e-Cloud Activity of DLC and TiN Coated Chambers at KEKB Positron Ring

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Thanks for Technical Assistance :
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Contents

- Review of EC Conditioning : Electron Beam (shower, cloud) Induced Surface-graphitization
- Advantages of Carbon Materials for Mitigating EC
- Coating on Cu or Al Beam Chamber at Arc Section
- Cost-effective Surface Roughing of Beam Chamber
- Measured Data of Pressure, RGA and EC Activity during KEKB Operation
- Summary

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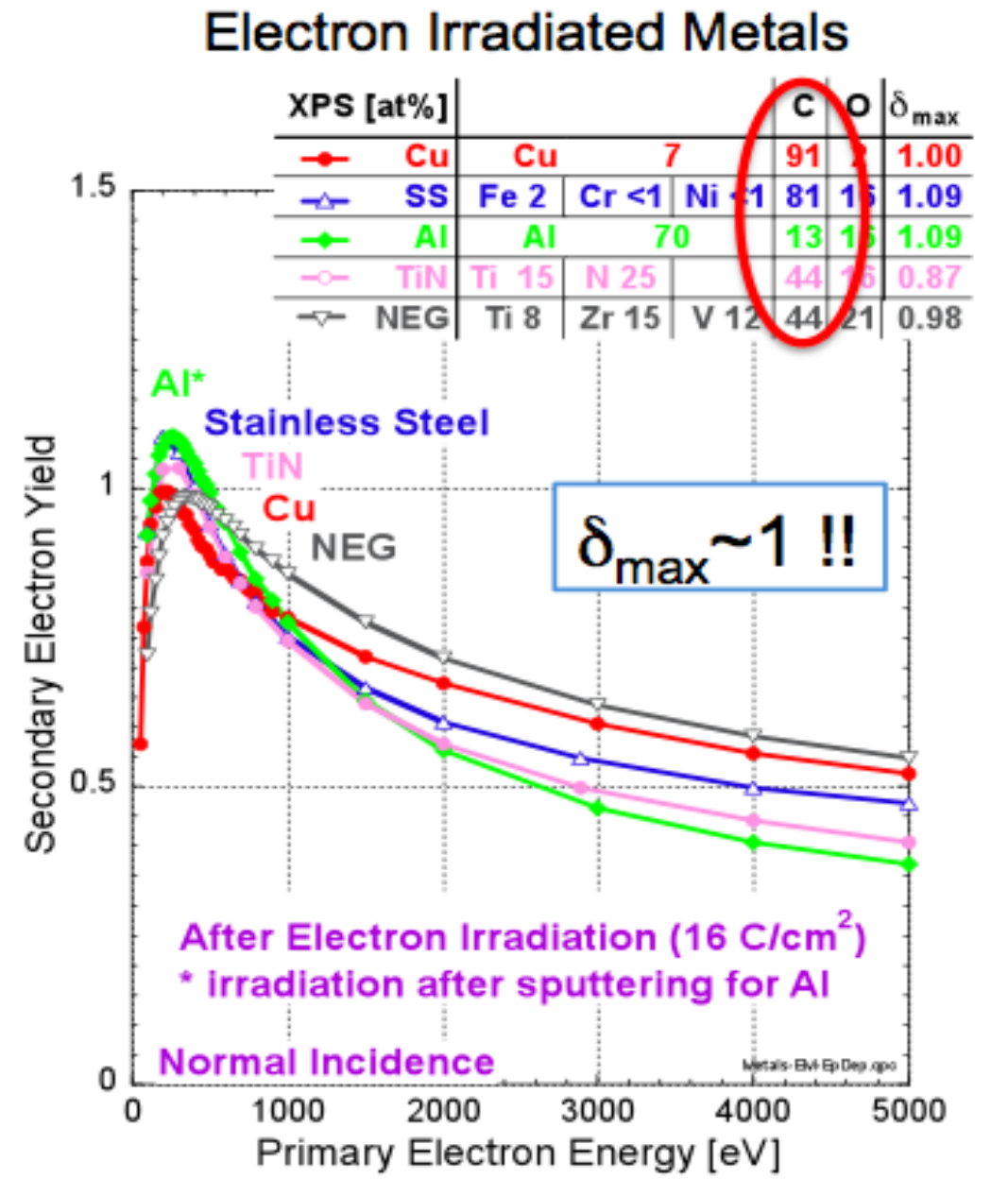
Measured SEYs Conditioned with e⁻ Beam at KEK Lab.



Measured in 2002~2005

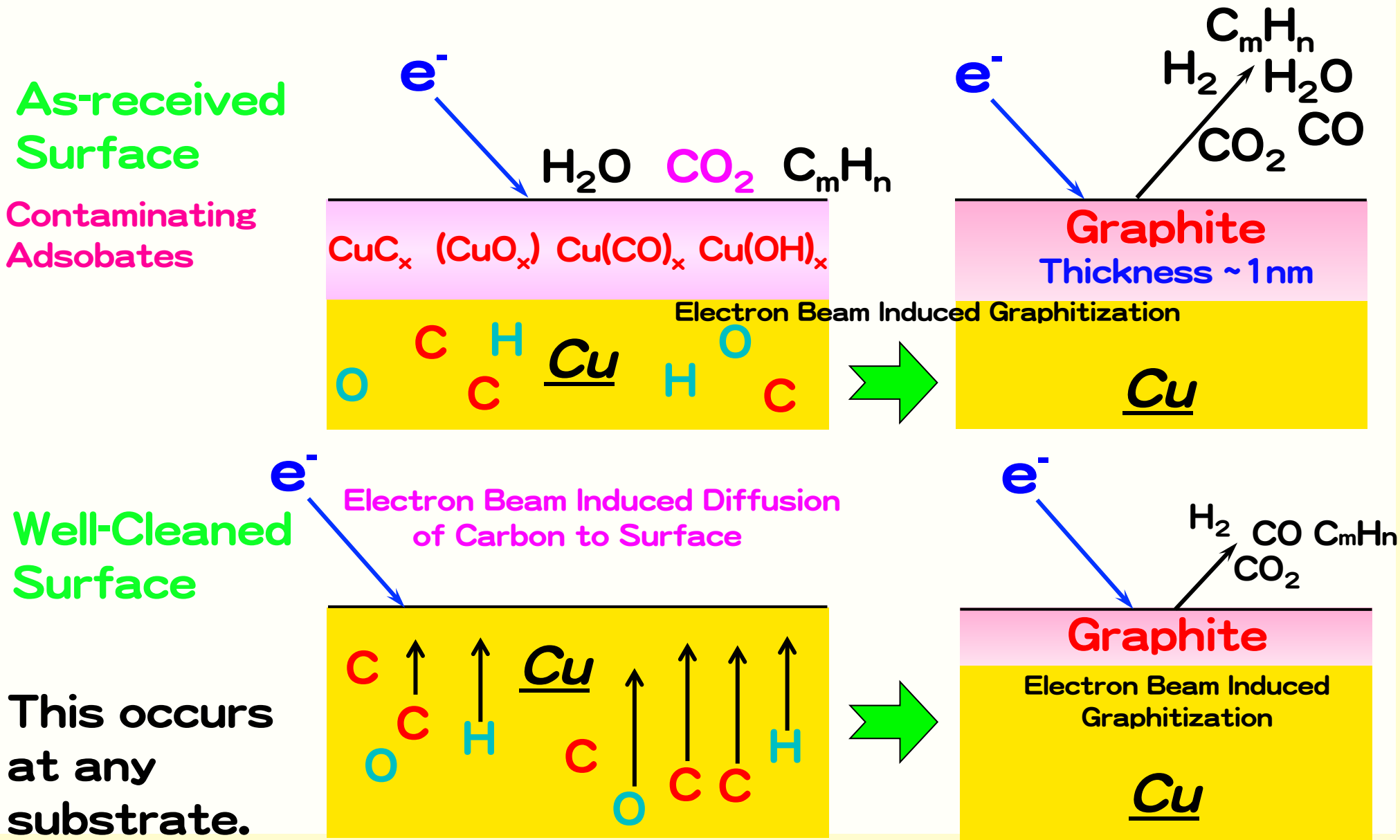
All these SEYs are not intrinsic!

★ All the surfaces are covered not by simple carbon but graphite.

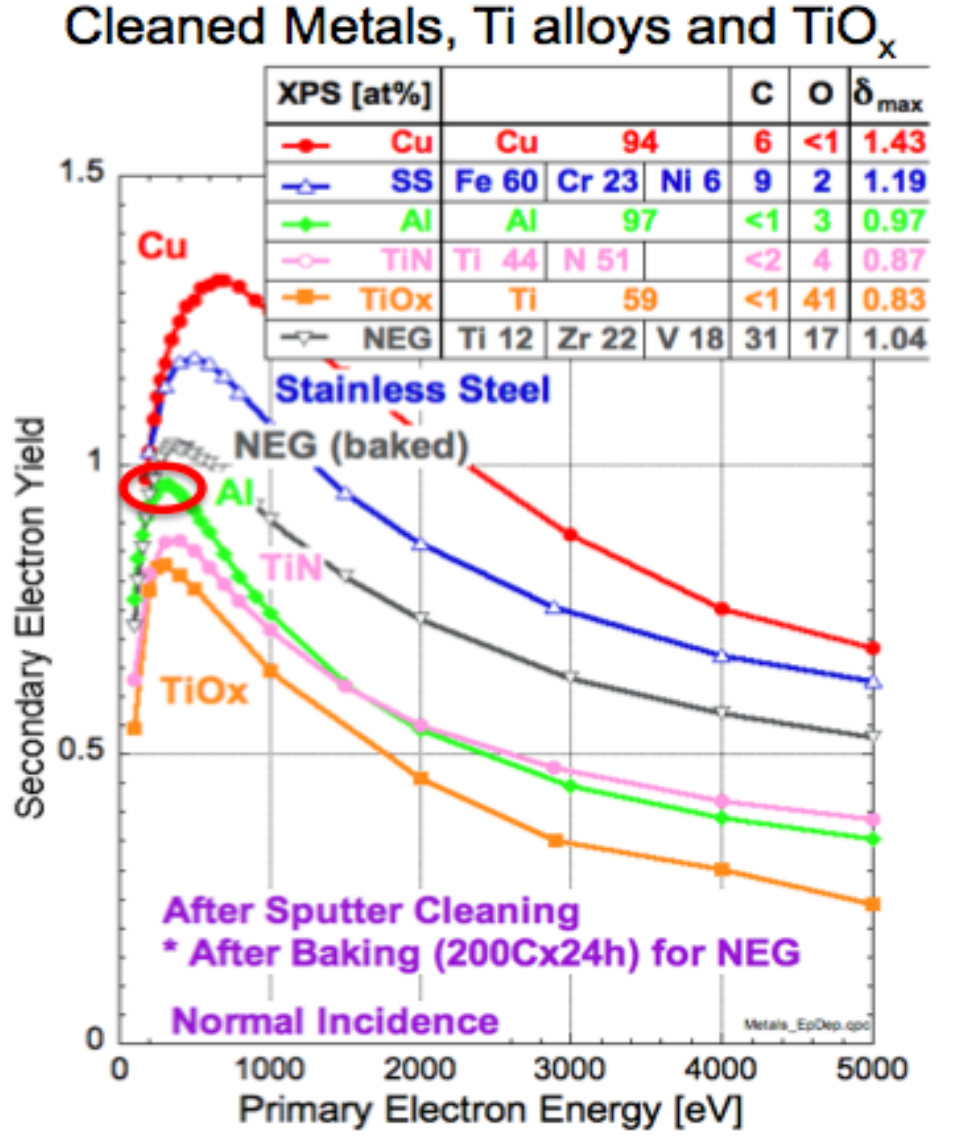
★ Graphite grows with increase of e- dose.

