The chemical origin of SEY at technical surfaces

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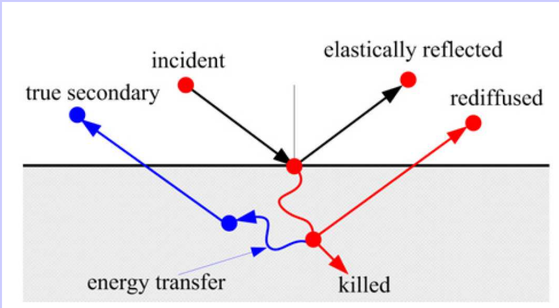
Secondary Electron Yield

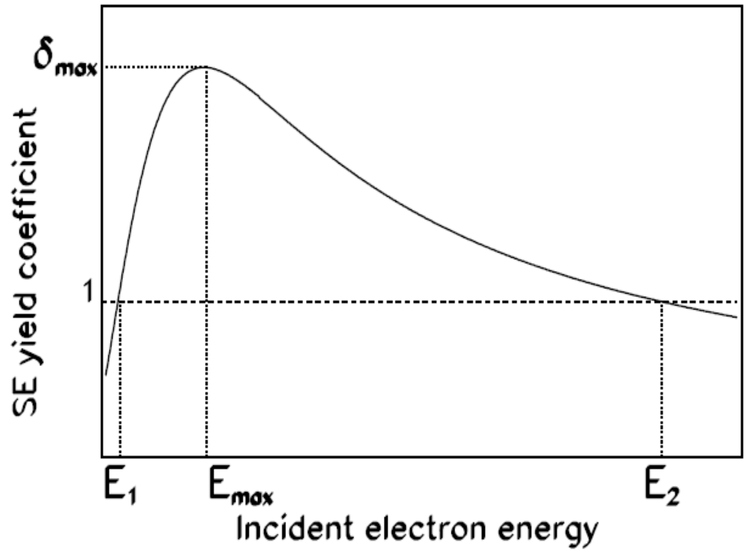


secondary electron emission

three-step process:

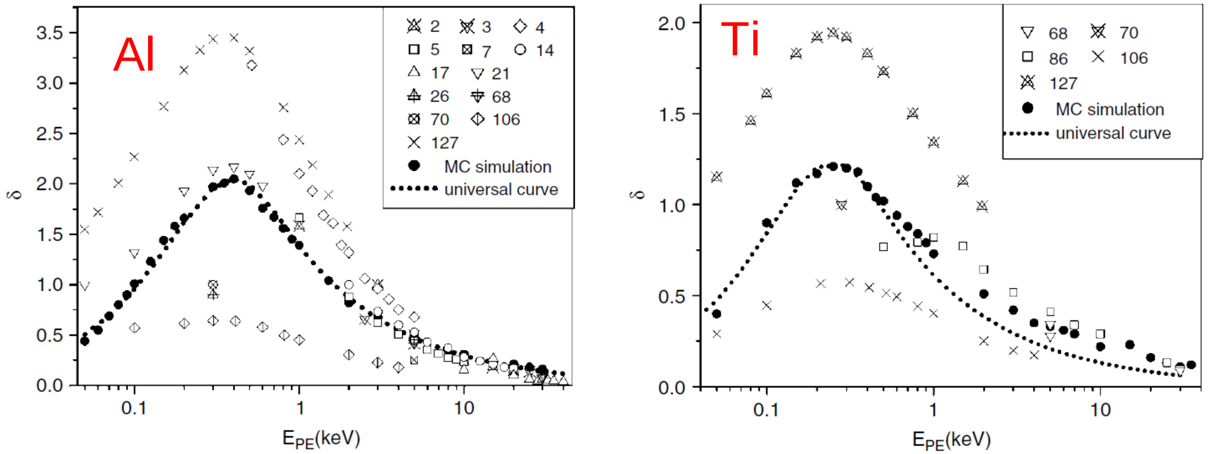
- production of SEs at a depth *z*
- transport of the SE toward the surface
- emission of SE across the surface barrier

universal curve

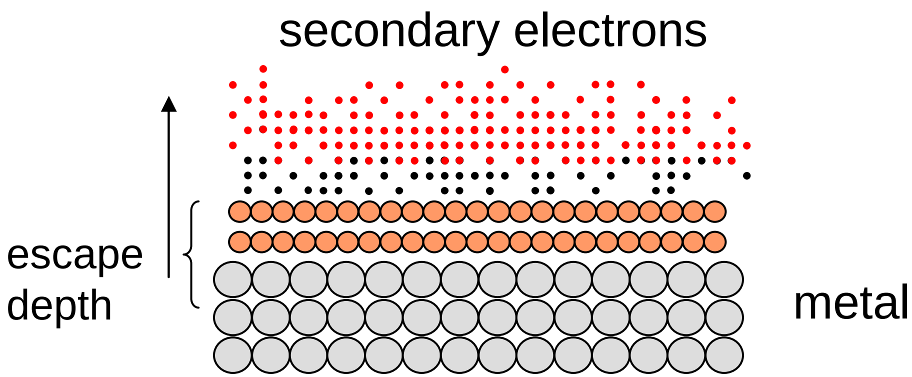


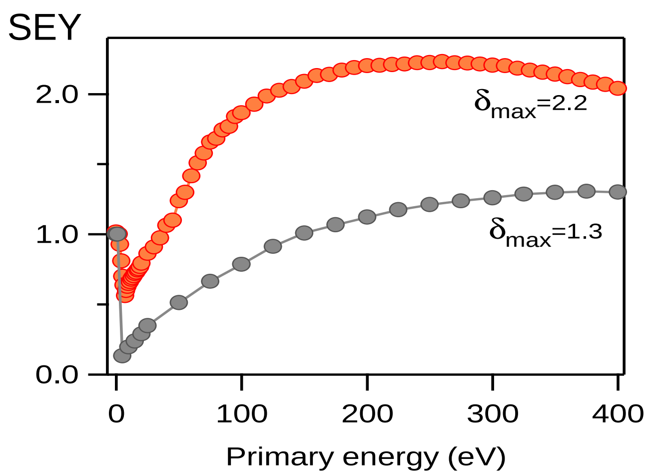
the material parameters influencing SEY are:
penetration depth of the primary electrons,
stopping power,
escape depth of the secondary electrons,
work function - Z number

