

## E-CLOUD ACTIVITY OF DLC AND TIN COATED CHAMBERS AT KEKB POSITRON RING

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### Abstract

A TiN coated copper chamber and diamond like carbon (DLC) coated aluminium chambers were installed to an arc section of the KEKB positron ring to make comparisons of electron cloud activity as well as total pressure and residual gas components during the beam operation under the same condition. For the DLC coating, two different types of surface roughness: smooth and rough were prepared. The chamber with large surface roughness that was obtained with cost-effective simple abrasive of the large grain before the coating was installed in the same arc section and exposed to the electron cloud until the KEKB shutdown. The measured electron cloud activity in the DLC coated chamber with smooth surface showed half and one-sixth of those in the TiN coated chamber and the copper chamber, respectively at the operation of around 1000 Ah. Much more reduction of the e-cloud activity owing to the DLC on the roughed chamber surface was found, that is a reduction of one-fifth and one-tenth, respectively, in comparison with the DLC on non-roughed chamber and the TiN coating on non-roughed chamber at around 1000 Ah.

with an average size of 30 microns was adopted with a process speed of 100 mm/min along with the chamber.

The DLC coating for the chamber shown in Fig. 1 was carried out mainly with acetylene gas of 1Pa in a pulsed DC plasma-CVD (chemical vapor deposition) chamber which allows us to coat DLC on a less than 3.5m-long chamber. The measured chamber temperature was not larger than 140 degrees C during the coating. Sample coupons were set inside of the envelopes that were connected to the Al chamber to confirm the film quality and the film thickness. The DLC deposition rate was measured to be 100 nm/min and the coating homogeneity was measured to be  $\pm 5\%$ .



Figure 1: 0.9m long DLC coated Al Chamber after the surface roughing.

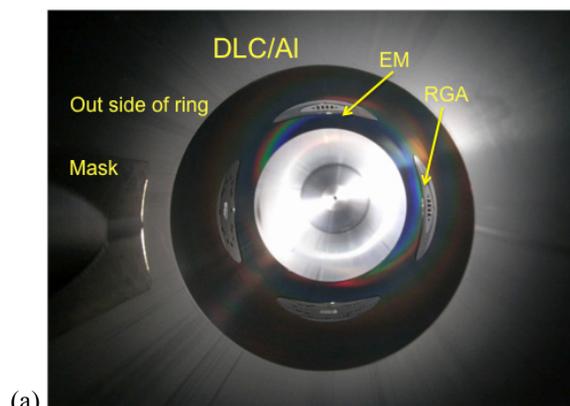
### INTRODUCTION

After we found reduction of secondary electron yield (SEY) due to electron beam induced graphitization at surfaces of many metals, alloys and compounds, we have been performing comparative investigation to show validity of carbon materials such as graphite, diamond, amorphous carbon, electron induced graphite layer and so on with other metals and compounds in order to reduce e-cloud activity in accelerators [1-6].

One can find a couple of advantages of carbon materials for mitigating e-cloud in the following: (a) low  $\delta_{max}$  and low SEYs at higher incident energies and at oblique incident angles of electrons are shown due to mainly the low mass density of carbon materials, (b) low outgassing is achievable, depending on the method to make the films, (c) carbon materials show less adsorption (low sticking coefficient) and quick desorption (low activation energy of desorption), (d) hard coating with good adhesion is possible, (e) carbon raw materials are inexpensive [1-3, 7-9].

### EXPERIMENTAL

Surface roughing was done before DLC coating on the inner surface of a 0.9 m-long Al beam chamber. For this purpose, cost-effective simple abrasive of the large grain



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Figure 2: (a) Inside of the non-roughed DLC chamber. (b) The DLC coated surface after roughing.

While the total thickness of the film was  $3.4\ \mu\text{m}$ , the pure DLC was in a thickness of  $0.2\ \mu\text{m}$  because of the multi layer system in order to enhance the film adhesion.

Some of measured characteristics show an atomic hydrogen composition of about 0.3, a Vickers hardness of 700~800 (a measured Hv of the A5052 Al chamber was 97), a resistivity of  $10^{10-11}\ \Omega\text{cm}$ . The measured Rys after the coating with a mechanical surface profile meter were  $1.3\ \mu\text{m}$  and  $21\ \mu\text{m}$  for the non-roughed and roughed surfaces, respectively.