★ Therefore all the δ maxs meet at around one.

Models of Electron Beam Induced Surface-graphitization (2004)



Other Cases of No Graphitization



★ If ion (energetic neutral) irradiation or photon irradiation are intense in e^+ or proton machines, graphitization does not occur and will show intrinsic SEYs through sputtering or photon abrasion.

★ Surface darkening may gradually disappear when beam operation or chamber configuration is changed where sputtering or photon abrasion starts.

★ Then intrinsic SEYs appear as shown in the left.

CONCLUSIONS From Slide of CERN Seminar in 2004

- New Findings of SEY Were Done in Conjunction with In-situ Suface State.
- First Observation and Proof of Electron Beam Induced Graphitization Causing Small SEY were Made.
- As-received TiN showed Highest δmax because of Heavy Oxidation of Ti (PEP-II?).
- Dose Effects of Electron and Ion Irradiation on SEYs of TiN and SS are Similar. However Surfaces are Completely Different.
- As-received Copper Surface is Not Oxidized.
- Carbon Supplyer during Graphitization for As-received Materials is Residual Carbonatious Contamination on Suface But Not Diffused Carbon from Bulk.
- For Sputtered Clean OFHC Copper, Graphitization Still Occurs due to Heating or Electron Beam Irradiation even in UHV, w/o Residual Carbonatious Adsobates. The Source was Proved Carbon Atoms from Bulk.
- Electron Beam Induced Graphitizaion is Inevitable at Least on Copper in Practical Application Because of the No Passive Layer.
- No Need of Conditioning for Graphite was Found Even for Need of SEY<1.

- Carbonatious Contamination and Free Carbon are Evil but Graphite Would be Helper.
- Beam Conditioning in Lepton Accelerator Seems Graphization Process.
- Activie Graphitization to reduce SEY Does Not Seem Bad Idea (Graphite Thin Film Also Gives Low Outgassing and is Stable against Air Exposue) . It can be Used to Keep Property In Enviroment with No Sputtering Phenomenon.
- No Special Chemical Treatment for Some Metals Might be Required after Proper Mechanical Surface Treatment Because of Electron Beam Induced Graphitization in Anycase.

Carbon, c est bon !?

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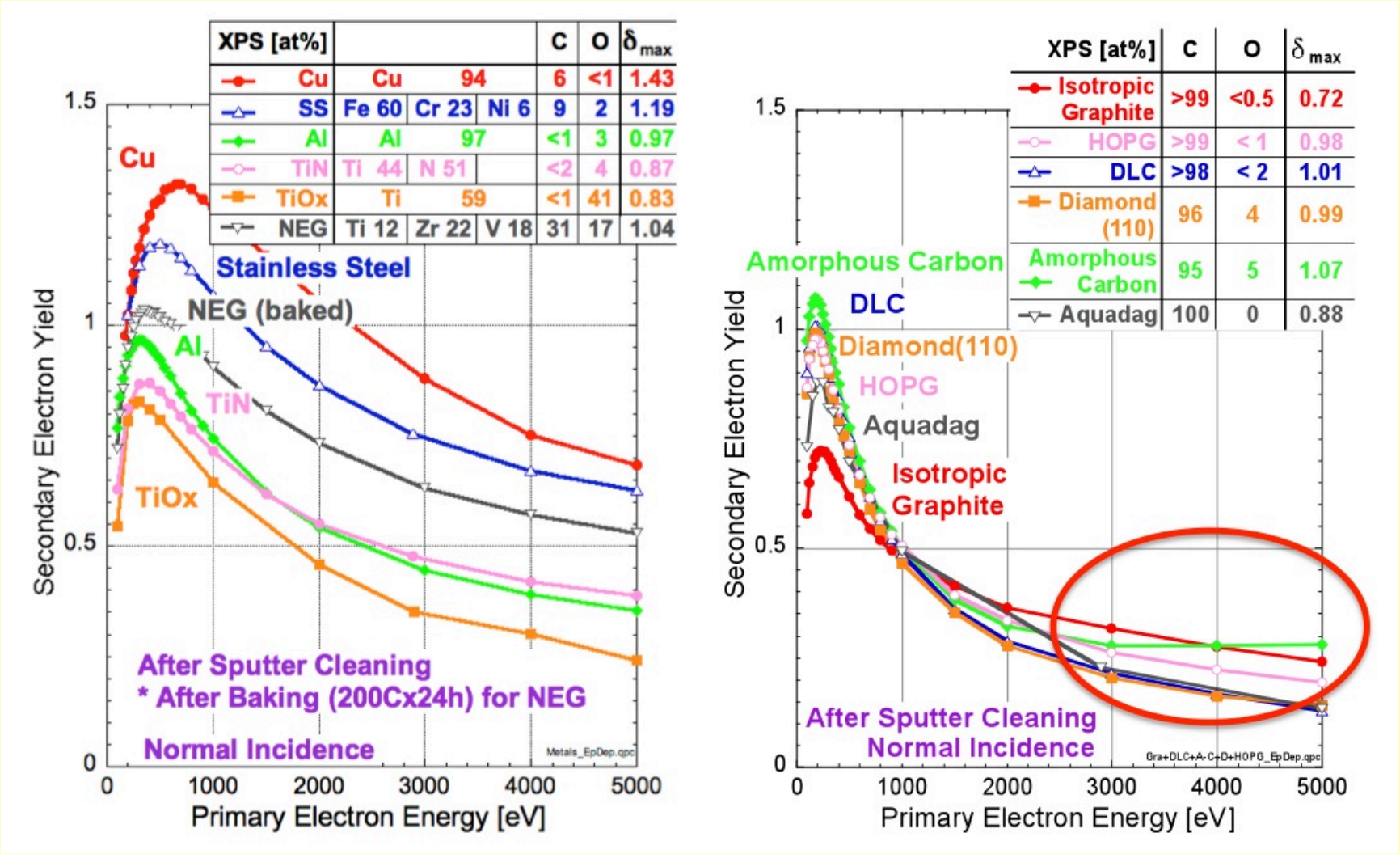
Advantages of Carbon Materials for Mitigating EC

- Low δmax and low SEY at higher incident energy and at oblique incident angle of e- due to mainly the low mass density of carbon materials.
- Low outgassing is achievable, depending on the method to make the films.
- Carbon materials show less adsorption (low sticking coefficient) and quick desorption (low activation energy of desorption).
- Hard coating with good adhesion is possible.
- Carbon materials are inexpensive, except real diamond.