Spread in the SEY data



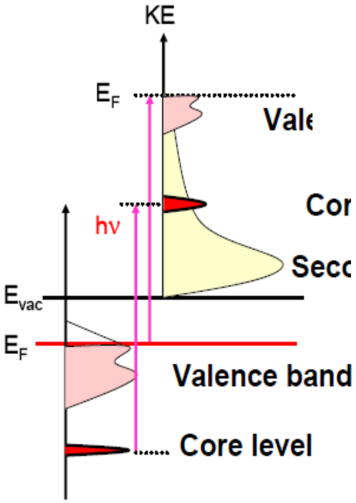
Lin et al. SIA 2005, 37 895





the effective SEY of the metal is strongly modified by the surface contamination

X-ray photoelectron spectroscopy

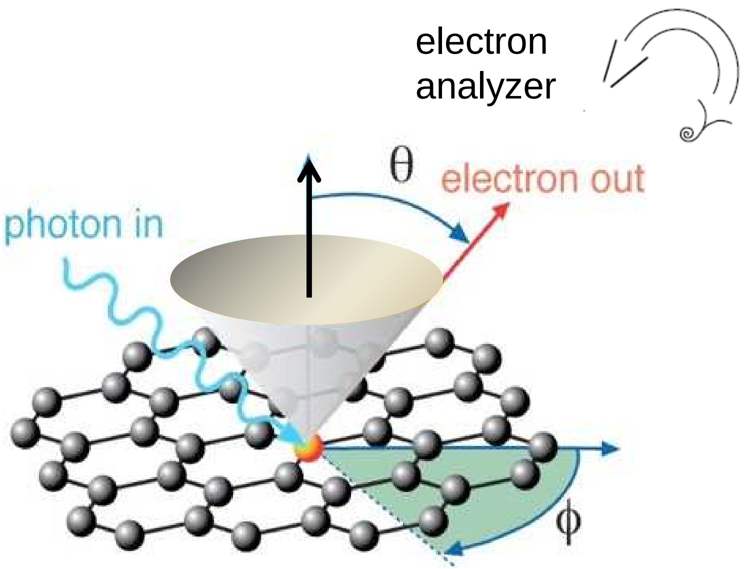


KE=hv-BE-φ

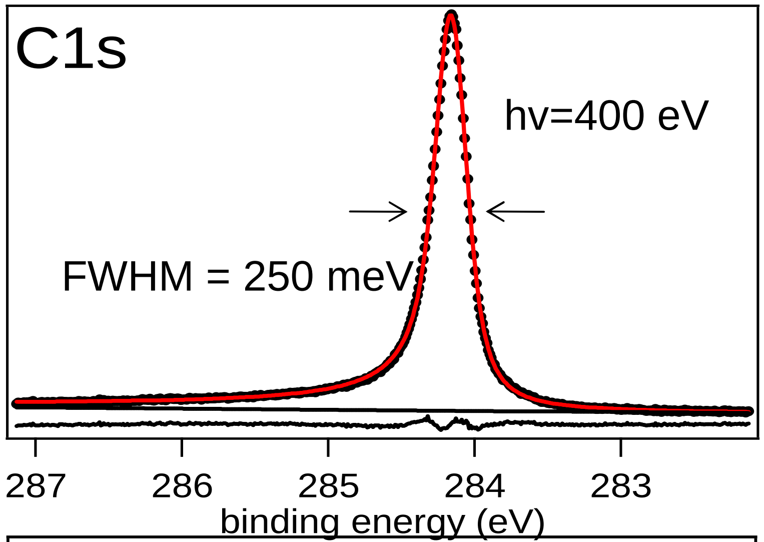
KE: kinetic energy

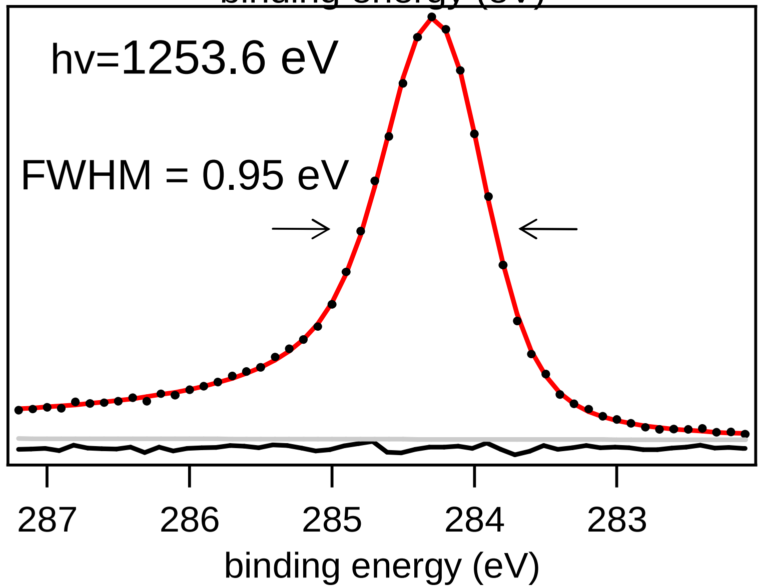
φ: work function

BE: binding energy

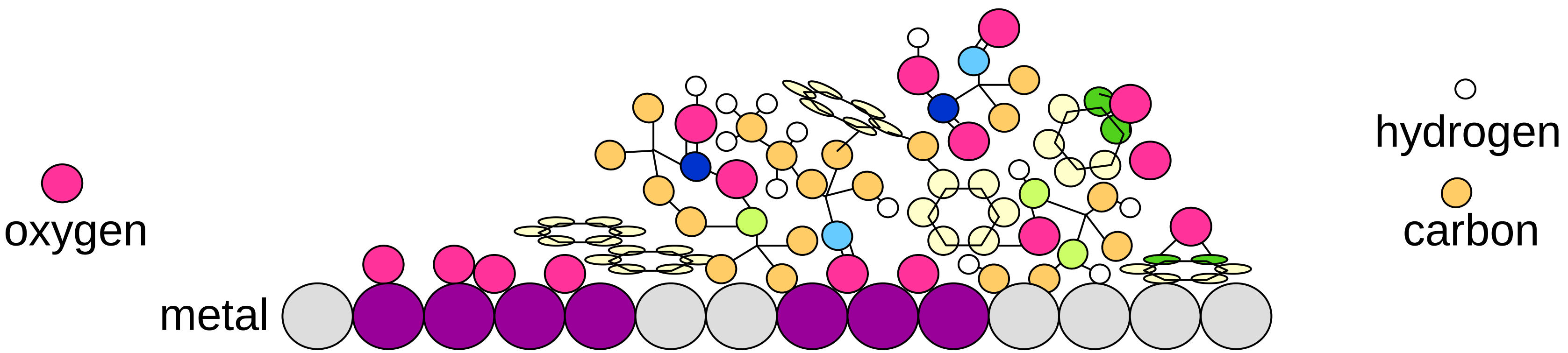