In addition to a previous report of e-cloud activities for differently treated chambers at the KEKB positron ring [6], the surface-roughed DLC coated chamber was also installed to the same arc section together with a cold cathode gauge (CCG) a residual gas analyser (RGA), a retarding filed analyser (RFA) and sample coupons of which SEYs can be measured via UHV suitcases at lab.

## RESULTS AND DISCUSSIONS

Table 1 shows an exposure history of the four types of beam chambers to the e-cloud with a positron beam current of 1.5 - 1.7 A in a period from Feb. 8, 2008 to June 30, 2010 at the same arc section. In Fig. 3, a pressure trend for four beam chambers is shown as a function of the integrated positron beam current.

Table 1: Exposure history of the four types of beam chambers to the e-cloud of the KEKB positron ring.

| YYYY-MMDD             | Coating / Beam Chamber  |
|-----------------------|-------------------------|
| 2008-0208 ~ 2009-0630 | Cu                      |
| 2009-1014 ~ 2009-1116 | DLC / Al                |
| 2009-1117 ~ 2009-1224 | TiN / Cu                |
| 2010-0513 ~ 2010-0630 | DLC/ Roughed Al Surface |

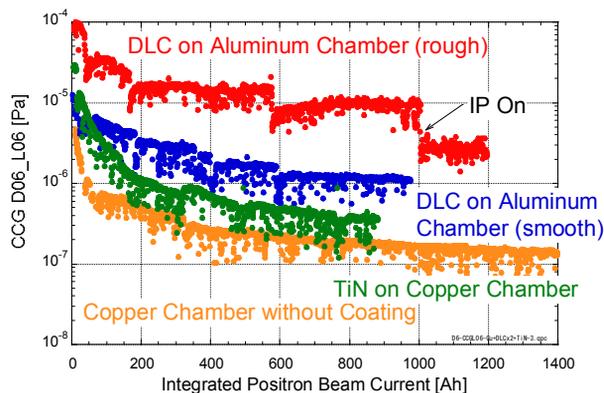


Figure 3: Total pressure measured with CCG for four different beam chambers is shown as a function of the integrated positron beam current.

Large outgassing from the surface-roughed DLC coated chamber as shown in Fig. 3 was expected before the beam operation because of the relatively thick coat and the large surface roughness. However it turned out later that a sputter ion pump (SIP) for the chamber had been out of order due to the controller breakdown just after the beam operation started. The high pressure had been thought to be intrinsic to the surface-roughed DLC film and nobody had doubt of the pump. After replacing the controller at 1000Ah, the pressure at the chamber dropped one-third, that is roughly 10 times and 3 times higher pressure compared with copper chamber and the non-roughed DLC chamber, respectively. This result of the surface-roughed DLC coat is not anymore surprising and this might be acceptable for the beam operation if hydrogen gas is dominant and the mitigation for e-cloud is remarkable, that is trade-off. In any case, it took roughly 1000Ah to get reasonable conditioning in a viewpoint of outgassing.

Comparison of the RGA spectra as shown in Fig.4 was made at the different integrated beam current unfortunately because of the SIP trouble. However the pressures in the chambers were almost constant for those integrated beam current and all the other conditions like the beam current were almost the same during the measurements.

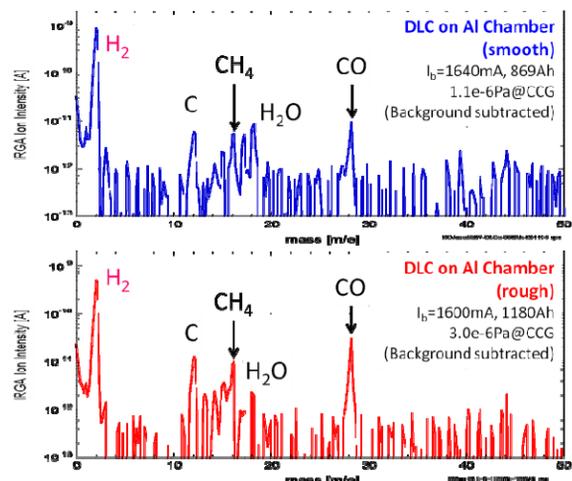


Figure 4: RGA Spectra for the non-roughed and the roughed DLC coated chambers. Background spectra acquired without the beam operation were subtracted.