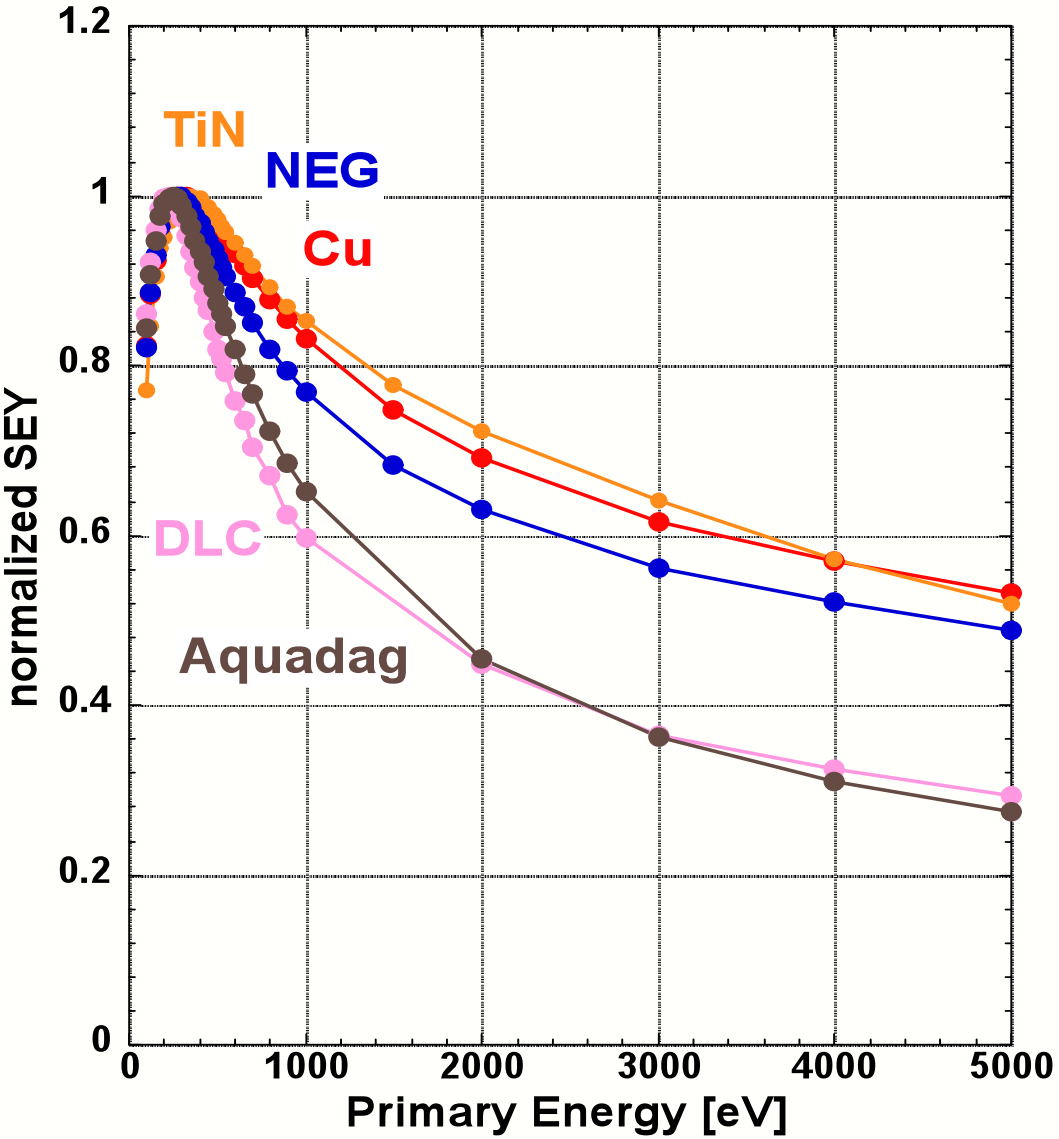
Advantages of Carbon Materials -SEY-

Cleaned Metals, Ti alloys and TiO_x Carbon Materials



⊙ Carbon materials show lower δ_{max} and large decay

Comparison of Normalized SEY Slope



★ DLC and Aquadag (as well as graphite) show steeper decay of SEYs, mainly due to their mass density.

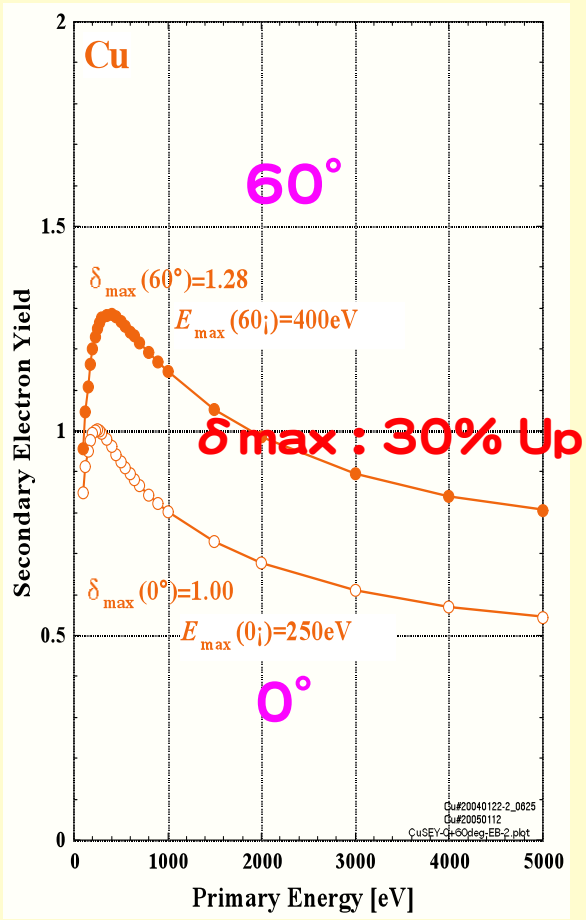
★ At high intensity operation machine, SEYs at higher primary energy would influence much more to e-cloud.

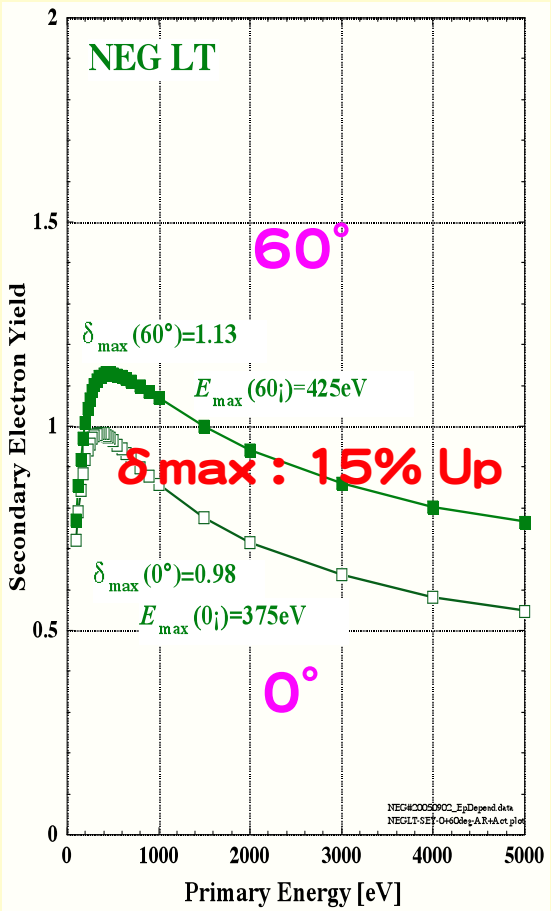
★ Furthermore, difference between the two groups becomes more at oblique incident angle of e- .

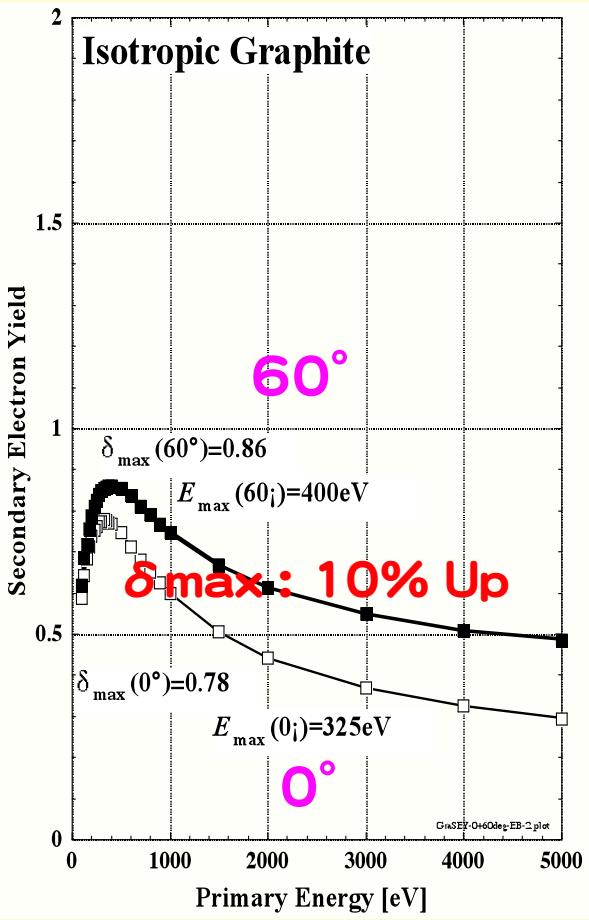
Dependence of SEYs on Incident e- Beam Angle (lab)

- Larger SEYs : Oblique Incident Angle of e- Beam.
- This dependence is important for both dipoles, quads etc because of spiral motion of electrons

SEY Results for e- Beam Irradiated Surfaces : Close to Real Surface State





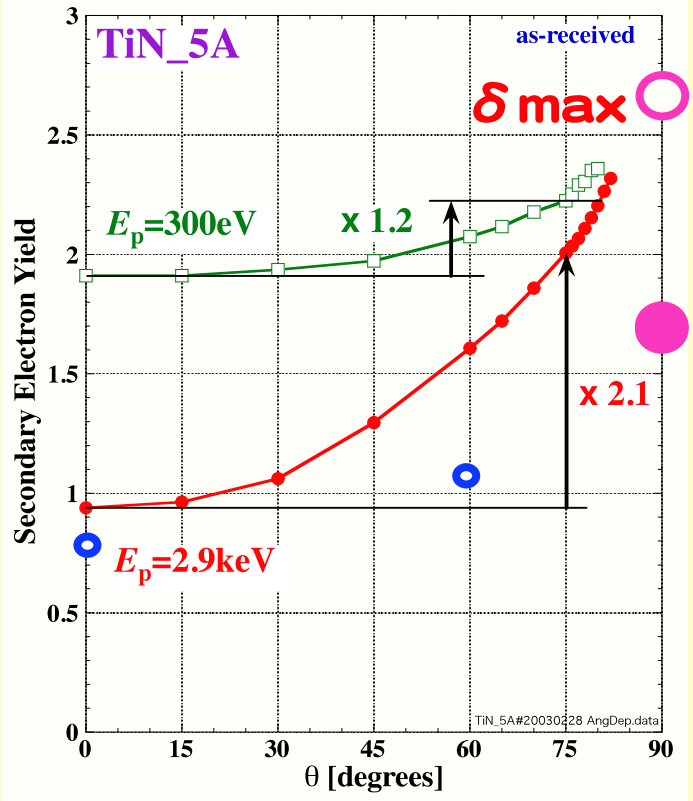


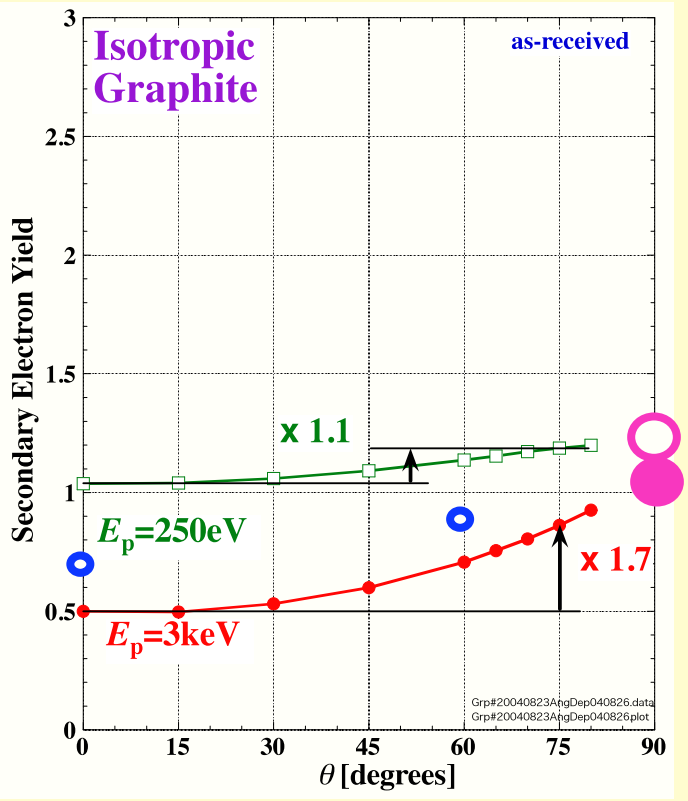
- Lower ρ Materials : Less Enhancement of δmax with Sallower Incident Angle.