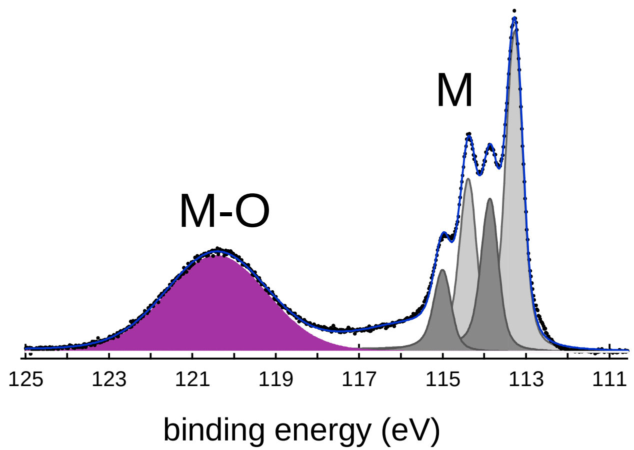
θ_{emiss}=0°

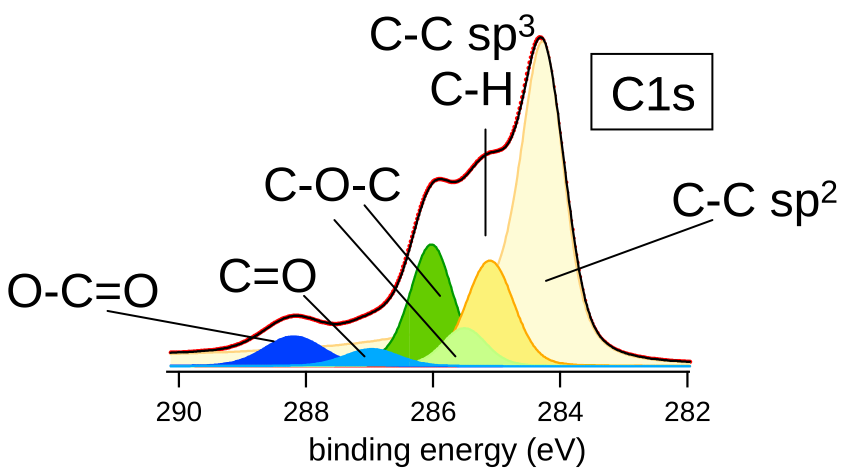




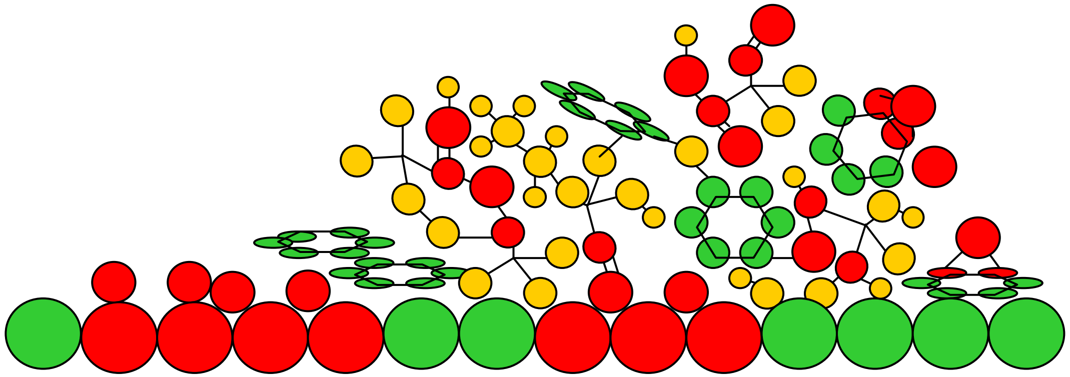
XPS spectroscopy of technical samples







SEY of technical samples

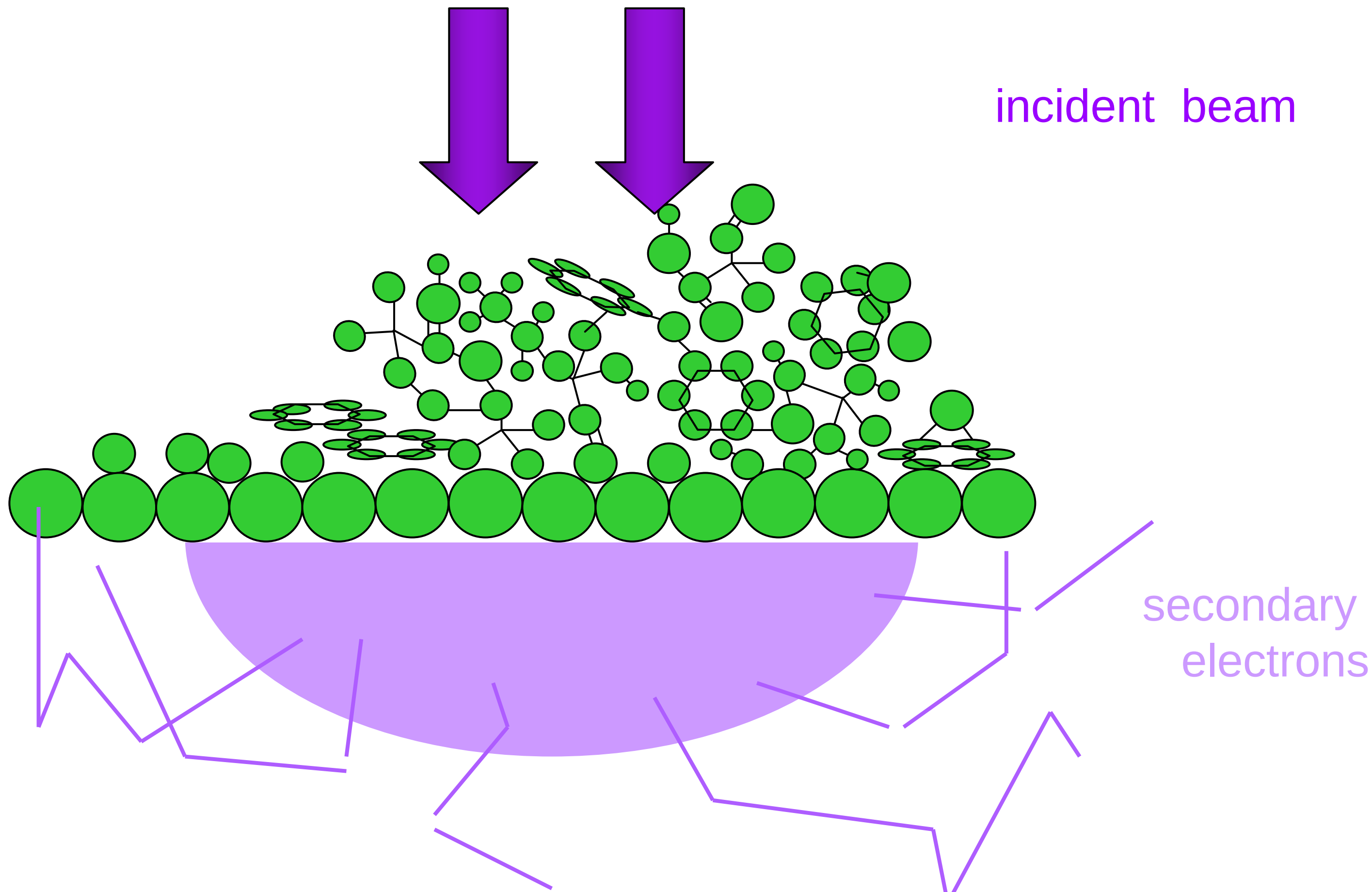


high SEY

medium SEY

low SEY

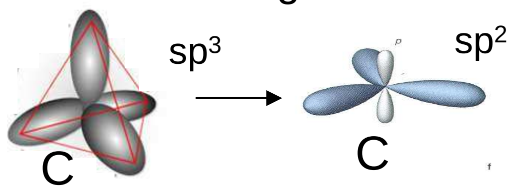
SEY of technical samples



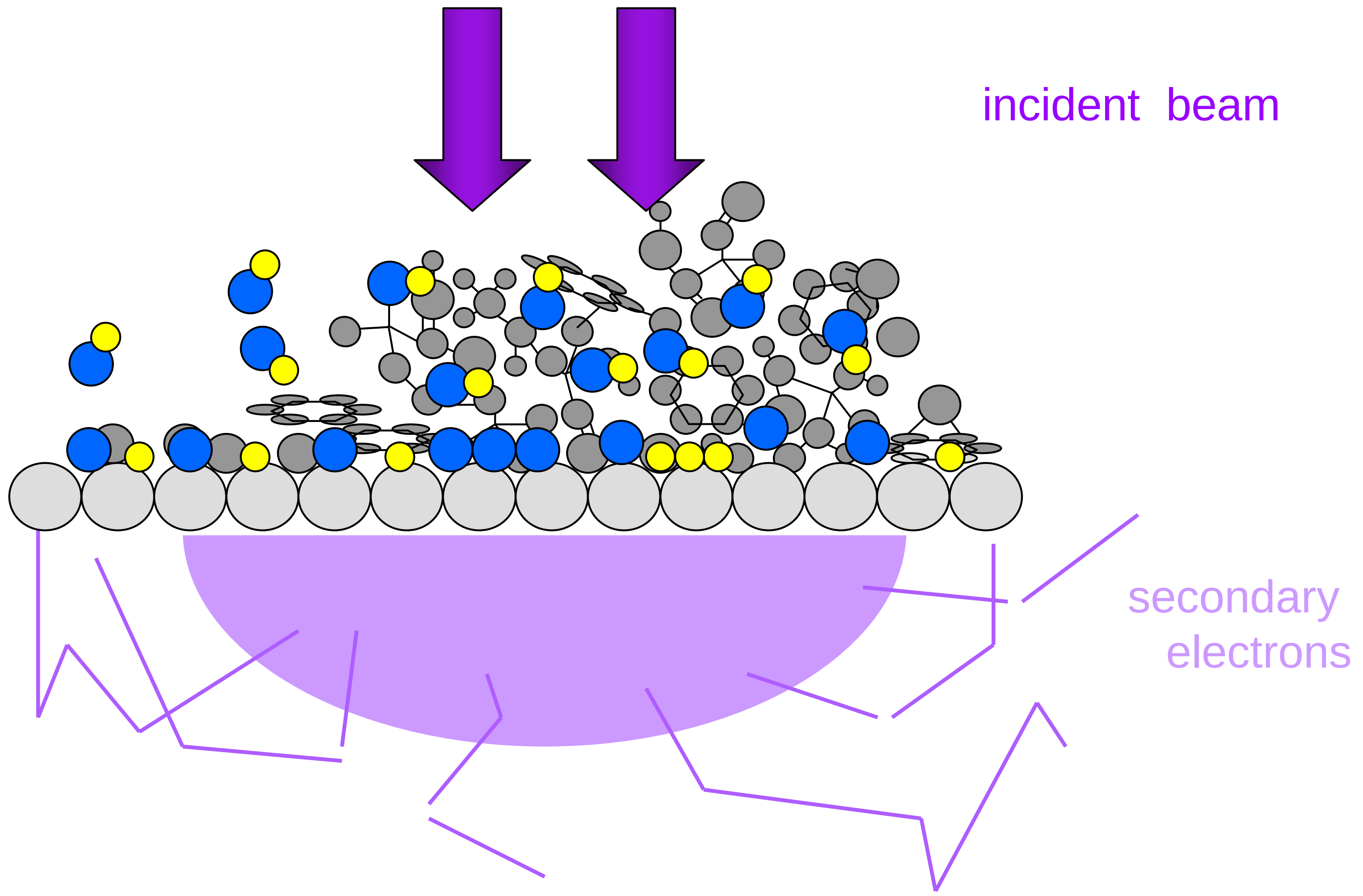
bond dissociation M-O, C-OH, C-O, C=O, C