These two spectra where hydrogen gas is dominant are similar each other and no hydrocarbon gas component except  $\text{CH}_4$  that is usually seen in any accelerator to a certain extent was observed up to  $m/e\ 100$ . The detailed

difference in ion current intensities of four gas species is shown in Table 2 also using the data of the other types of coating[6]. Here one sees higher intensities for the roughed DLC chamber than the intensities of the others as expected. However the measured CCG pressure was not so high as the expectation considering the actual rough-surface area. The relatively large ratios of C, CH<sub>4</sub> and CO/N<sub>2</sub> to H<sub>2</sub> for the roughed DLC chamber might be due to partially uncoated areas on the quite rough surface or partial decomposition of the DLC film at the top edges specially in an area which is irradiated with the synchrotron light. In Table 2, it is also noticeable that the residual gas species except hydrogen from the non-roughed DLC chamber are equivalent to the gas species from the TiN chamber. The m/e 28 current of 2.0e-11 A for the TiN coat includes contribution of nitrogen outgassing from the TiN film to some extent due its decomposition since nitrogen of m/e 14 was found only in the spectra of TiN coated chamber. Hydrogen outgassing which mainly affect to the total pressure would be only the issue in case of the DLC chambers. Even concerning to this issue, the hydrogen outgassing might not be eventually a problem of the accelerator operation because its low Z.

Table 2: RGA ion current intensities for the three different types of coating. Because of degradation of the RGA electron multiplier in the measurement for roughed DLC chamber, the ion intensities were corrected based on the CCG data.

|              | $\times 10^{-12}$ A |     |      |                 |                   |
|--------------|---------------------|-----|------|-----------------|-------------------|
|              | H <sub>2</sub>      | C   | N    | CH <sub>4</sub> | CO/N <sub>2</sub> |
| TiN          | 65                  | 5.0 | 7.0  | 5.0             | 20                |
| DLC (smooth) | 900                 | 6.0 | N.D. | 6.0             | 10                |
| DLC (rough)  | 2700                | 70  | N.D. | 54              | 160               |

Fig. 5 shows monitored currents at the RFA for the four types of chamber as a function of the integrated beam current. The e-cloud mitigation with the roughed DLC surface seems to be outstanding. At the beginning of the beam operation, the reduction factor of e-cloud activity for the roughed DLC chamber showed 60 when the activity in the copper chamber is defined to be one. While the activity gradually increased during the beam operation, the reduction factor was saturated to be 30.

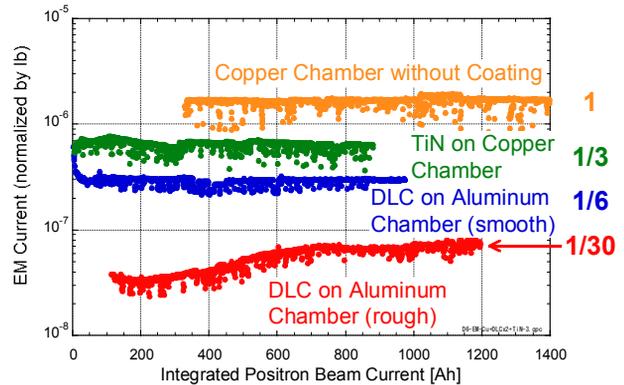


Figure 5: Monitored currents at the RFA for the four types of chamber as a function of the integrated beam current.

The gradual increase of the e-cloud activity in the roughed DLC chamber might be due to partial decomposition or partial exfoliation. In a visual check of the inside of the roughed DLC chamber after the KEKB shutdown at the end of June, 2010, light reflection change at the surface along with a line that is irradiated with the synchrotron light was found. Some partial exfoliation was also found at the circular boundary line between the non-roughed surface with the old DLC coating and the roughed surface followed with the DLC coating. This might be because of two sorts of geometric mismatching, that is mismatching of the old and new coating layers and mismatching of the smooth and rough coating substrates. This geometric mismatching would have caused mechanical stress at the circular boundary. Some cure should have been done before the roughing. However this was only the position where the partial exfoliation was found for the roughed DLC chamber.

### CONCLUSION

The e-cloud activity as well as the total pressure and the RGA spectra in the newly installed DLC coated chamber with rough surface into the KEKB positron ring were measured in comparison with those in the copper, TiN and non-roughed DLC chambers. A remarkable reduction of the e-cloud activity of around 30 was achieved when the activity in the copper chamber is defined to be one. The dominant hydrogen outgassing from the surface-roughed DLC chamber might be acceptable for the beam operation if the mitigation for e-cloud is significant, that is trade-off. However further effort to reduce the outgassing should be made.

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