Dependence of SEYs on Incident Angle (cntn'd)

- Sallower Incident Angle of e^- Beam : Larger SEYs

SEYs Results for As-received Surface





- Metal Surfaces : High SEYs and Large Enhancement of SEYs with Sallower Incident Angle
- Graphite Surfaces : Low SEYs and Small Enhancement of SEYs in a Wide Range of Incident Angle

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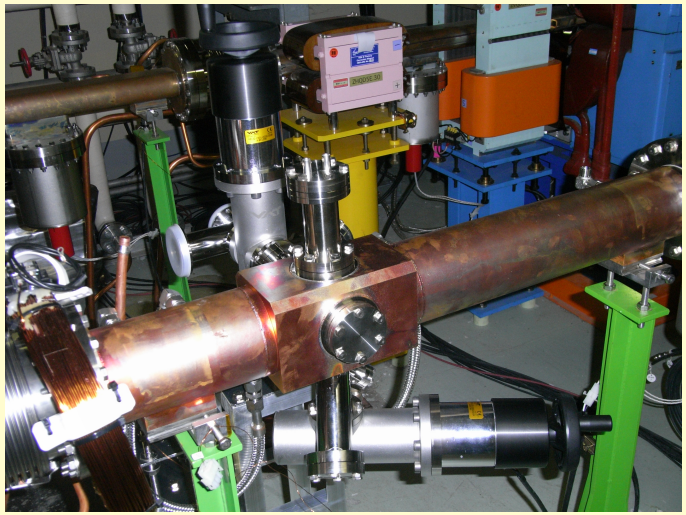
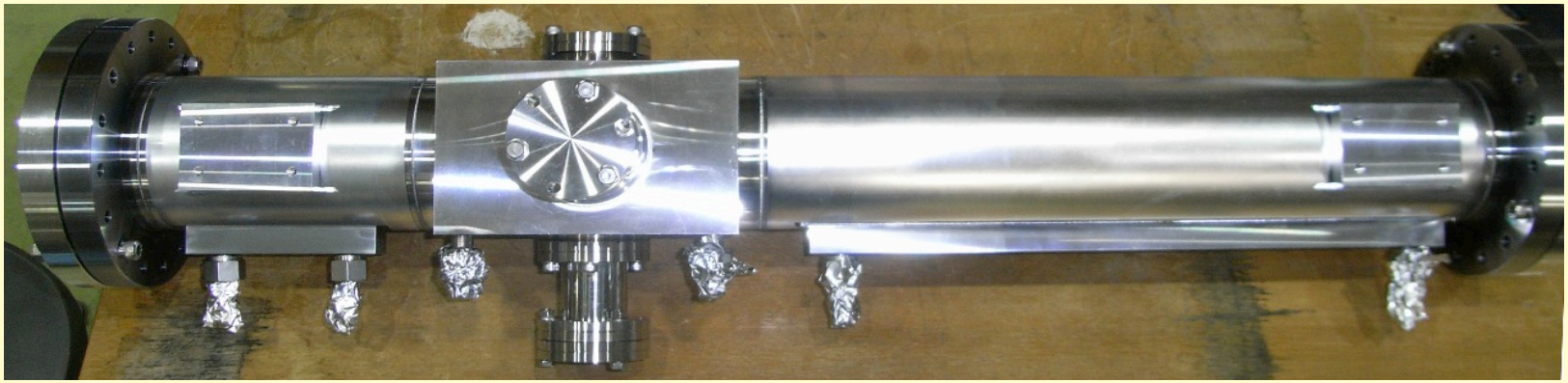
Coating on Cu or Al Chamber at Arc Section

- TiN Coating (200nm) on Cu Chamber (1.3m)



Done by Shibata san
& Hisamatsu san, KEK

- DLC Coating (600nm) on Al Chamber (identical to Cu One)



Why DLC Coating?

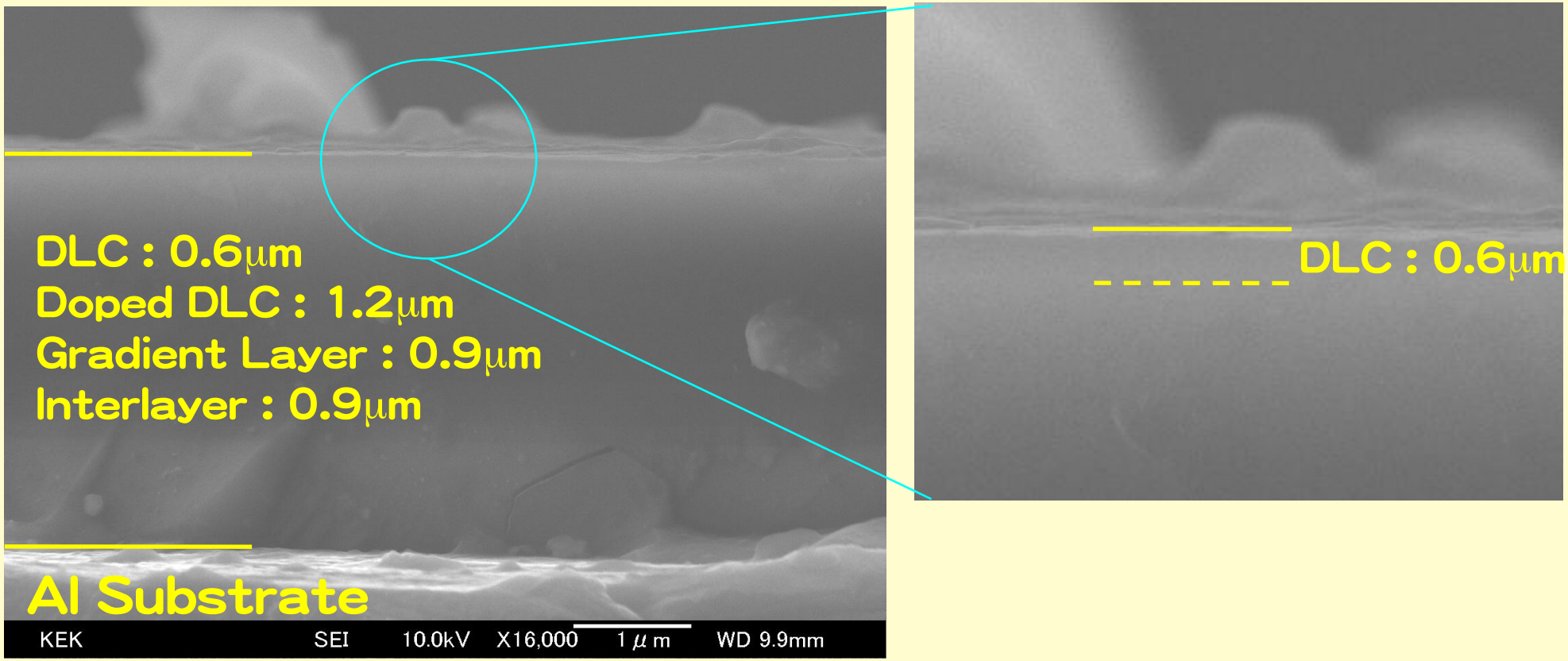
- Many Techniques for Carbon Coating

1. PCVD-based DLC (KEK)
2. PCVD-based a-Carbon
3. Electron Beam Induced Surface Graphitization (KEK)
4. Sputter-deposited Carbon (CERN)
5. Brazing of Isotropic Graphite Liner
6. Paint or Spray of Graphite Microparticles (Aquadag)
7. Plasma Spray of Graphite Microparticles

- Why DLC?

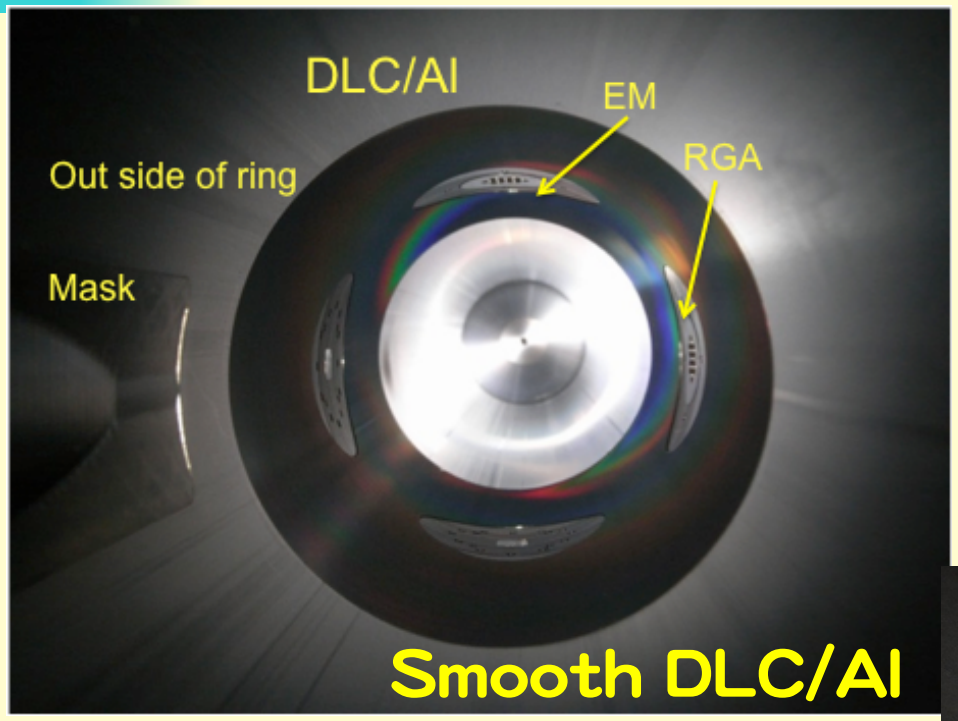
1. Inexpensive : ~US$800.- /m for coating of 100m.
2. Deposition rate is large (a couple of μm/h) and uniform(±5%).
3. Coating is possible for any type of beam chamber (even bent one) and on any material.
4. No sputtering target inside of chamber is necessary.
5. No magnetic field is necessary.
6. High hardness + quite good adhesion + high heat-resistivity
7. Less dust particle generation