electron beam desorption → O_2, H_2O, H_2 CO, CO_2

bond rearrangement

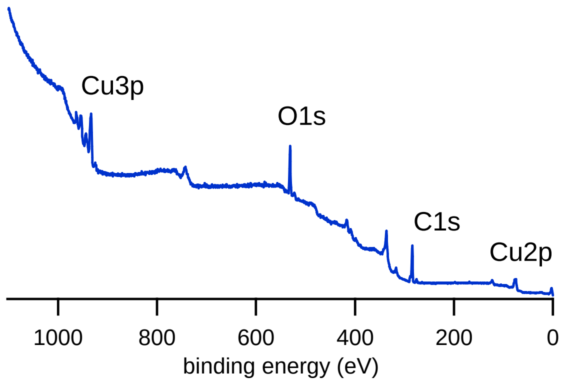


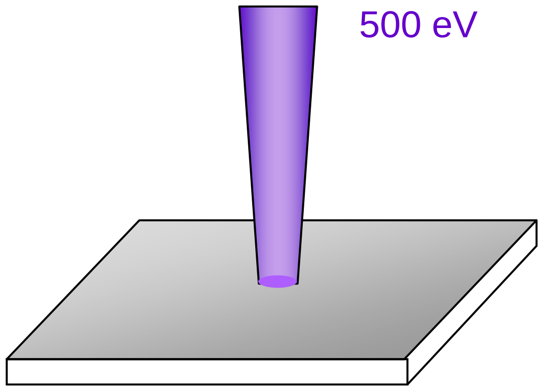
SEY of technical samples

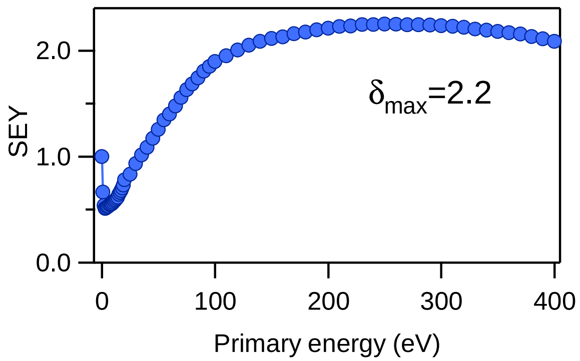


dissociation of “environmental” molecules $\rightarrow$ reactions, film growth

co-laminated Cu for LHC beam screen

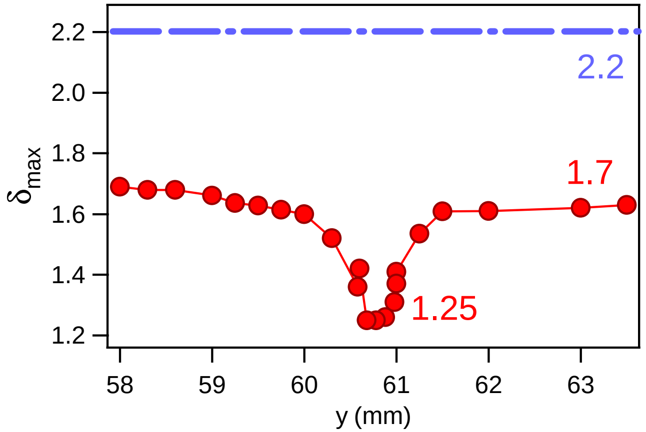






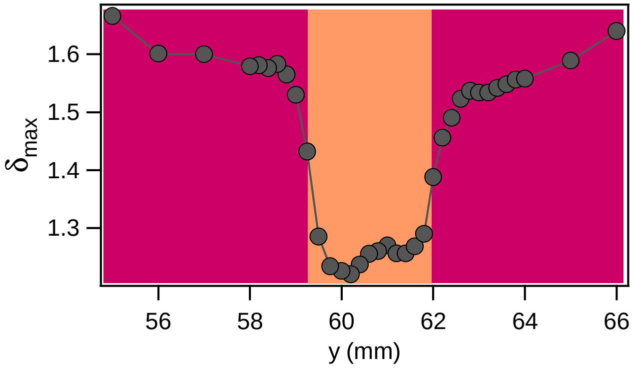
I=5μA

Q=1.2x10^{-3} C/mm^2



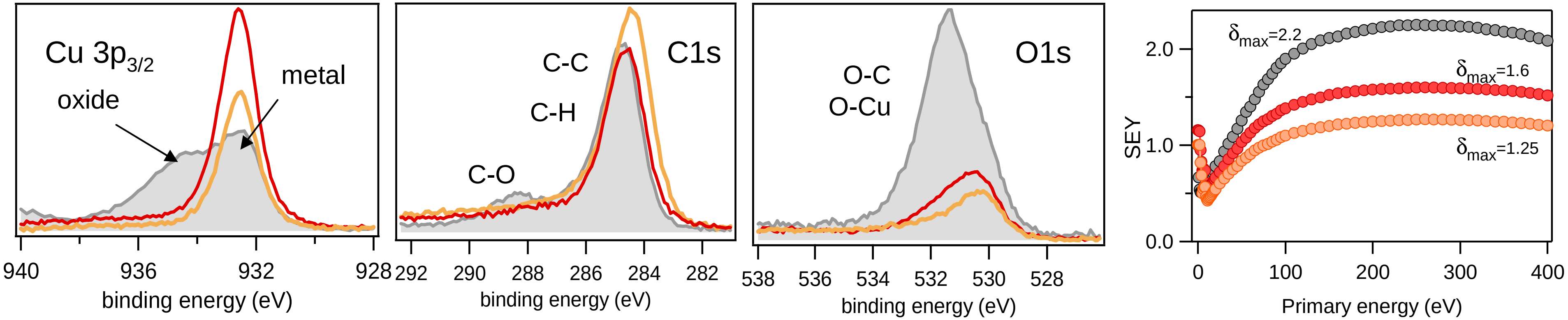
SEY decreases also outside the beam spot

