KEK

Secondary Electron Emission from Vacuum Materials and in-situ Surface Characterization

Shigeki KATO
Michiru NISHIWAKI
Masayuki SHIMAMOTO
and Michiru SHIRAI

★ Electron Dose Effect on S.E.Y.
= Aging, Conditioning to Reduce S.E.Y.

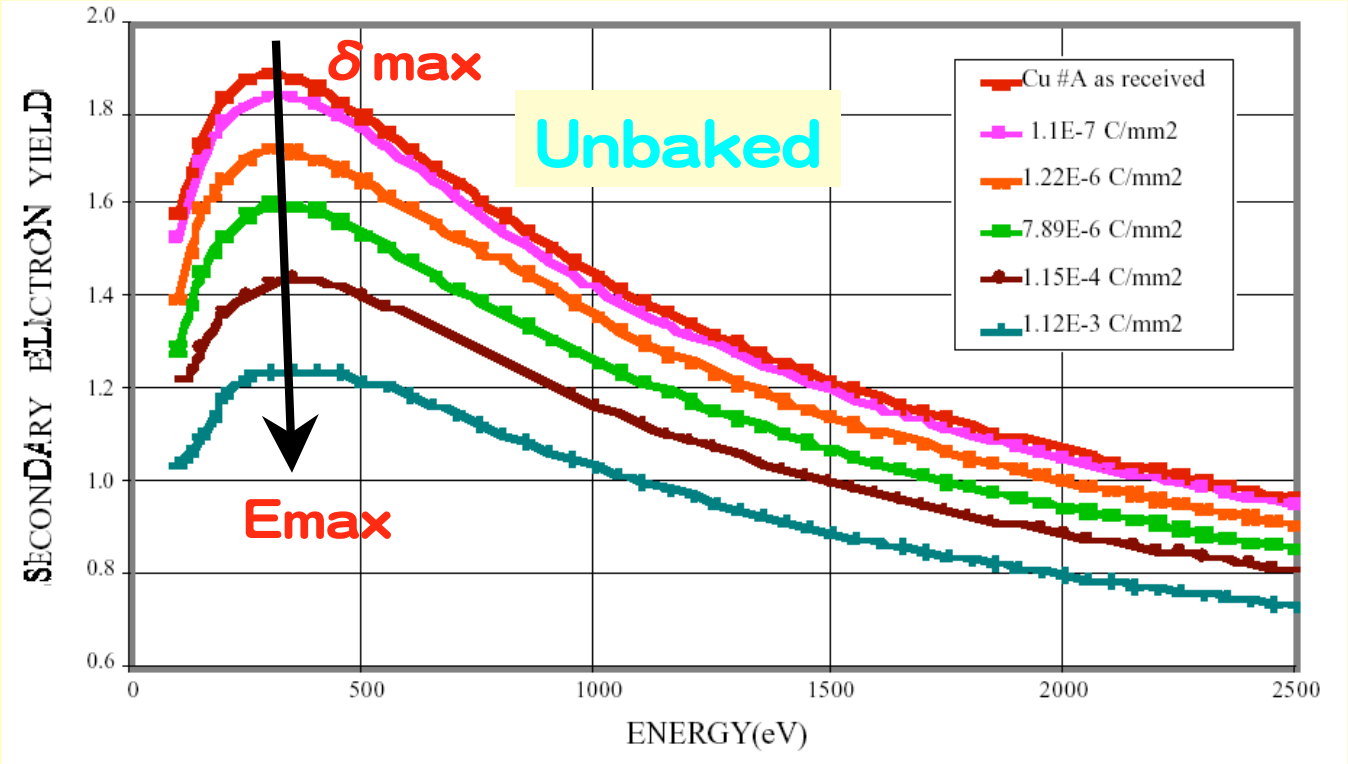
at Vacuum Surface of Power Fed Devices

- ◆ Comments on Reported Secondary Electron Yields
- ◆ Sample Materials and Experimental Setup
- ◆ Results
  - SEYs : Dependences on Materials, Primary Electron Energy and Surface State
  - (Incident Angle Dependence of SEYs, Surface History Dependence of SEYs, Energy Distributions of Emitted Electrons)
- ◆ Conclusions

KEK

Primary Electron Energy Dependence of SEYs at Unbaked Copper Surface with Different Electron Doses (CERN data)

δ max of Copper : ~1.3



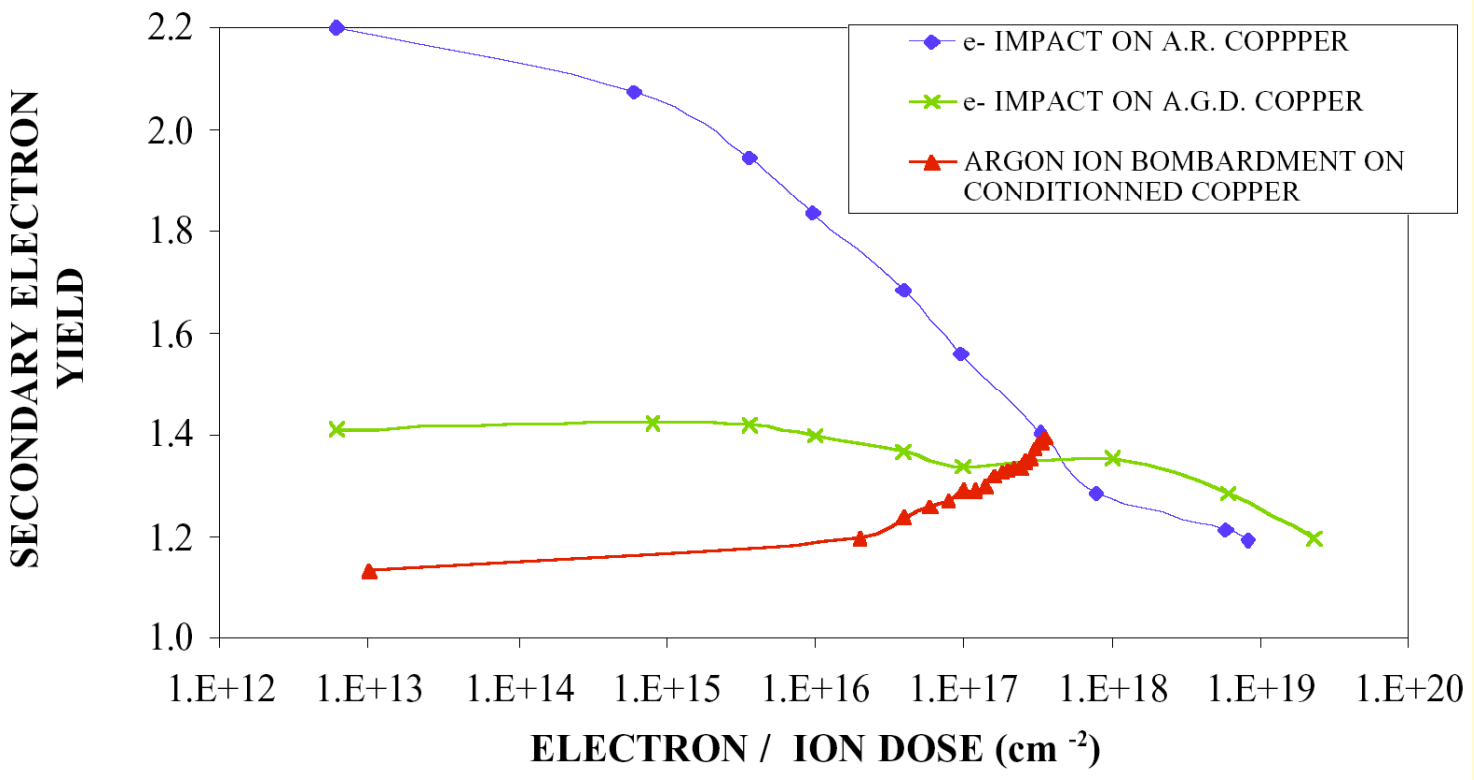
Measured : V. Baglin, J. Bojko, O. Groener, B. Henrist, N. Hilleret , C. Scheuerlein, M. Taborelli (CERN), EPAC2000

★ Due to Beam Cleaning Effect ?