SEM Image of DLC Film Layers

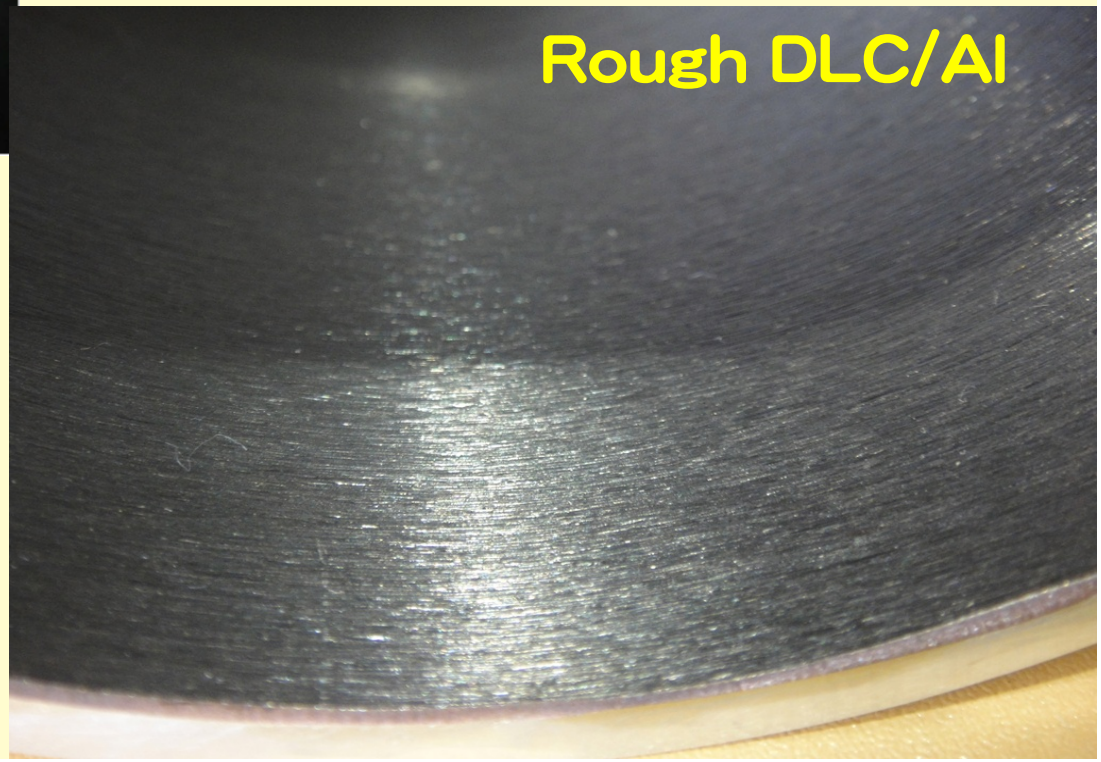


- The coated film has a layered structure to fix on the substrate.
- Total thickness of the film is ~3.6μm (process time : ~90 min)
- The thickness of DLC is ~0.6μm.
- The coating process and its characteristics will be introduced in the poster.

Cost-effective Surface Roughing of Beam Chamber



R_y=1.3 μm
: extrusion
or EL machining



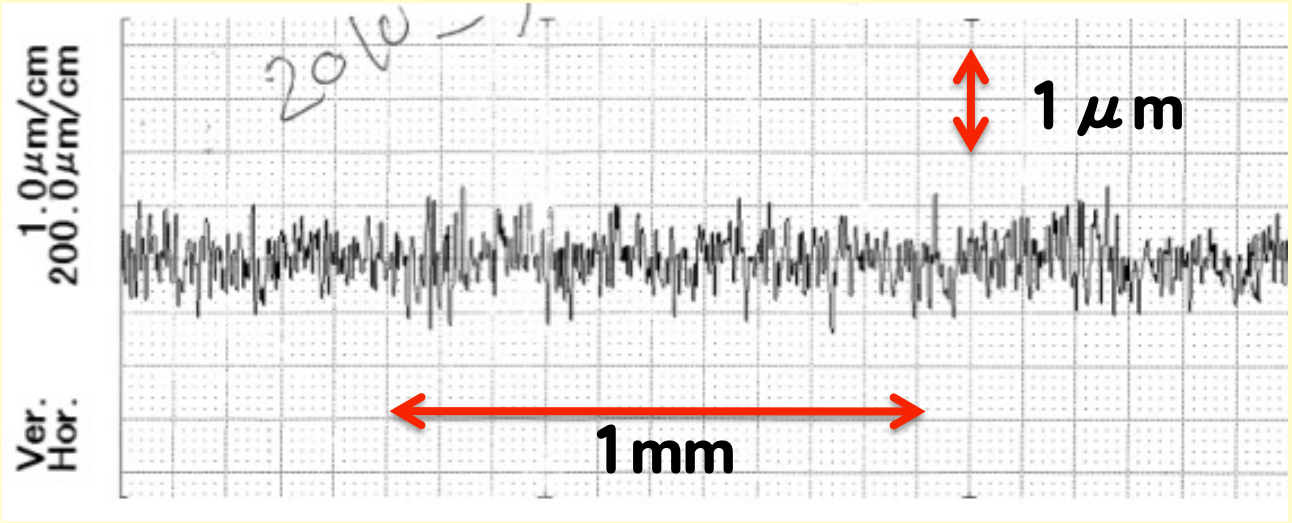
R_y=21 μm
: grinding with a large grain of abrasive, before DLC coating

