressure and residual gas components and measurement of electron cloud activity were performed during usual beam operation with 1.6 – 1.7 A of the total positron beam current.

Fig. 3 shows the total pressure measured with CCG for three test chambers as a function of an integrated beam current. In DLC coating, a decreasing rate of pressure was the slowest and the pressure decreasing was saturated on the order of 10^{-6} Pa. In TiN coating, the pressure was achieved to 3×10^{-7} Pa.

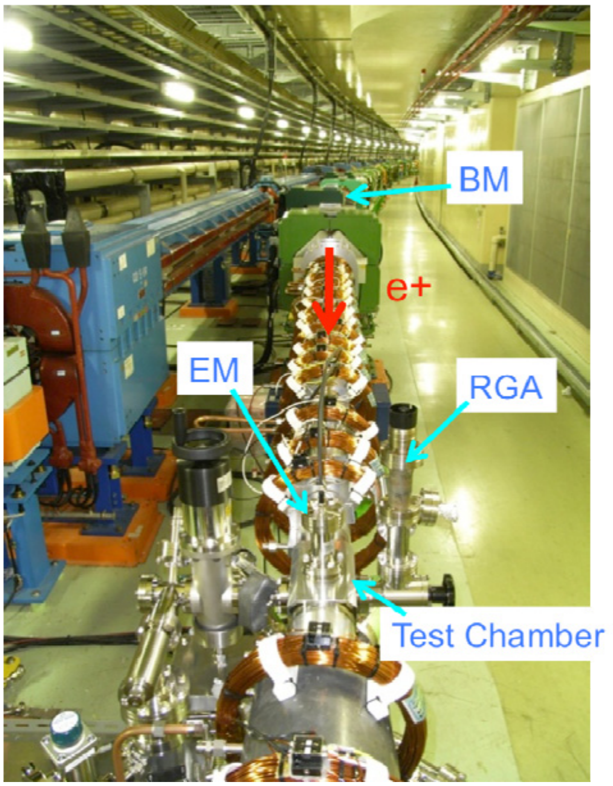

Figure 2: Outline of aluminum test chamber installed at arc section of KEKB LER. BM ; bending magnet, EM ; electron monitor, RGA ; residual gas analyzer.

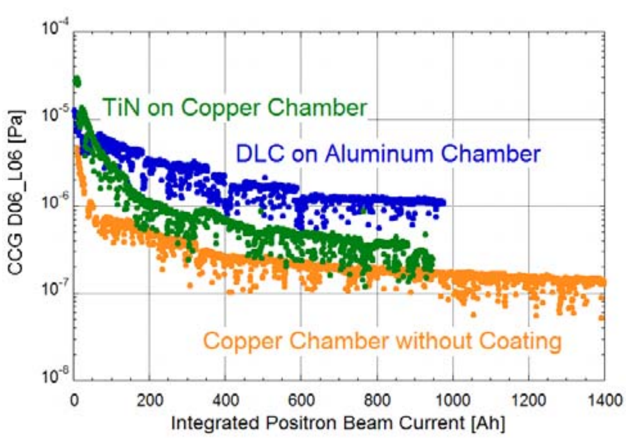

Figure 3: Total pressure measured with CCG for DLC, TiN coating chambers and copper chamber without coating as a function of integrated positron beam current.

Residual gas mass spectra in DLC and TiN coating chambers are shown in Fig. 4 (a) (b) at around 620 Ah of the integrated beam current. The mass spectra without beam operation were subtracted as background signal. One can see remarkable high hydrogen peak for DLC coating chamber. The much hydrogen gas desorption might be caused by the process gas including hydrogen for the DLC film growth and the thick film including hydrogen gas. But hydrocarbon gas components which were considered to be desorbed from DLC film, were not remarkable in comparison with TiN coating chamber. The high total pressure for DLC coating was determined by only much hydrogen gas desorption. To reduce hydrogen gas desorption, further R&D are necessary to get thinner DLC film.