However...

- ◆ Emax Remains Almost the Same !
- ◆ Showing Lower δ max than δ max of Copper !

Electron or Ion Dose Effects of δ max in UHV at Different Copper Surfaces (CERN data)



V. BAGLIN, I. COLLINS, O. GROBNER, B. HENRIST, N.HILLERET, G. VORLAUFER
CERN - LHC/VAC, NH ≷ 2STREAMS/01

- How is the Dose Effect Explained?
- What Are Happening on Material Surfaces?
  - ★ However No In-site Surface Data Reported Before

---> Now Answers Found with In-situ Surface Characterization !

Samples & Experimental Procedure

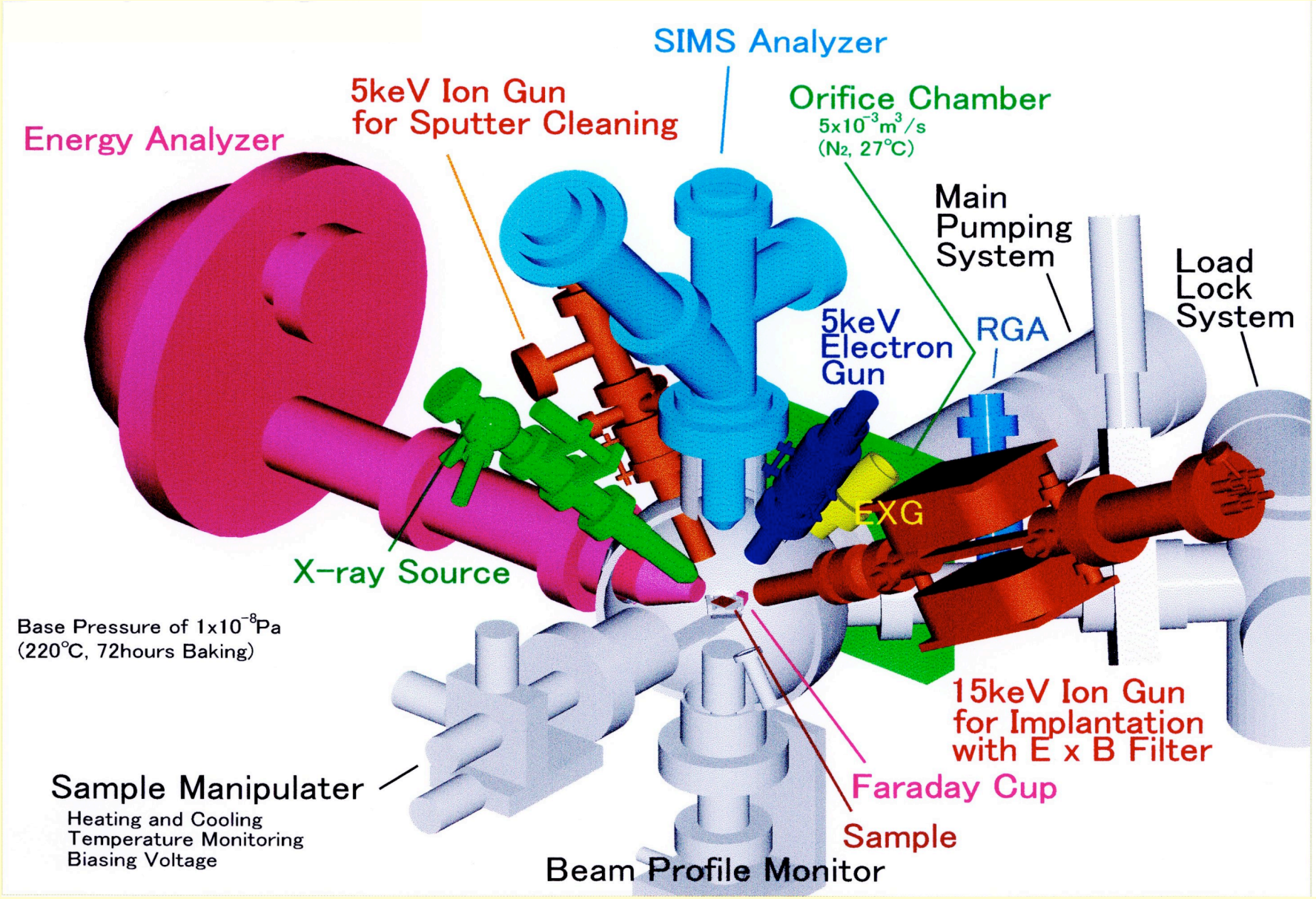
	Descriptions
★ TiNx	prepared by ion plating with a film thickness of 1.5 μm or by magnetron sputtering with a film thickness of 0.1~0.2 μm (BNL) on a type 304 stainless steel
SS304	treated with electro-chemical buffing (ECB) BNL
Ti	oxidized pure titanium at 720K after pickling
CrOx	chromium suboxide plating on a type 304 stainless steel
Ni	black nickel plating on a type 304 stainless steel
★ Cu	oxygen free copper (C10100) treated with a water solution of H_2O_2 and H_2SO_4
Al	chemically polished aluminum:ALpika
★ Isotopic Graphite	a high grade of isotropic graphite purified with halogen gas
Aquadag	ultra fine particles of graphite deposited on copper with a film thickness of some tens μm

1. Measurement of SEYs in UHV (Ambient Temperature, ⊥ Incident Angle)
   - As-received
   - After Electron Bombardment
   - After Sputter Cleaning

★ Electron Beam Dose for a Series of Measurements : < 10 nC mm^{-2}

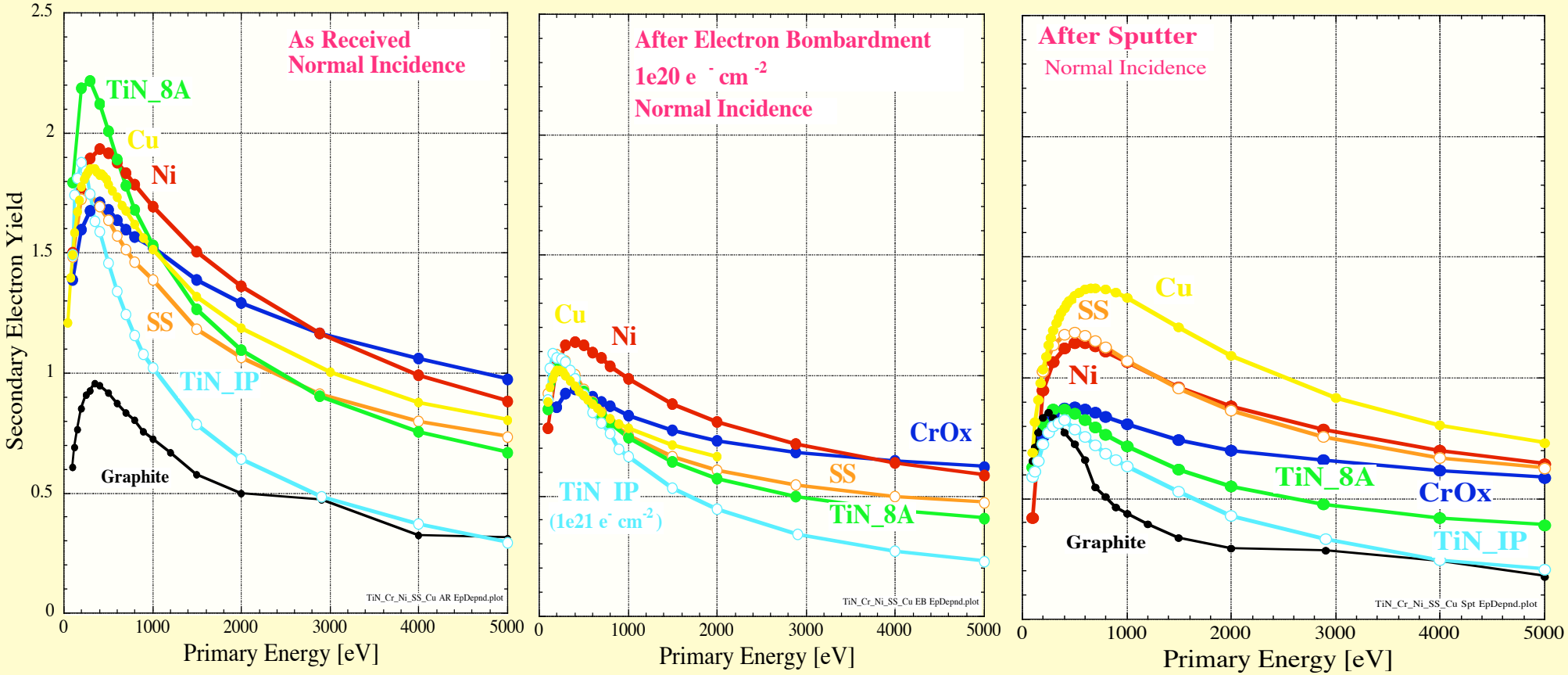
2. In-situ Surface Analyses with XPS in UHV