co-laminated Cu for LHC beam screen



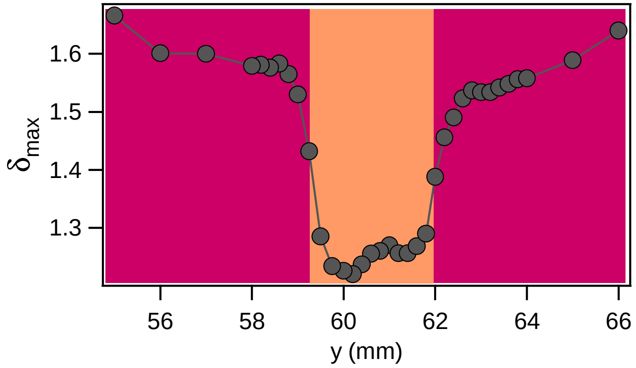
E=500 eV
I=5μA

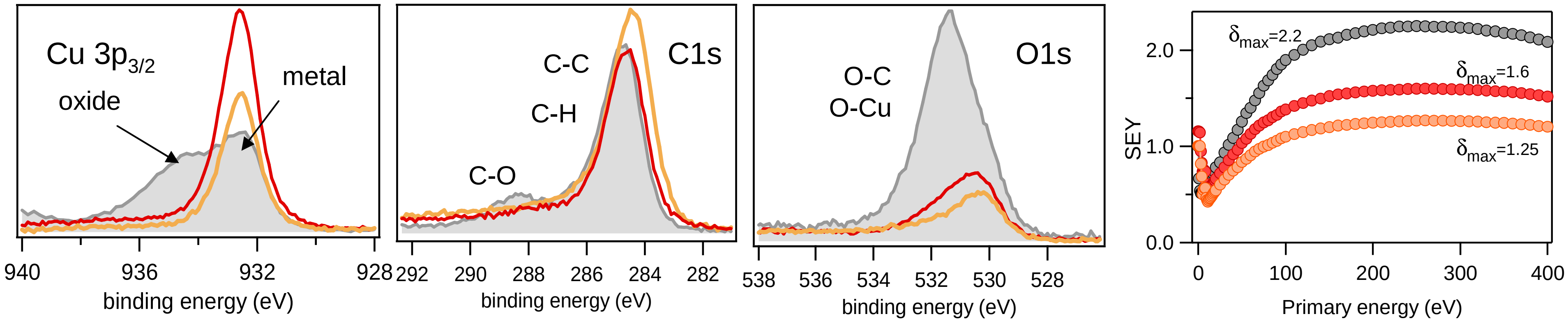
Q=1.2x10^{-3} C/mm^2



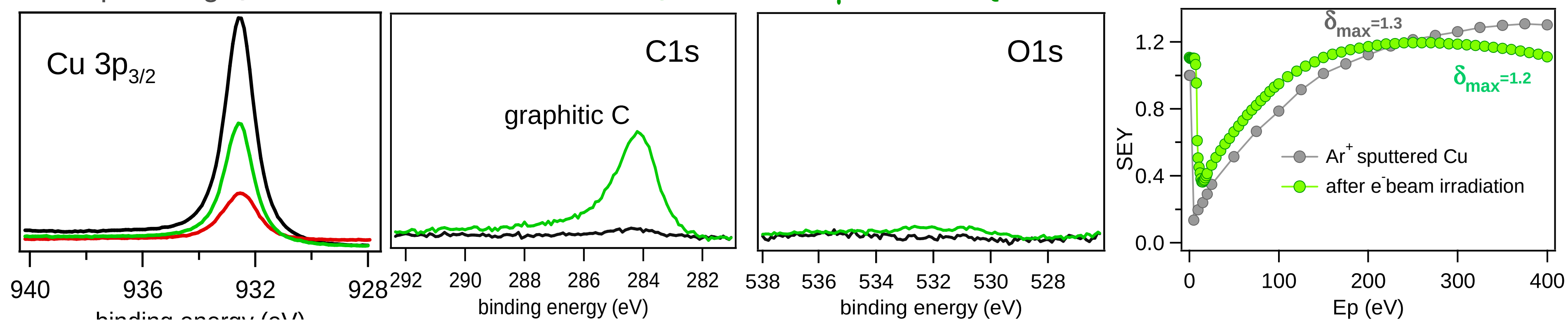
- the beam spot but also the surrounding area is modified
- in the beam spot the quantity of surface C increases → graphitic film growth

co-laminated Cu for LHC beam screen

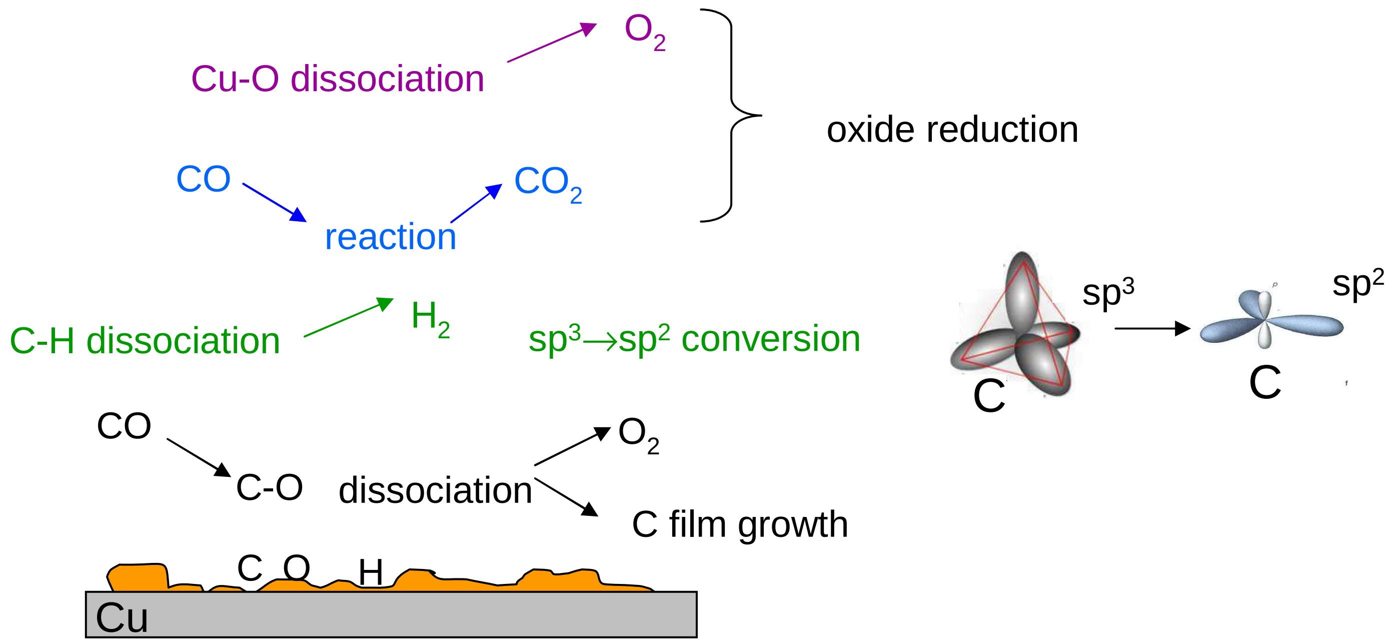




Ar$^+$ sputtering @ 2.2 KV + e$^-$beam irradiation @ 500 eV, 10μA, 15 h, Q=3.6x10^{-2} C/mm^2