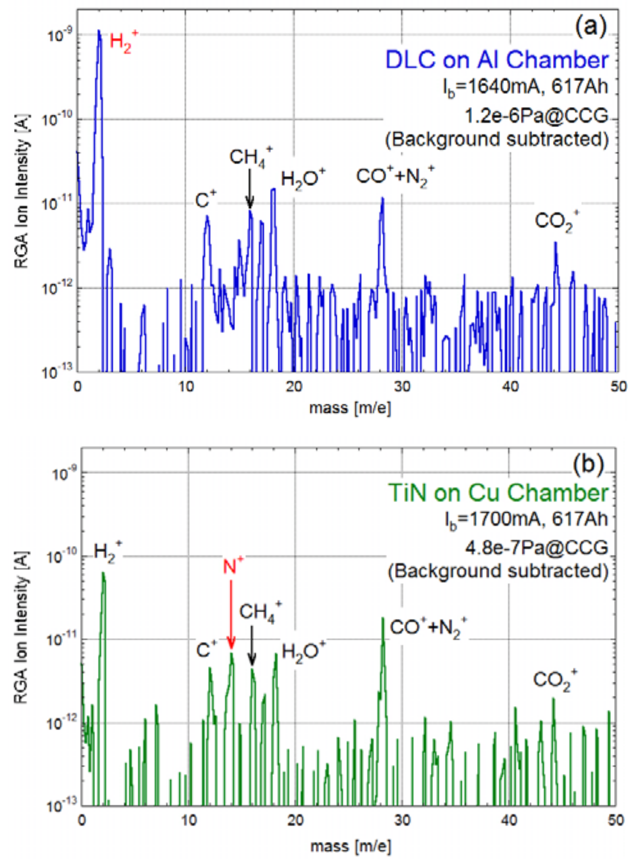

Figure 4: Residual gas mass spectra for DLC (a) and TiN (b) coating chambers at around 620 Ah. Background spectra obtained without beam operation was subtracted.

In TiN coating chamber, a ratio of amu = 14 to 28 is higher than 0.3. If the peak of amu = 28 is only from nitrogen gas, the cracking ratio of amu = 14 to 28 is around 0.13 from our experiment. This means that much nitrogen atoms and/or ions were dissociated from TiN film due to exposure to beam operation. The ratio of amu = 14 to 28 was almost constant from low to high integrated beam current.

Fig. 5 shows the electron monitor current that was depending on electron cloud activity as a function of the integrated beam current. The monitor current of DLC and

TiN coating chambers were 1/5 and 1/3 in comparison with one of copper chamber without coating. Both coatings were effective to reduce the electron cloud activity even in arc section.

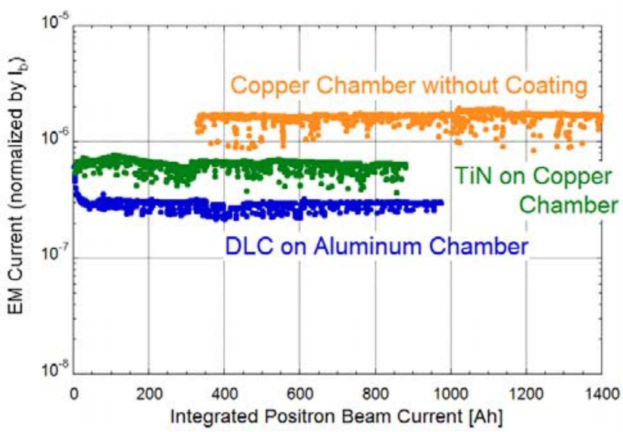

Figure 5: Electron monitor current for DLC and TiN coating chambers and copper chamber without coating during beam operation as a function of integrated beam current.

CONCLUSION

The DLC and TiN coating test chambers were installed to observe residual gas components and to measure electron cloud activity during beam operation. According to RGA observation, much hydrogen gas and no carbonaceous gas desorption was revealed from DLC film. On the other hand, the mass peak of N^+ was distinct in TiN coating chamber. Although the total pressure of DLC coating chamber was 1×10^{-6} Pa that was ten times higher than copper chamber without coating even after enough aging with beam operation, it has little influence on the beam quality because the desorbed gas components are almost only hydrogen. However further researches are necessary to reduce the hydrogen desorption gas from DLC film. In the measurement of electron monitor, DLC and TiN coatings were effective to reduce the electron cloud activity.

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