Experimental Setup



KEK Secondary Electron Yields of Vacuum Surface Materials

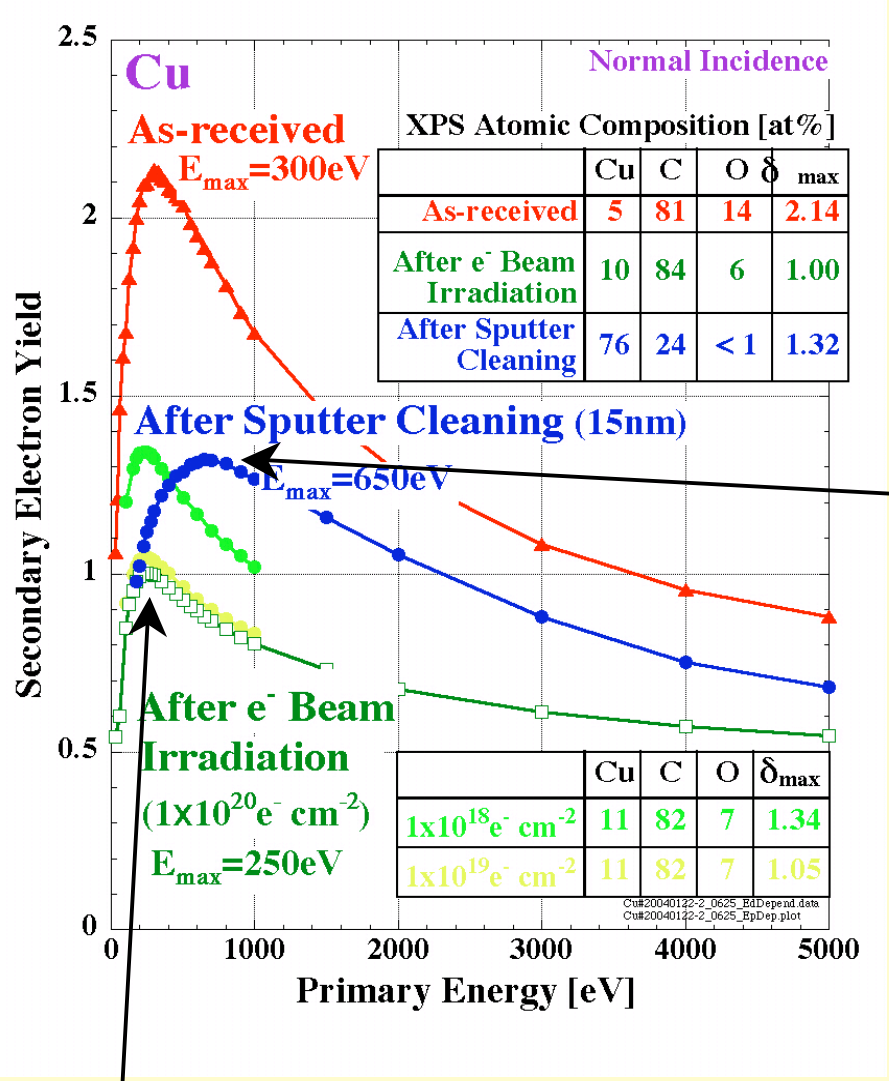
Primary Electron Energy Dependence



- All as-received Samples except Graphite : High δmax (TiN : Highest δmax)
- After Electron Beam Irradiation of 0.16 Cmm^{-2} : Drastic Decease
- After Ion Sputtering : Comparable to δmax After Electron Irradiation

◆ Surface Characteristics after Electron & Ion Conditioning : Completely Different.

Primary Energy Dependence of SEYs at As-received Copper Surfaces with Different Doses of Electron or Ion



	Cu	C	O	δ_{max}
As-received	5	81	14	2.14
After e⁻ Beam Irradiation	10	84	6	1.00
After Sputter Cleaning	76	24	< 1	1.32

	Cu	C	O	δ_{max}
1x10¹⁸e⁻ cm⁻²	11	82	7	1.34
1x10¹⁹e⁻ cm⁻²	11	82	7	1.05

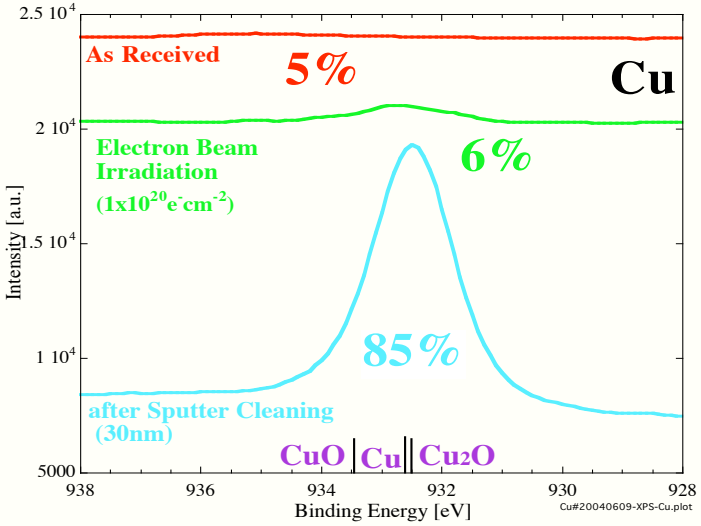
Cu#20040122-2_0625_EdDepend.data
Cu#20040122-2_0625_EpDep.plot

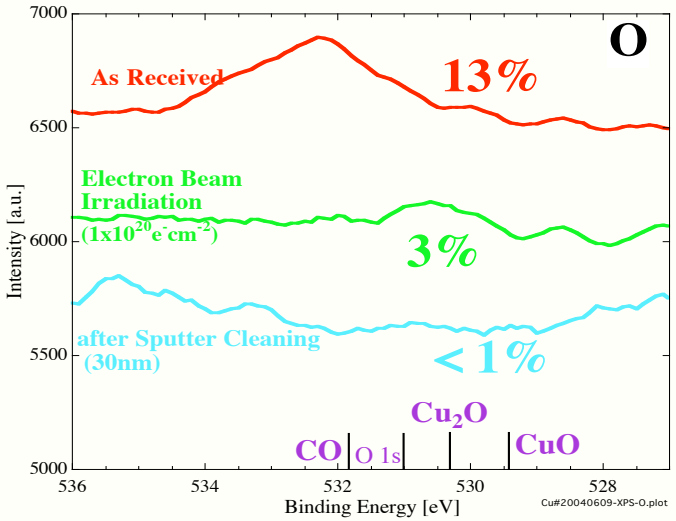
The Surface Becomes Contaminated Again After Ion Beam Irradiation due to Bad Beam Quality???