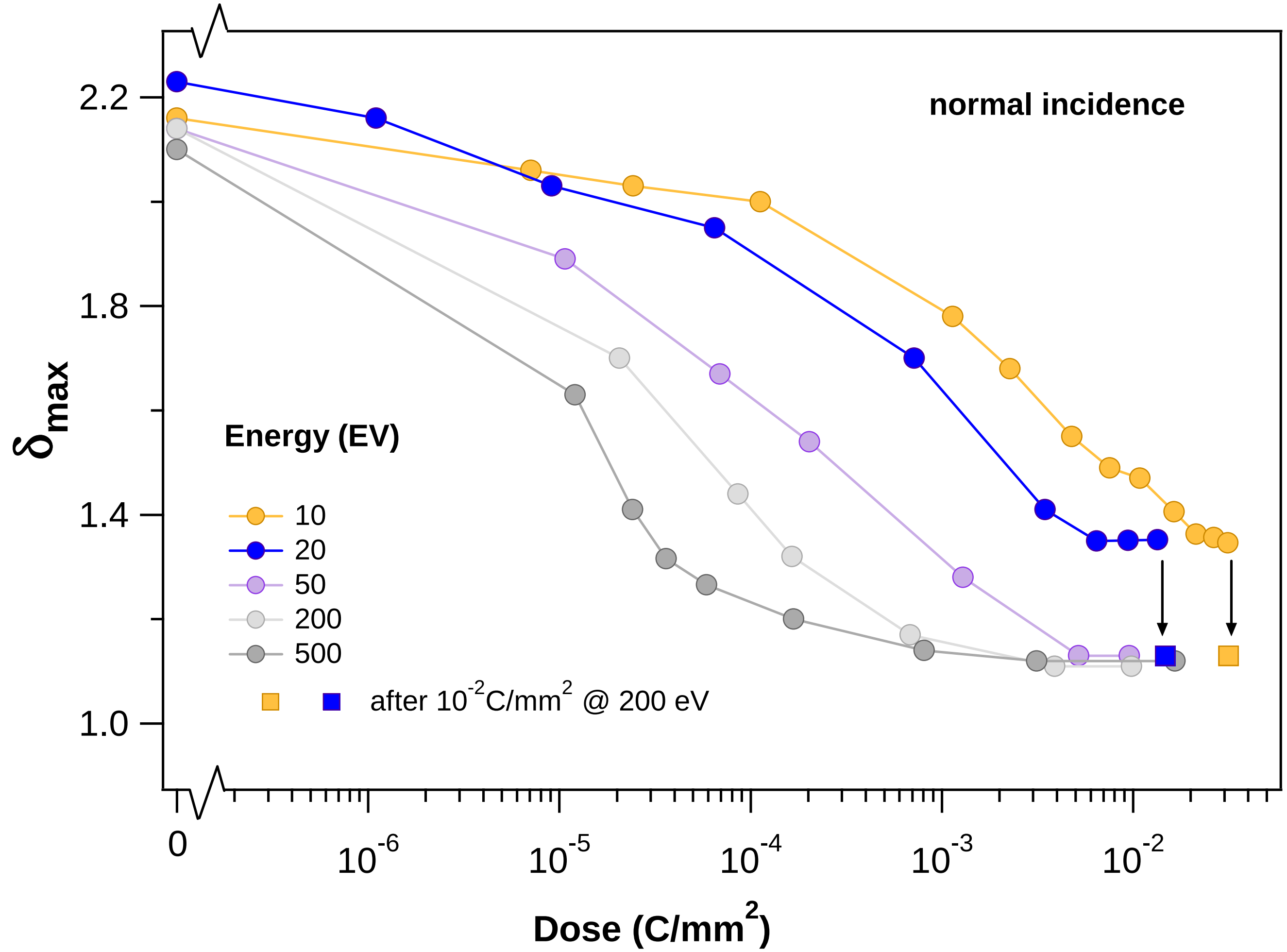


e^- beam induced surface reactions



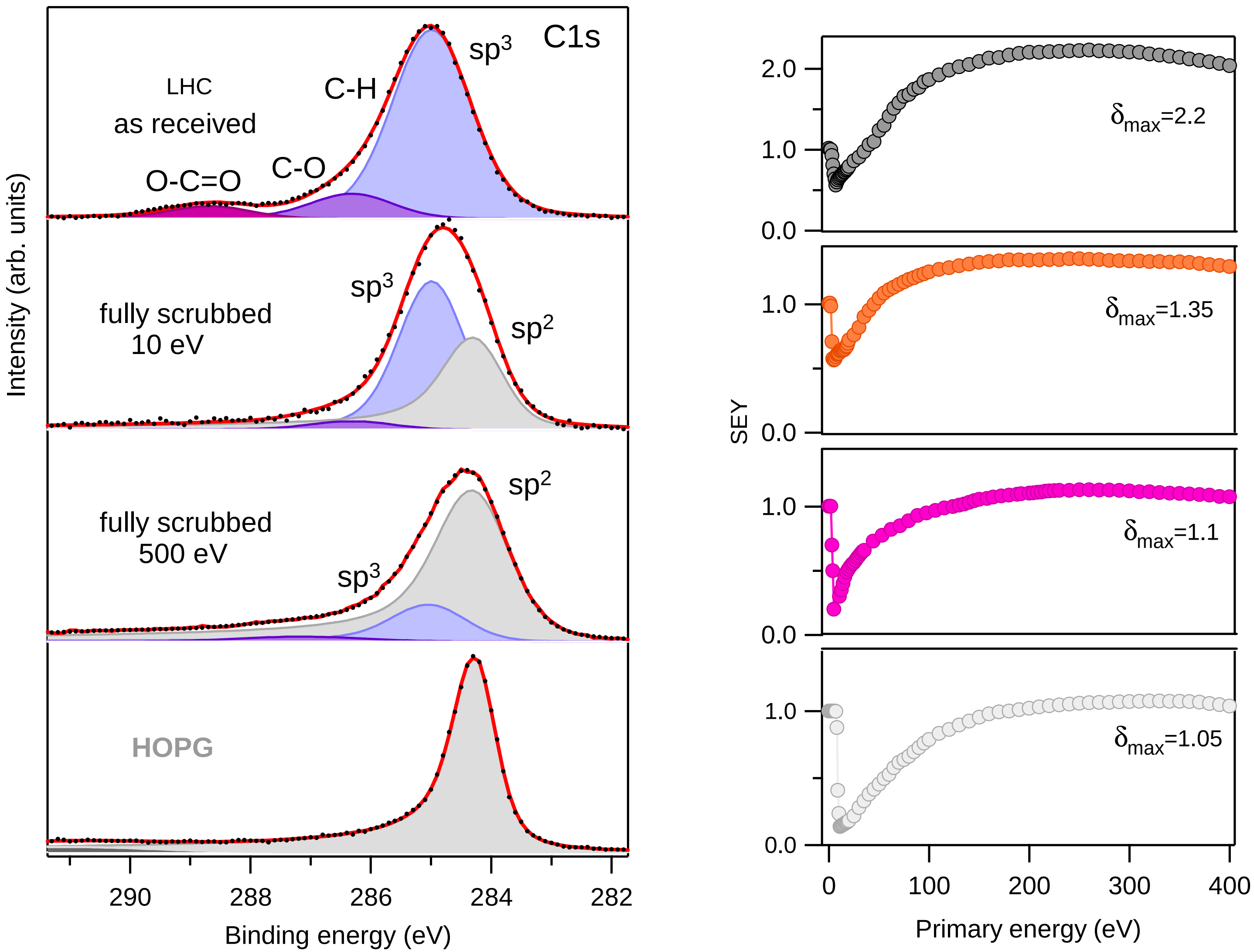
the contribution of all electron-induced surface reactions reduces δ_{max} from 2.2 to 1.1