Grinding Speed :10 min/m

Surface Roughness Measured with Mechanical Surface Profile Meter

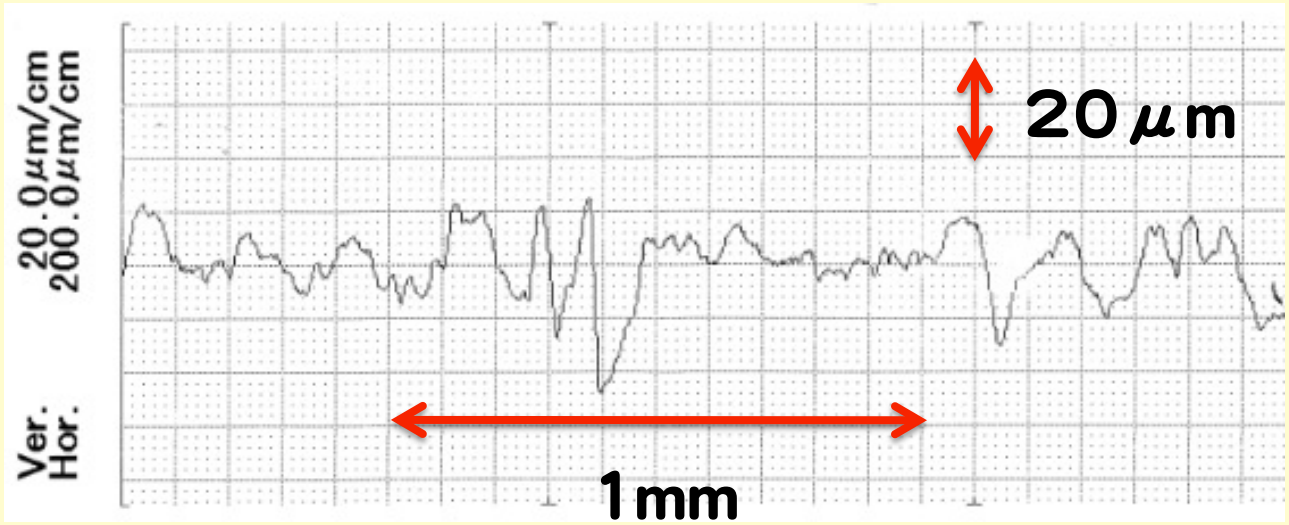
Smooth Surface

V. Scale : x20



R_y=1.3μm

Roughed Surface



R_y=21μm

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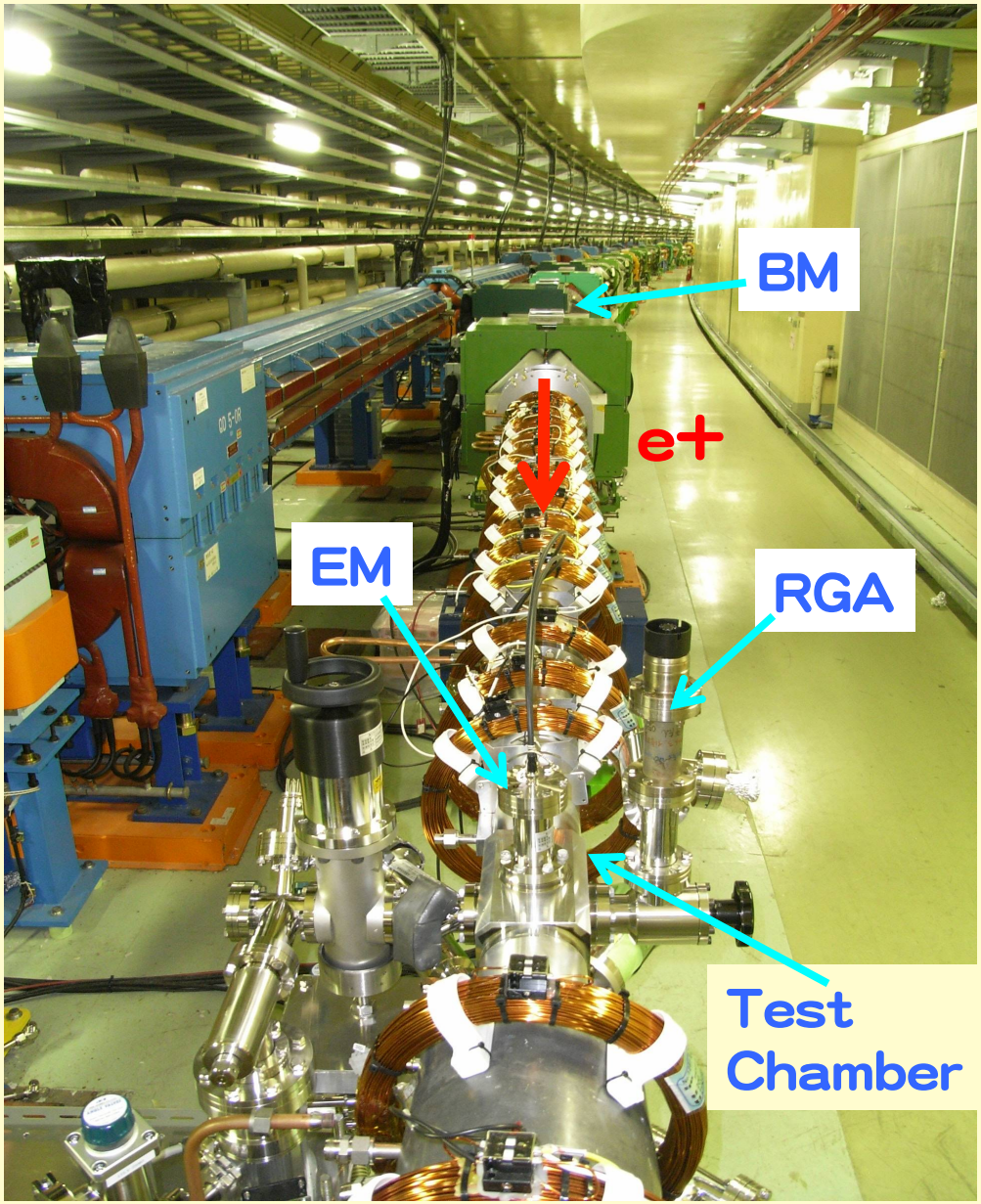
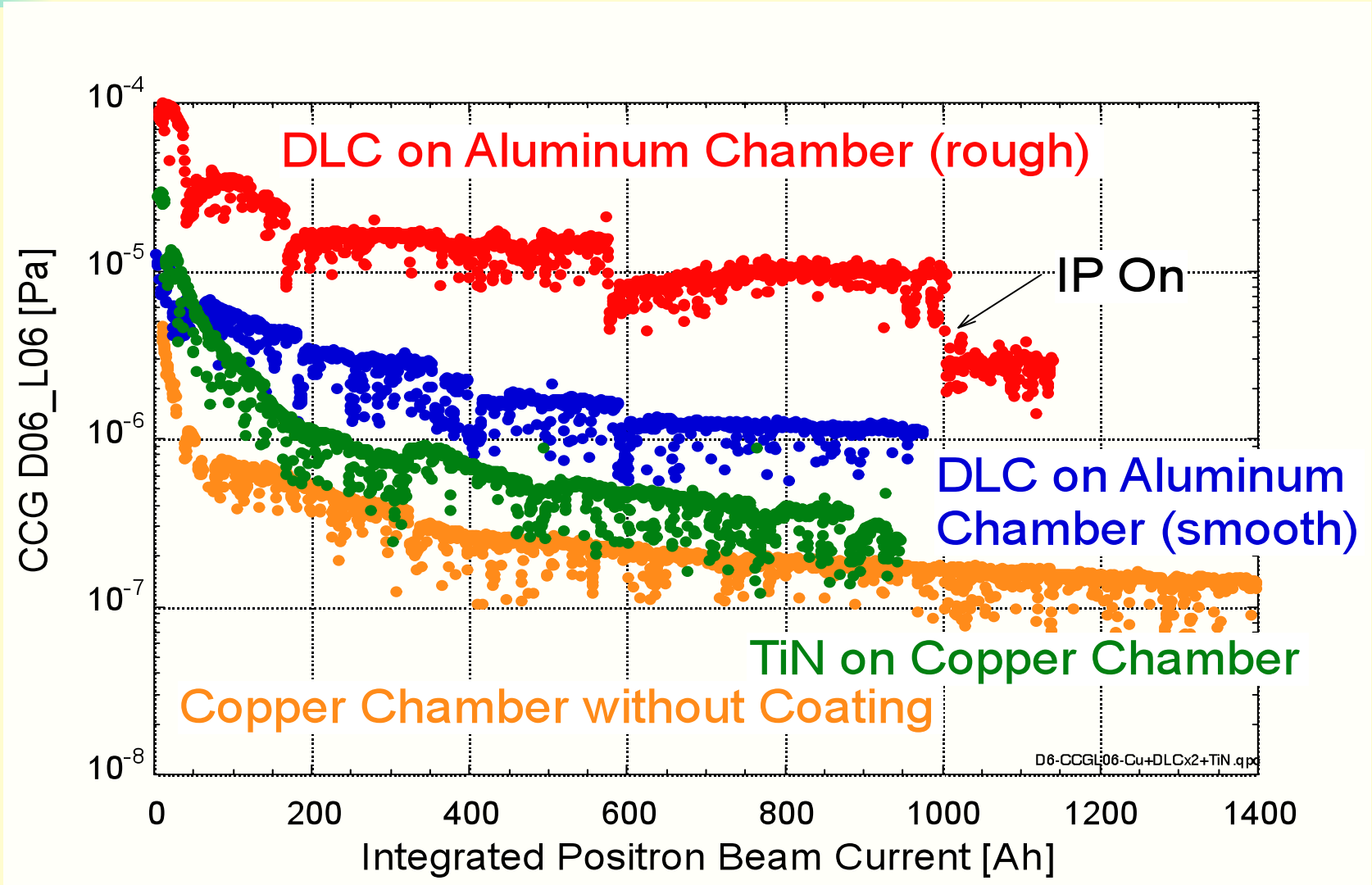
Four Types of Surfaces Compared at LER Arc Section



Test Chamber History

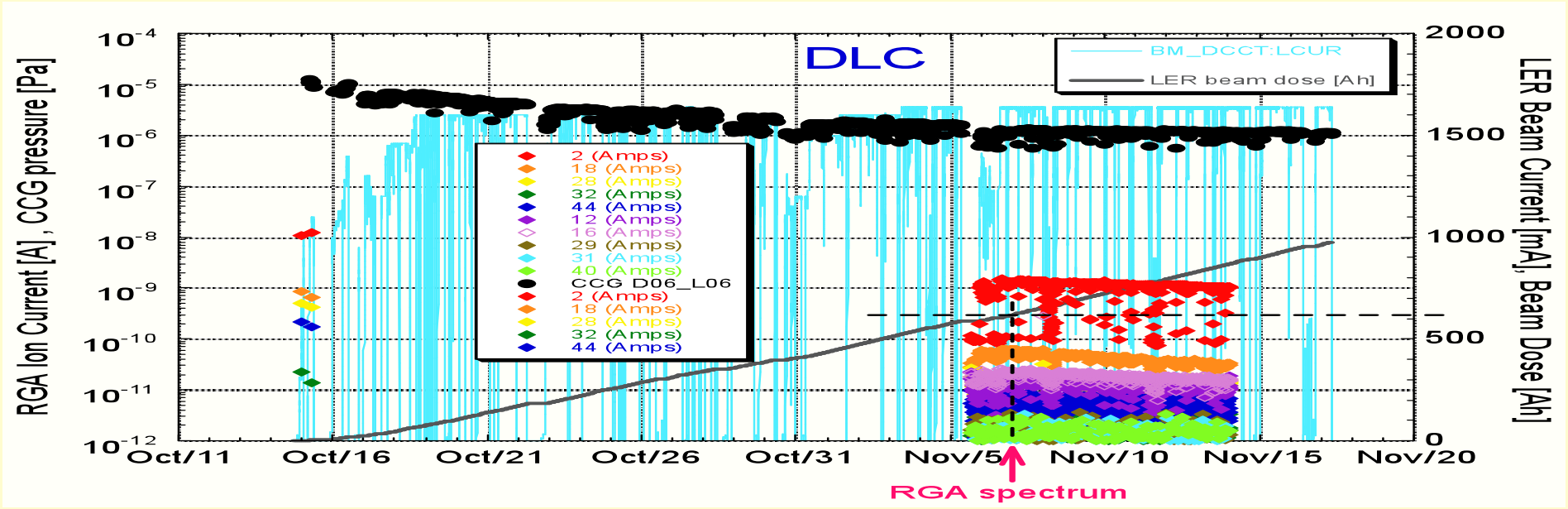
- 2008-0208 ~ 2009-0630 :
  Cu (without RGA)
- 2009-1014 ~1116 :
  DLC/Al (smooth surface)
- 2009-1117 ~1224 :
  TiN/Cu
- 2010-0513 ~0630 :
  DLC/Al (rough surface)

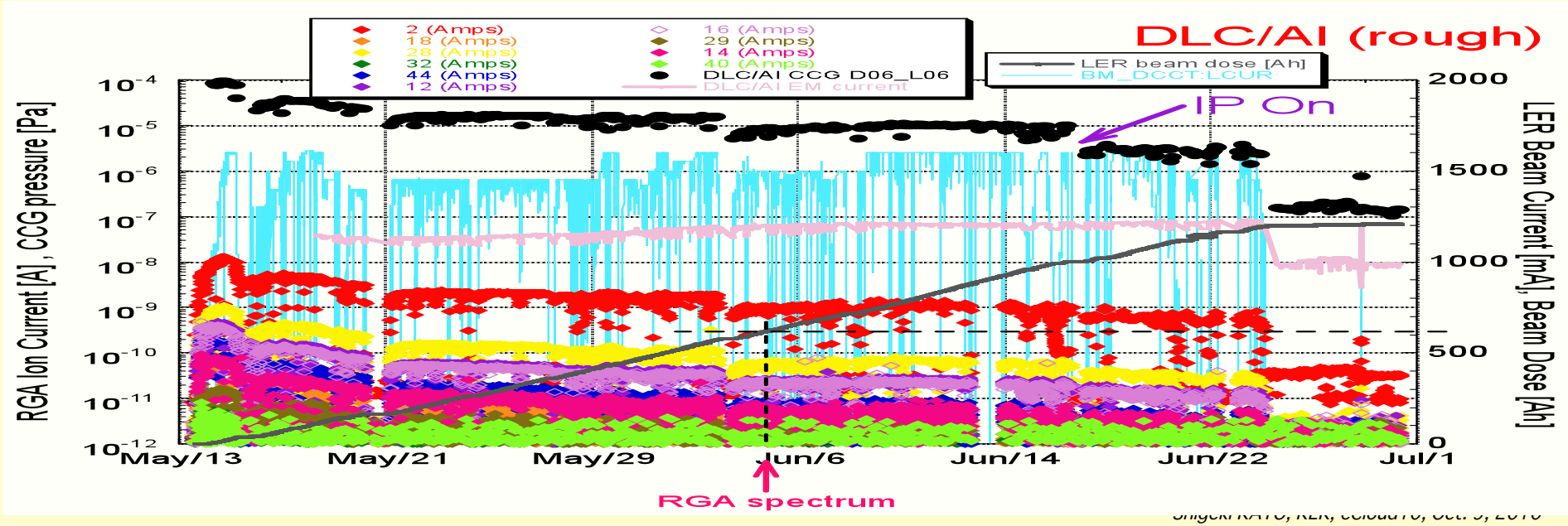
Total Pressure Trend during KEKB LER Operation