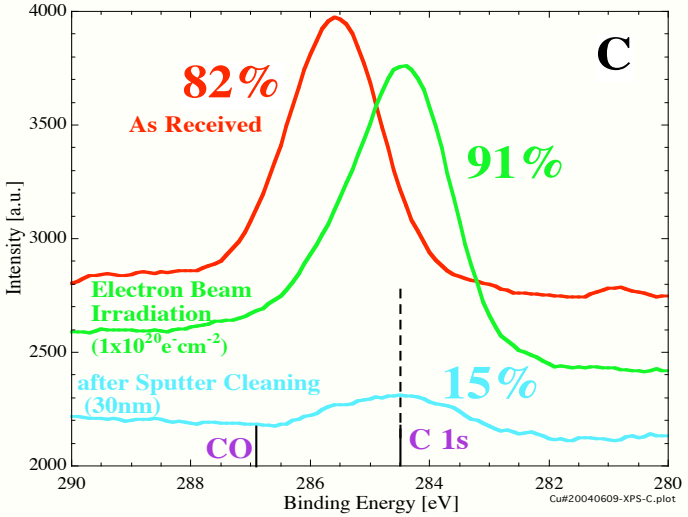
The Surface Becomes Cleaner After Electron Beam Irradiation???

Those Explanations are Not Right!!!
Complete Different Story!!!
What Are Happing on the Surfaces Then???

XPS Spectra at As - received Copper





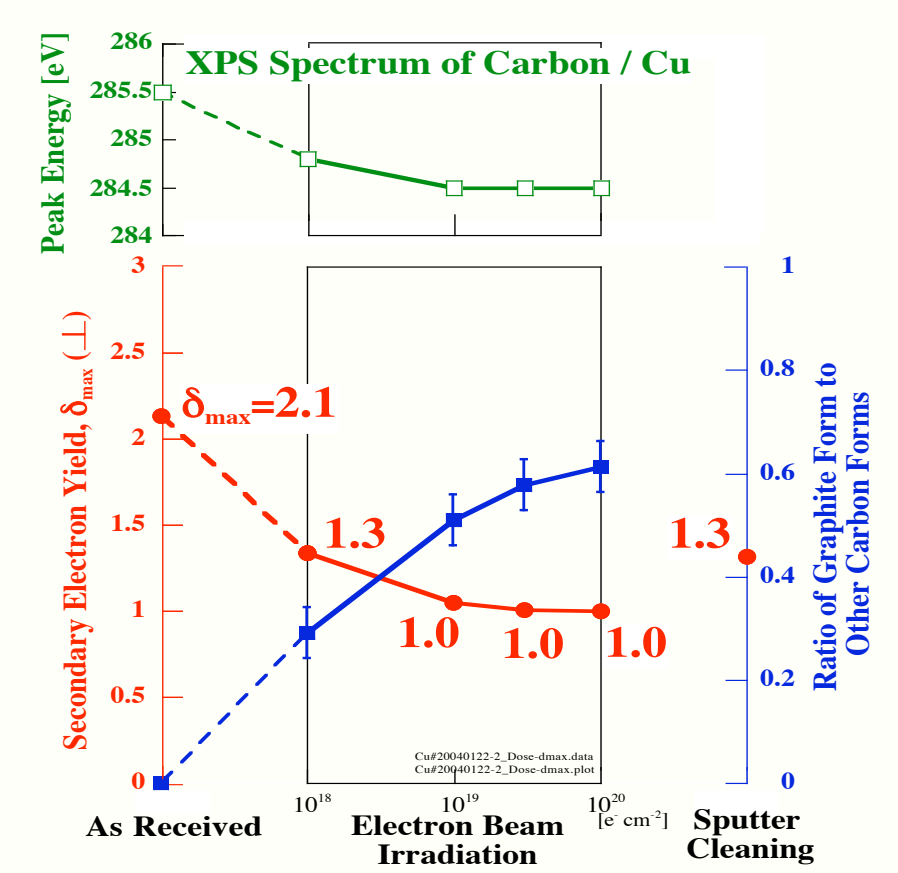


- As Received : δ max=2.14 <--- Surface with Carbonatious Contamination Cosisting of H, C and O + H_2O Molecules
  Copper Surface Not Oxidized
- Electron Beam Conditioning in UHV: δ max= 1.00 <--- Graphitized Surface !!!
  [In Poor Vacuum, Polymerization instead of Graphitization : Very High δ max]
- Ion Sputtering : δ max= 1.32 <--- Almost Clean Surface

◆ Carbon Supplyer during Graphitization : Residual Carbonatious Contamination at Suface

◆ Lowest δ max <-- Electron Beam Induced Surface-graphitization

Summary of Dose Effect on SEYs at Copper Surface & Surface-graphitization Observed with XPS