co-laminated Cu for LHC beam screen



R. Cimino et al. submitted to PRL

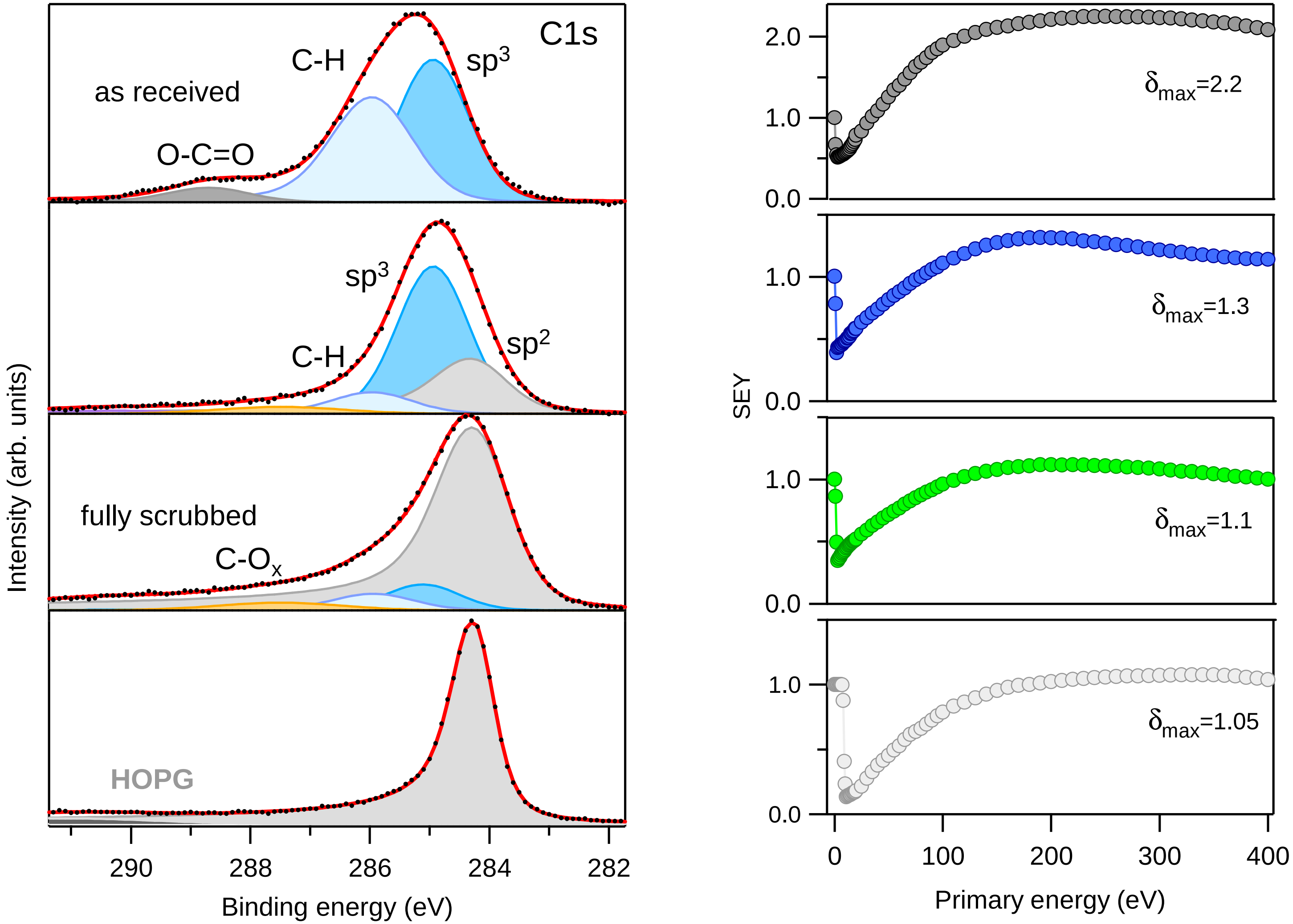
co-laminated Cu for LHC beam screen



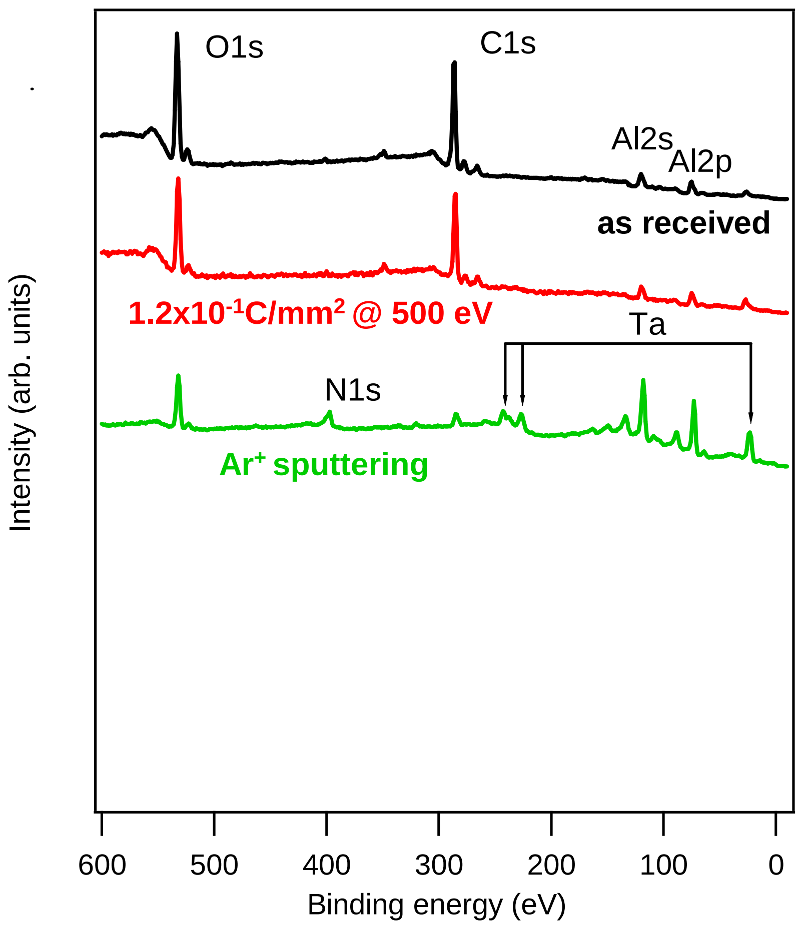
R. Cimino et al. submitted to PRL

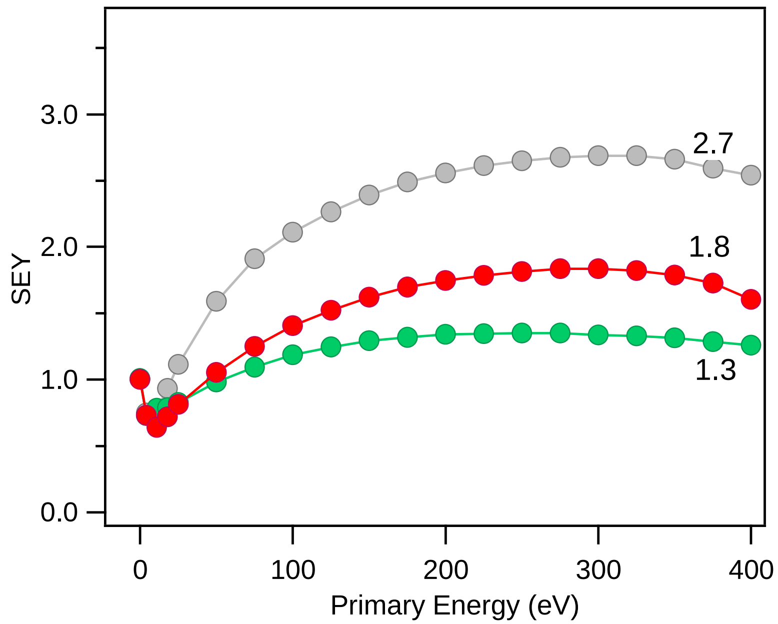
Stainless steel samples from RICH@BNL

E=500 eV



Al samples from Petra III





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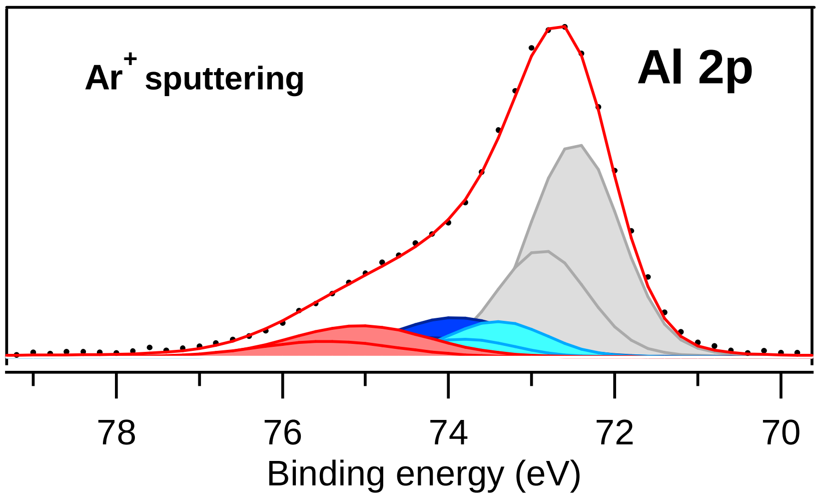
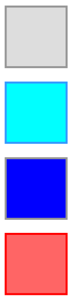
Al samples from Petra III





the minimal partial pressure of H_2O contained in the residual gas is sufficient to hinder the achievement of a stable, clean Al surface.

After prolonged ion bombardment there are still Al atoms bonded to O even in a Al_2O_3 phases

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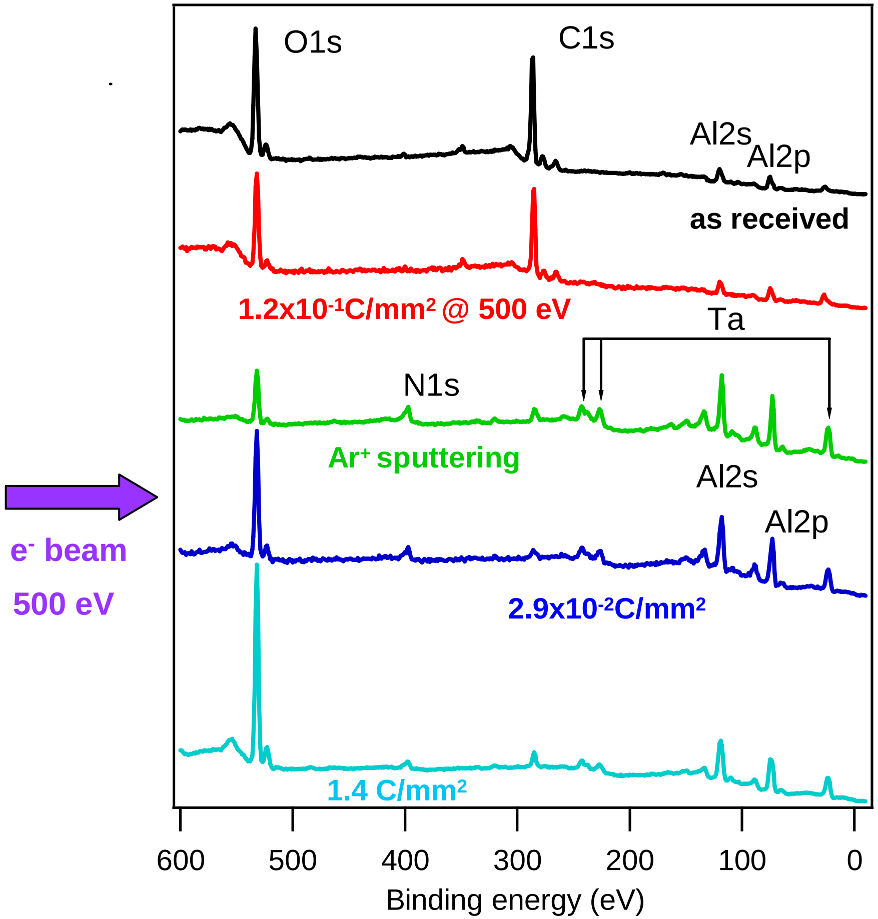
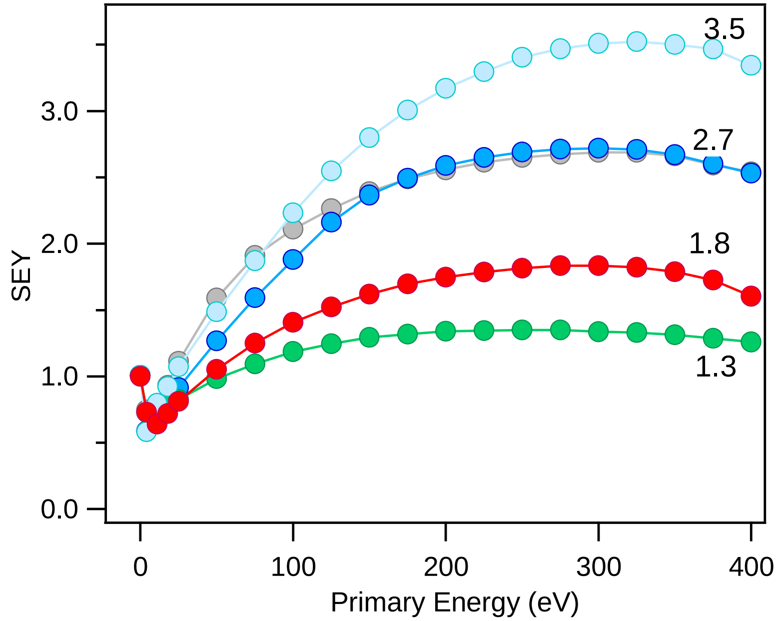
Al samples from Petra III





dissociation of residual gas molecules as H_2O and CO induced at the metal surface by the e^- beam determines a rapid oxidation of the irradiated area, as well as, although to a lesser extent, of the surrounding region