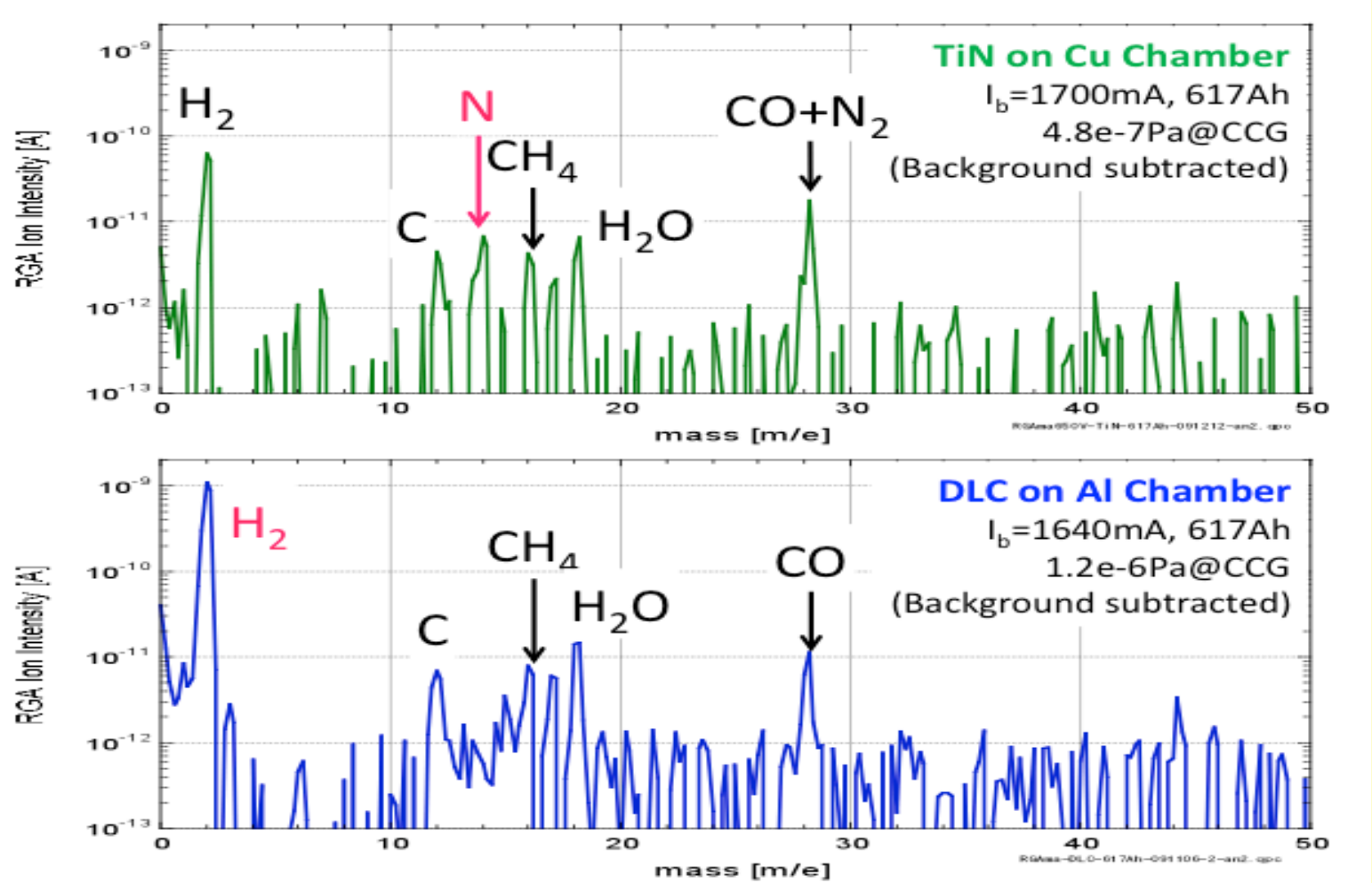
- DLC (rough) showed 10 times higher pressure compared with copper chamber, that is not surprising after IP was on.
- In any case, it took roughly 1000Ah to get reasonable conditioning.

RGA & CCG Trends for Two Types of DLC Coating



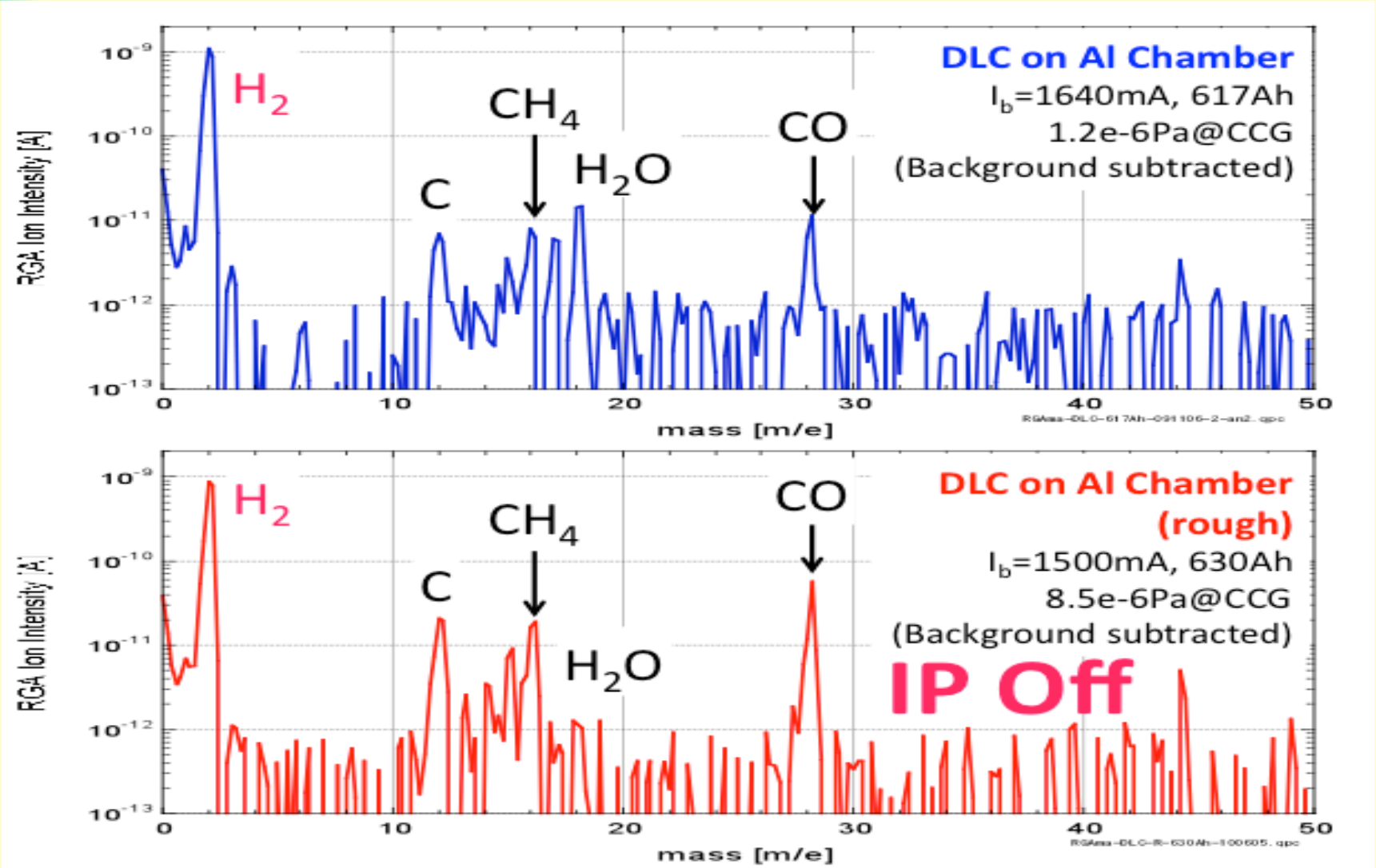


RGA Spectra at ~620Ah for TiN and DLC (smooth)