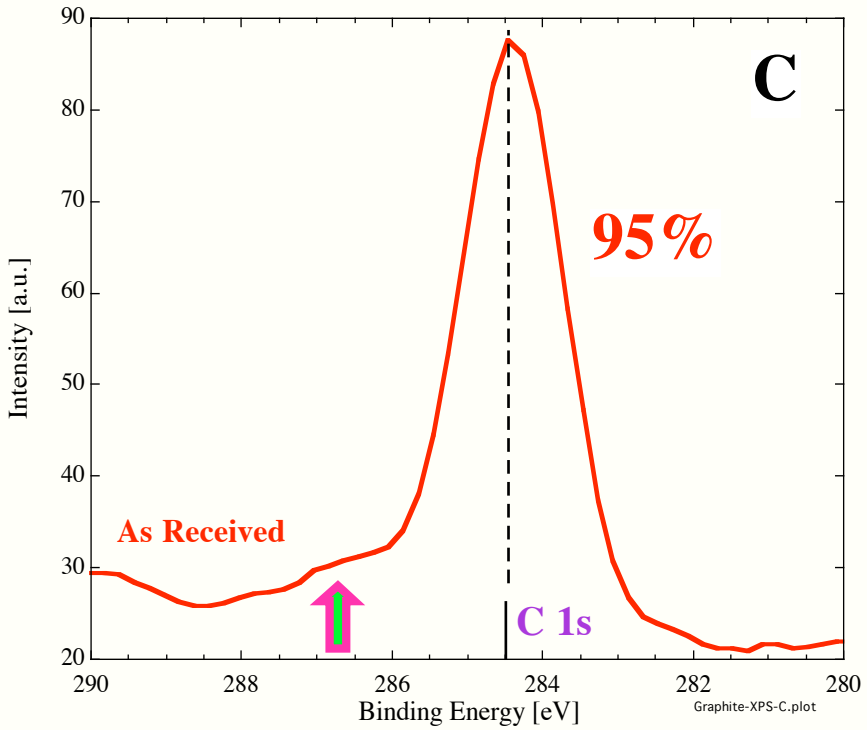


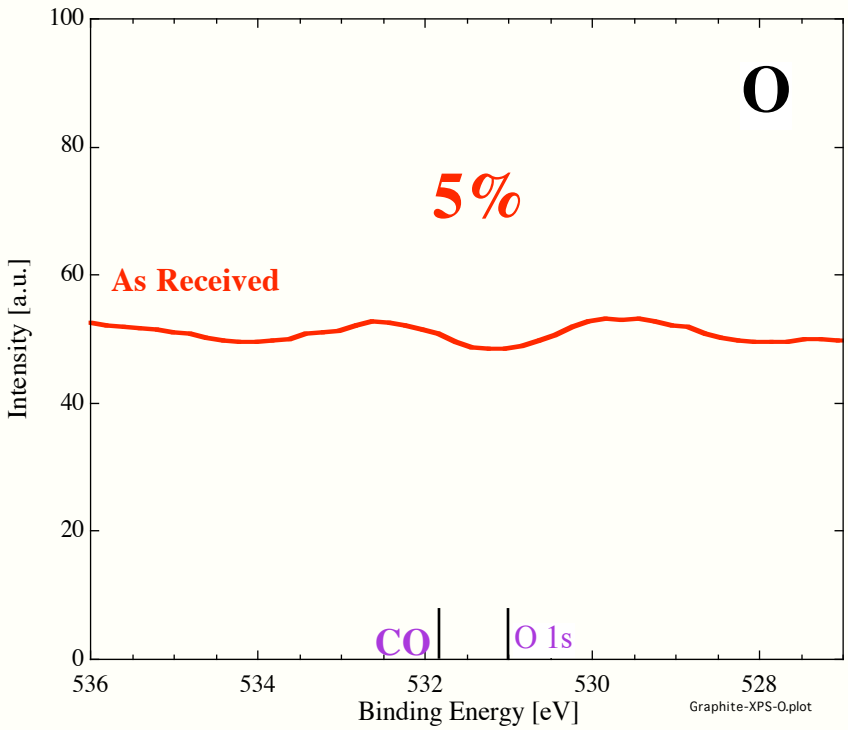
★ **What is Going on Well-cleaned Copper Surfaces after Electron Beam Irradiation?**

- Graphitization for Sputtered Clean Copper Still Occurs due to Electron Beam Irradiation or Heating in UHV.
- The Source at Cleaned Copper Surface : Carbon Atoms from Bulk.

KEK

XPS Spectra & SEYs at As-received Isotropic Graphite Surface





As Received : δ max=0.95, Almost No Adsobate

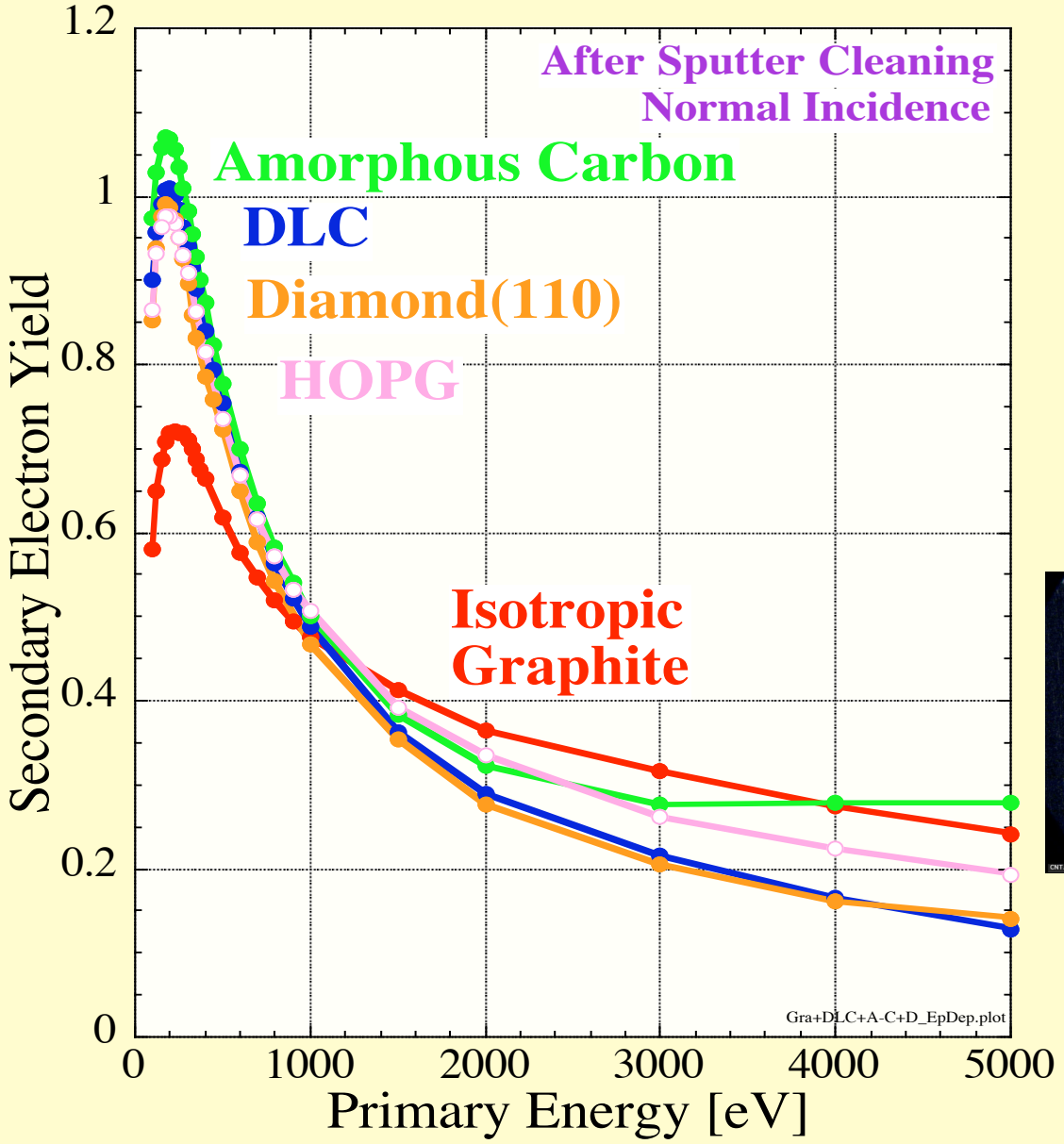
No Need of Conditioning Even for Need of SEY<1

Other Carbon Materials :

DLC (Diamond-like-carbon), s.c. Diamond (1 1 0), Amorphous Carbon, HOPG (Highly Oriented Pyrolytic Graphite)

KEK

Primary Energy Dependence of SEYs at Carbon Material Sufraces after Sputter Cleaning



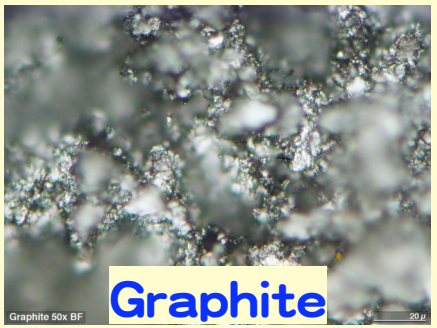
Very Low δmax of 0.7 for Isotropic Graphite !
Why?