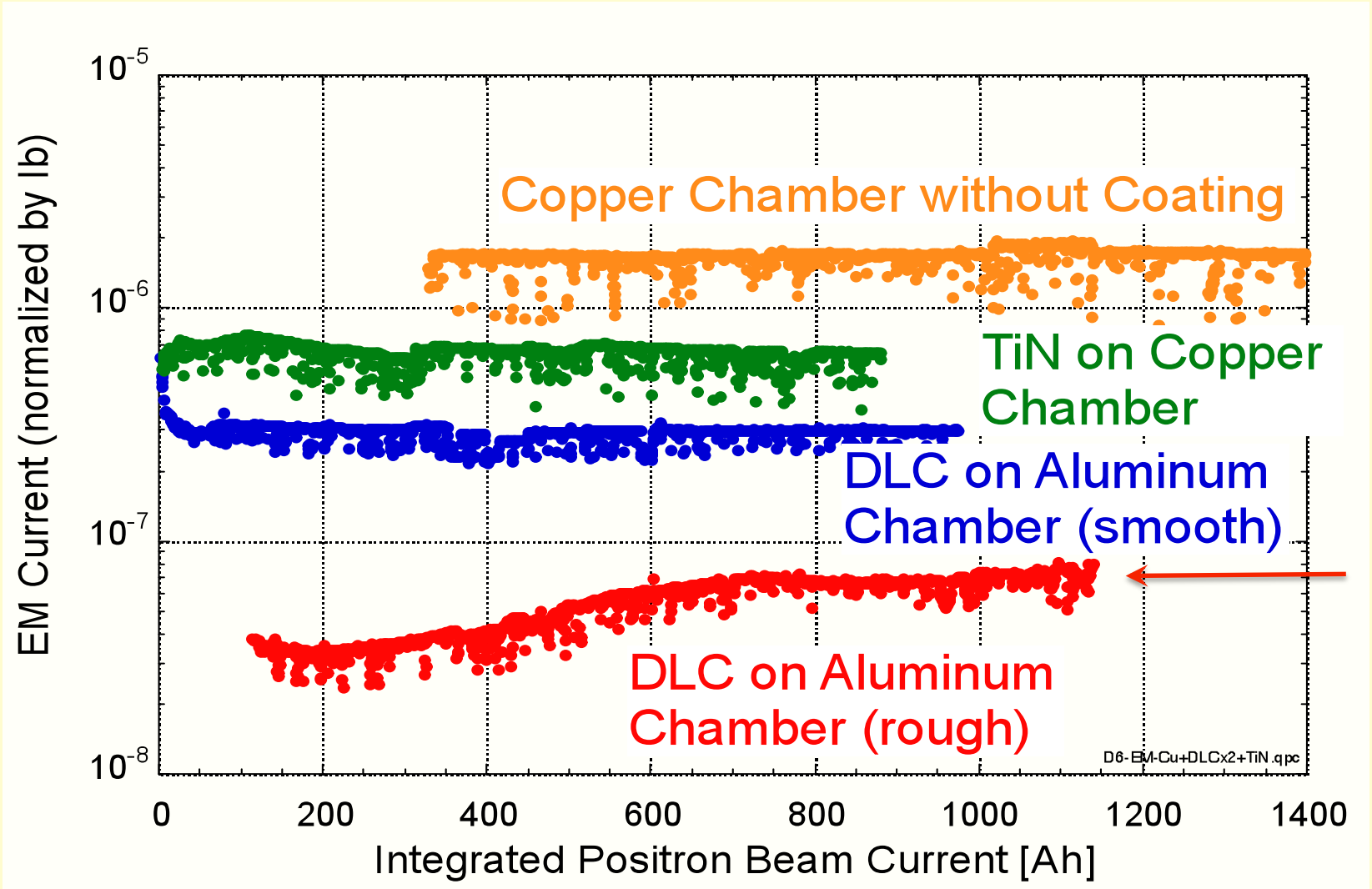
- **TiN : High nitrogen peak was found, indicating decomposition of TiN and it did not change with increase of EC dose.**
- **DLC : Hydrogen desorption was remarkably high. However it would give little influence on the beam quality because of the low mass.**
- **DLC : No hydrocarbon gas component was observed up to m/e 100.**

RGA Spectra at ~620Ah for DLC (smooth and rough)



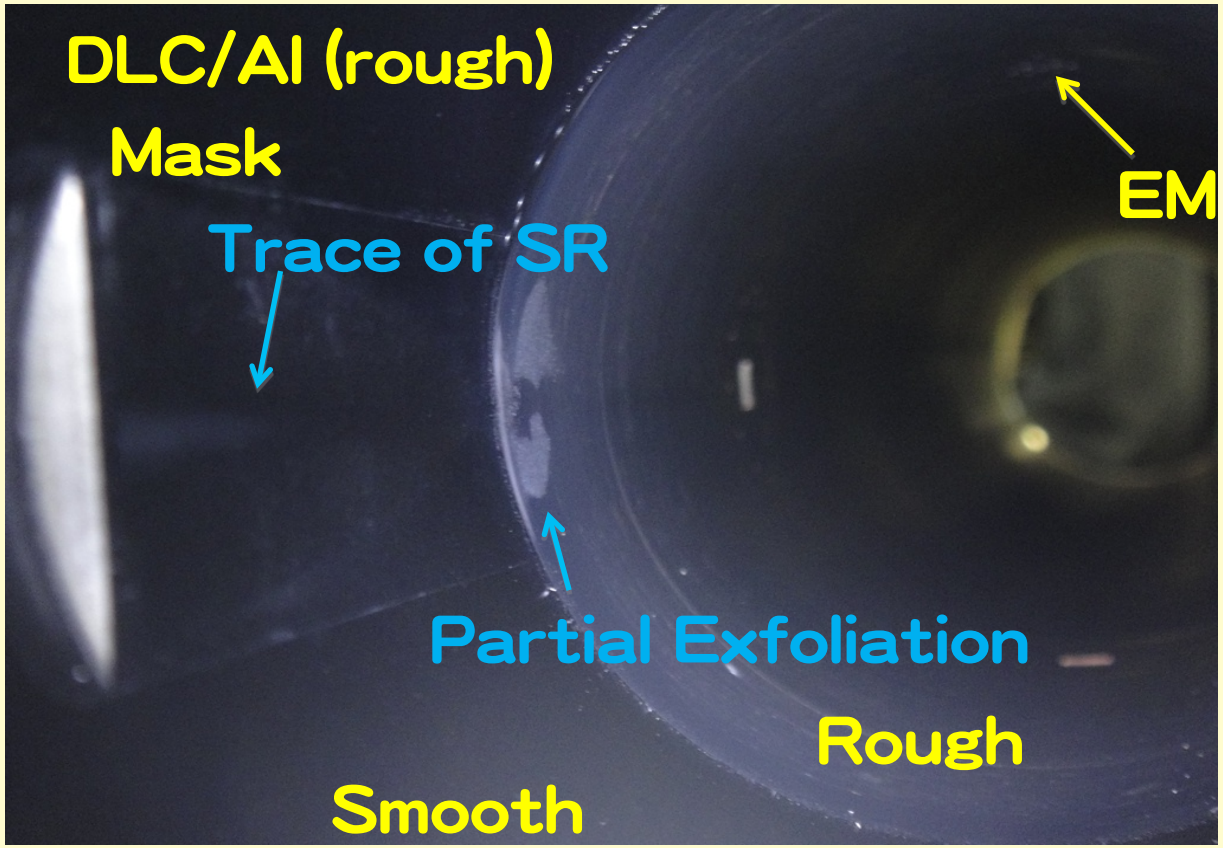
- Two spectra are similar except CH_4 and CO probably due to IP off.
- No hydrocarbon gas component from rough DLC surface was observed up to m/e 100 either.

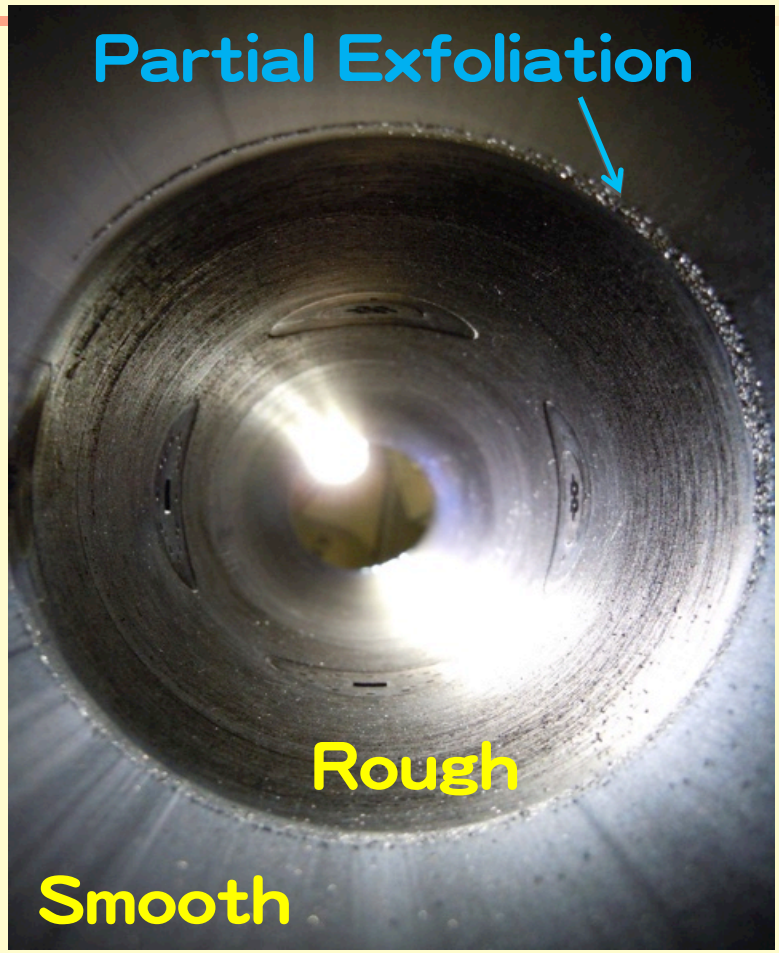
Trends of Electron Monitor Current for Different Surfaces



- EC mitigation with the roughed DLC surface seem to be outstanding.
- Gradual increase of EC activity might be due to partial exfoliation?

Visual Inspection of DLC Coated Chambers Afterward





- No change was found for smooth DLC surface.
- However partial exfoliation at the rough DLC surface was found at the boundary between the smooth and the rough surfaces. (the boundary was made since no surface roughing was done for the photon stop. Some cure should have been done before the roughing.)
- Trace of SR could be seen on the photon stop surface. However there was no exfoliation there.

Summary

1. Advantages of carbon materials for mitigating EC were mentioned.
2. DLC was chosen for many reasons.
3. Inexpensive roughed DLC surface was prepared.
4. Four types of beam chamber were installed to measure total and partial pressure, EC activity at LER arc section.
5. TiN : high nitrogen peak was found, indicating decomposition of TiN.
6. Smooth and rough DLC : hydrogen desorption was remarkably high. However it would give little influence on the beam quality because of the low mass.
7. Smooth and rough DLC : no hydrocarbon gas component was observed up to m/e 100.
8. EC mitigation with the roughed DLC surface seem to be outstanding.