---> Surface Roughness for the Graphite

Microscope Images

50μm

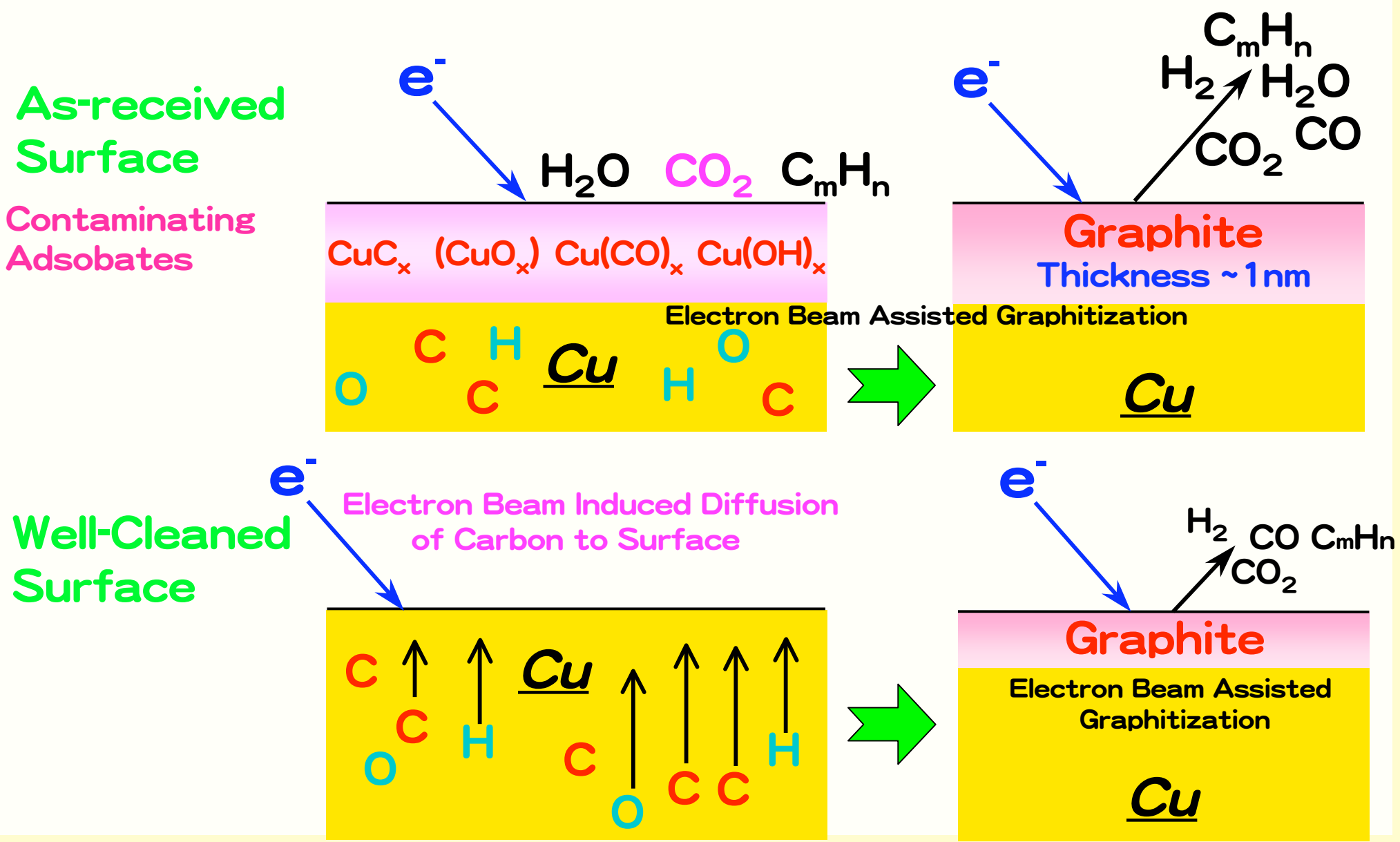
Ra=0.45μm
Ry=0.5μm



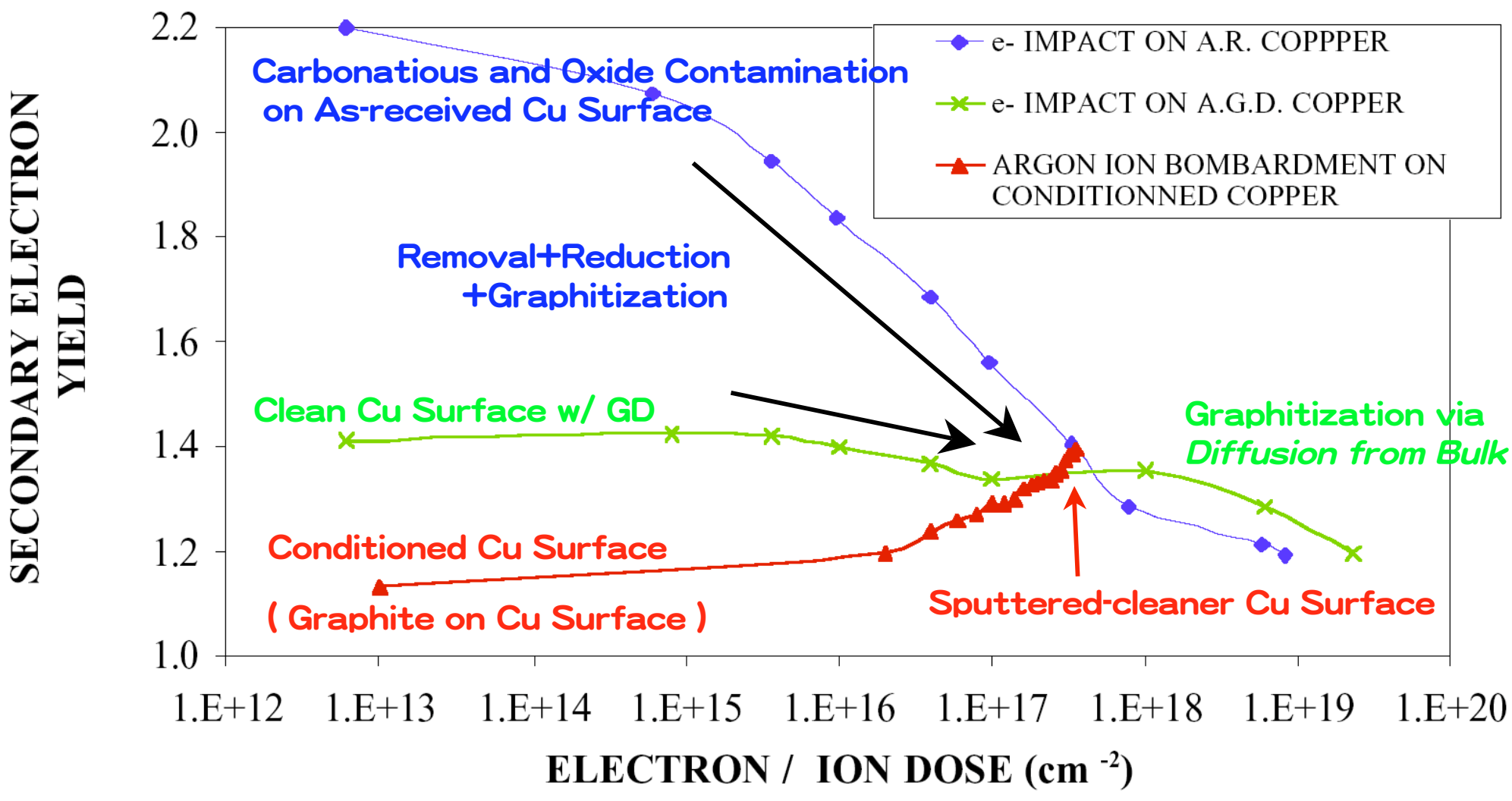
↑ Ra=1.383μm
Ry=10.71μm

Ra=1.223μm
Ry=13.71μm

Models of Electron Beam Induced Surface-graphitization



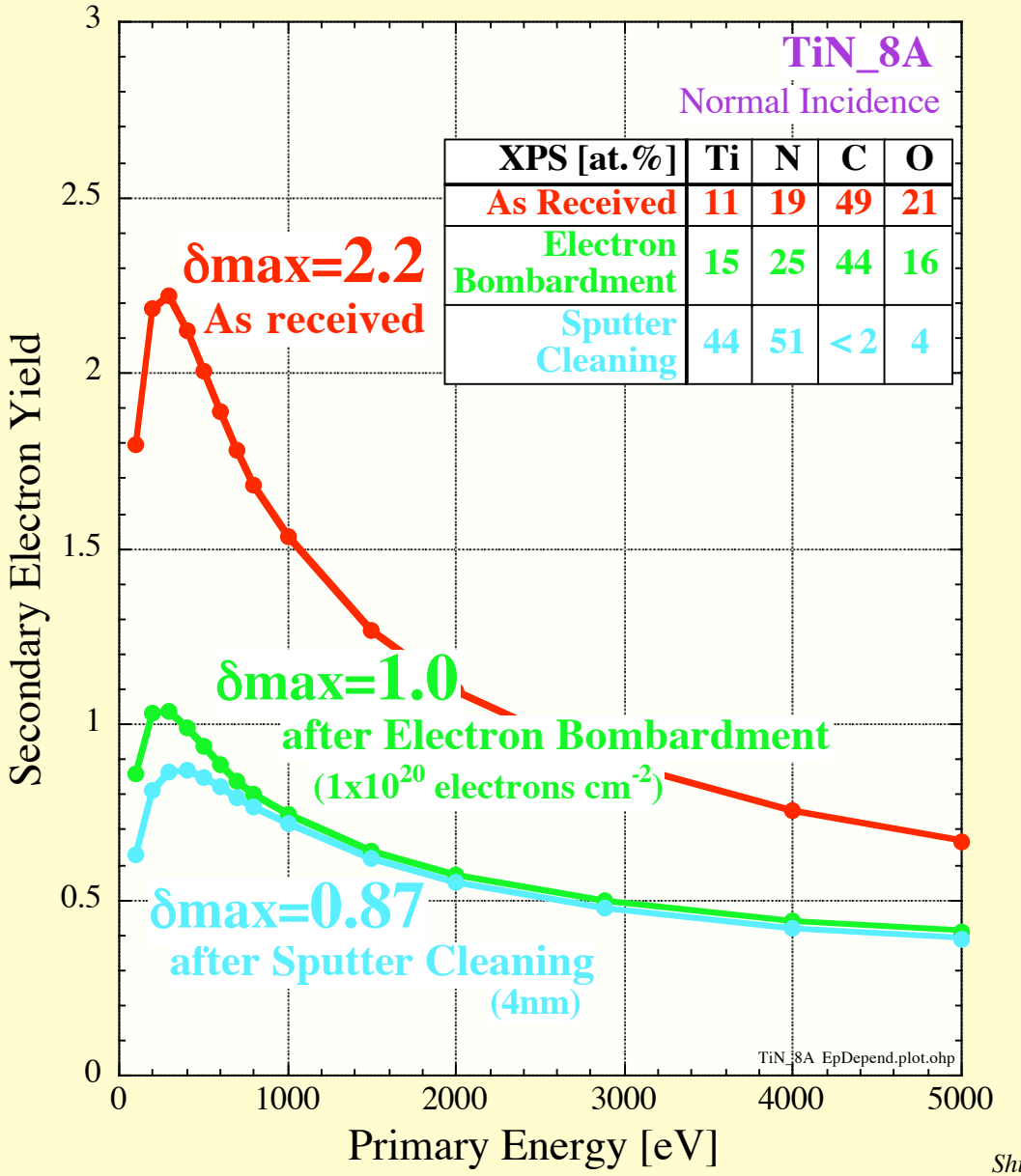
Explanation for Electron or Ion Dose Effects in UHV at Different Copper Surfaces



Measured : V. BAGLIN, I. COLLINS, O. GROBNER, B. HENRIST, N.HILLERET, G. VORLAUFER
CERN - LHC/VAC, NH ≷ 2STREAMS/01
Comment : S. KATO, KEK, June 04

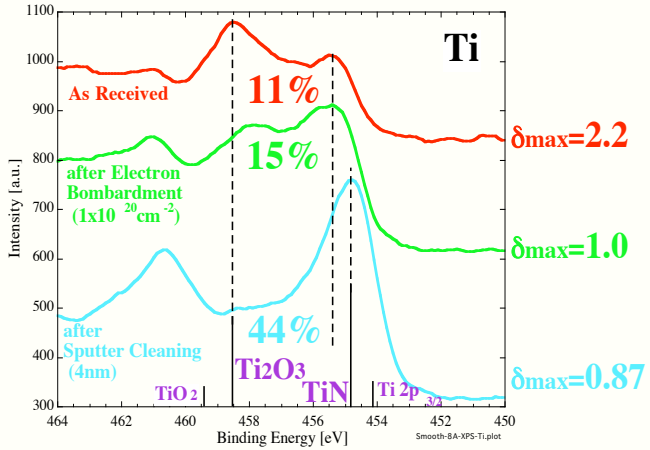
SEYs of TiN_8A with Different Conditions

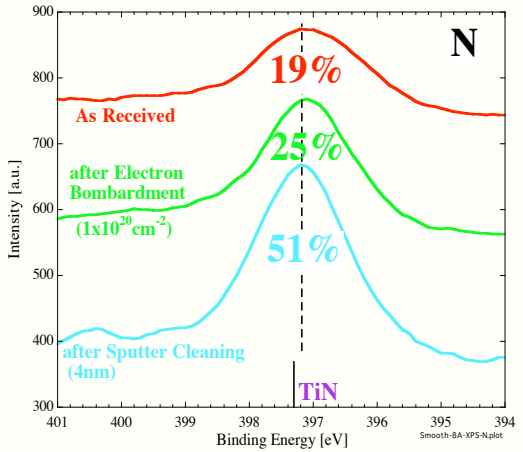
Primary Electron Energy Dependence

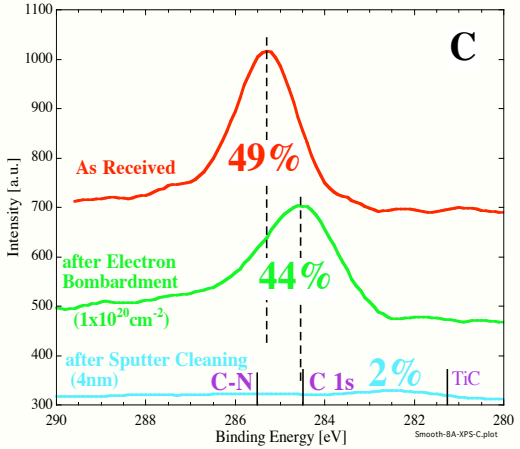


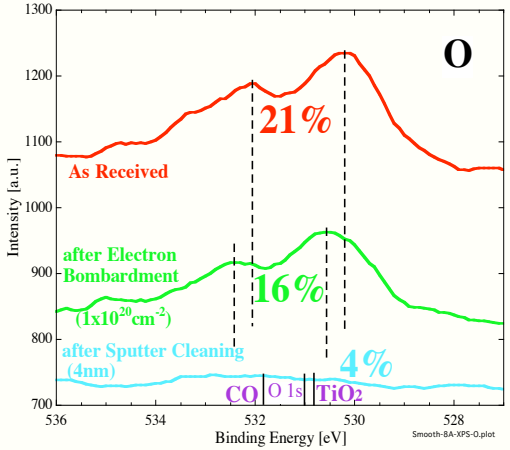
KEK

XPS Spectra & SEYs at TiN Surface









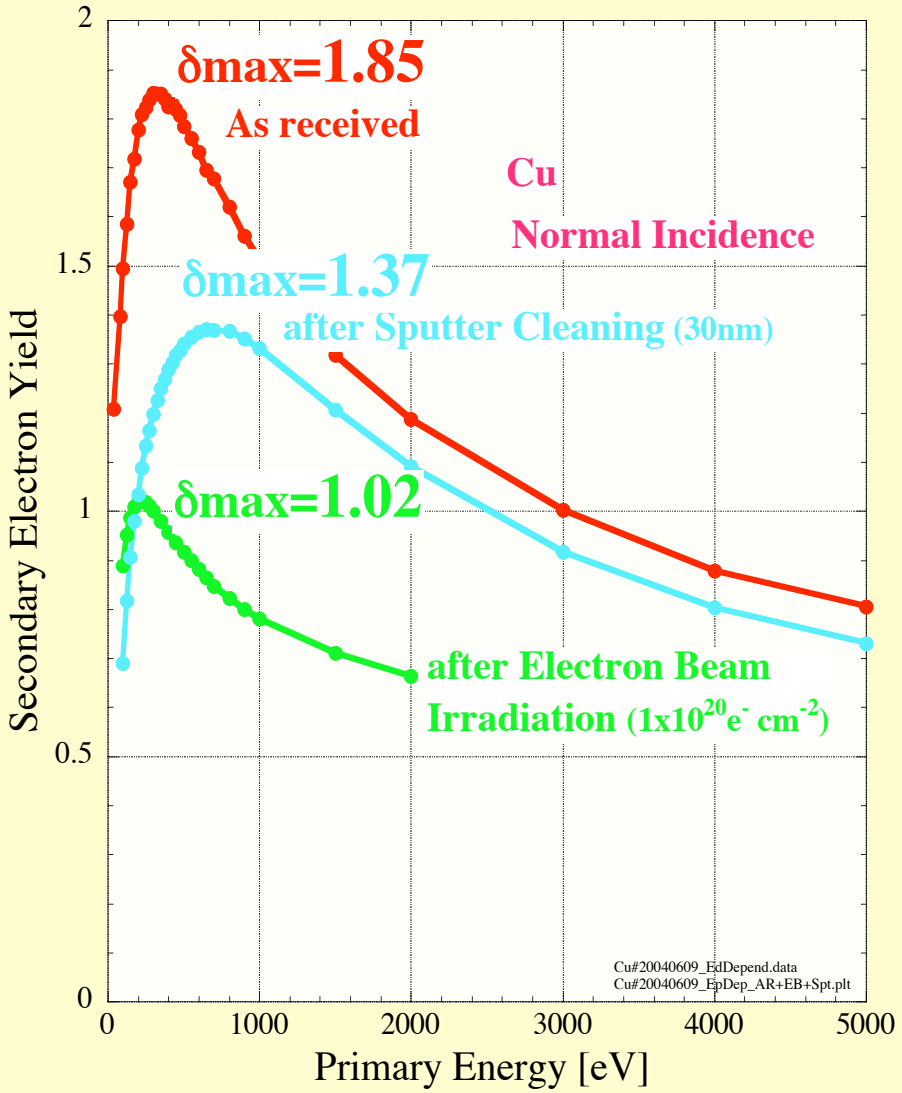
- As Received : δmax=2.2 <--- Covered w/ Carbonatious Contamination and Heavy Oxidation of Ti
- Electron Beam Conditioning in UHV: δmax=1.0 <--- More TiN and Graphitization in spite of Small Decrease of Oxygen
- Ion Sputtering : δmax=0.87 <--- Almost Clean Surface

◆ Dose Effects of Electron and Ion Irradiation on SEYs : Similar But Surfaces are Remarkbly Different !!!

KEK

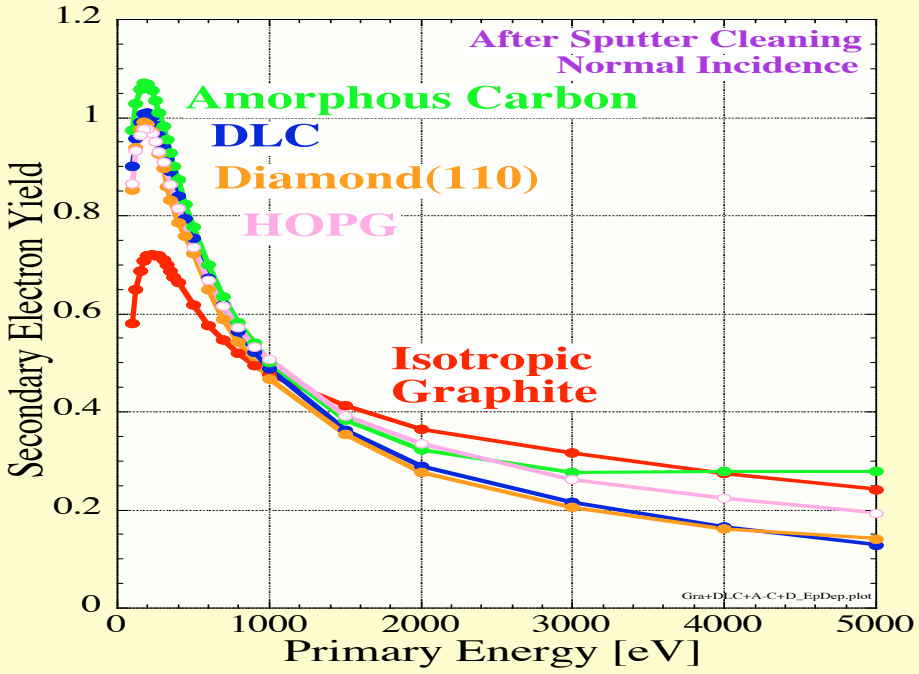
Proposal to Reduce SEY at Copper Surface of Power Fed Devices Using e- Beam Induced Surface Graphitization

Surface Composition



★ For Surface Not be Sputtered !

Surface Roughness



KEK

Proposal to Reduce SEY at Copper Surface of Power Fed Devices (contn'd)

★ How to Graphitize Copper Surface

1. Carbon Enrichment into Copper if Necessary.
2. Surface Roughing (press, tool bit ...).
   ※ Not for Surface Fed with High Electric Field
3. Surface Treatment Could be Simple.
4. Baking Could be Skipped.
5. Electron Irradiation.
   - with an Energy Range < keV
   - <10C/cm^2 is Sufficient (Wired Filament, Low Power e-gun ...)

★ Advantages of Electron Beam Induced Surface - graphitization

- ◆ No Coating Necessary (vs Other Carbon Materials, TiN, NEG)
- ◆ Stable Surface and Diffusion Barrier of Carbon into Copper
- ◆ No Dust Generation (vs Aquadag, NEG)
- ◆ Self-recovering Surface during Operation
- ◆ Lateral Homogenity of Graphitizaion Confirmed
- ◆ Small Skin Effect : Equivalent to ~1nm (1THz -> 2nm)

KEK CONCLUSIONS

1. New Findings of SEY Were Done in Conjunction with In - situ Measured Suface State.
2. First Observation and Proof of Electron Beam Induced Surface-graphitization Causing Small SEY were Made. The Surface-graphitization Explains the Reported Data Well.
3. Carbon Supplyer during Graphitization for As-received Materials is Mainly Residual Carbonatious Contamination on Sufaces.
4. For Sputtered Clean Copper, Graphitization Still Occurs due to Heating or Electron Beam Irradiation even in UHV. The Source was Proved Carbon Atoms from Bulk.'
5. Electron Beam Induced Surface-graphitizaion is Inevitable at Least on Copper in Practical Application Because of the No Passive Layer.
6. No Need of Conditioning for Graphite was Found Even for Need of SEY$<$1.
7. As-received TiN showed Highest δmax because of Heavy Oxidation of Ti.
8. Dose Effects of Electron or Ion Irradiation on SEYs of TiN and SS are Similar and Explained based on Electron Beam Induced Surface-graphitization.
9. Carbonatious Contamination and Free Carbon are Evil but Graphite Would be Helper.
10. Beam Conditioning of Vacuum Surface of Power Fed Devices Seems Graphitization Process.
11. Active Graphitization is Proposed to reduce SEY.

Carbon, c' est bon !

Fin