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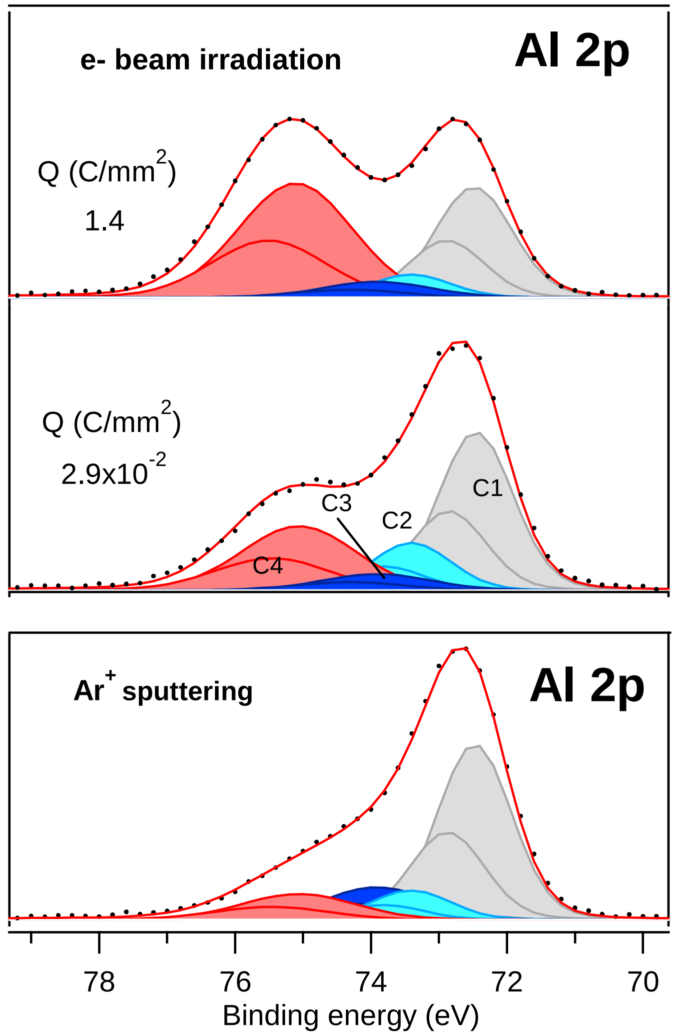
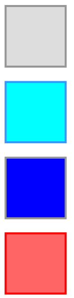
Al samples from Petra III



dramatic enhancement exclusively of the most oxidized Al_2O_3 phase



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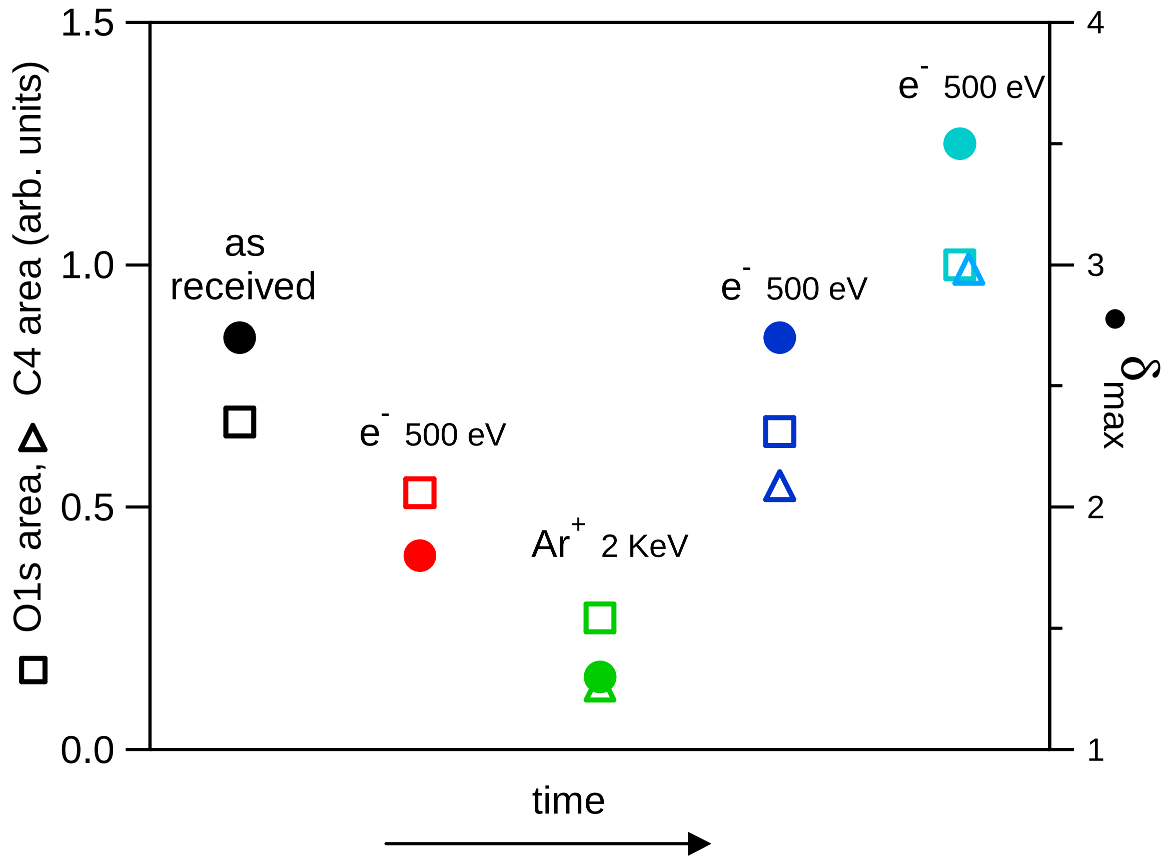
Al samples from Petra III



the SEY variation follows the oxygen content of the Al surface

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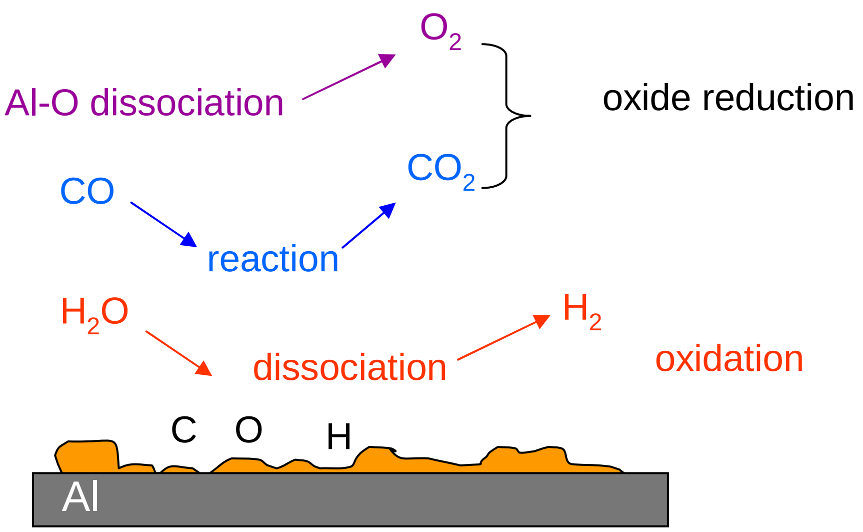
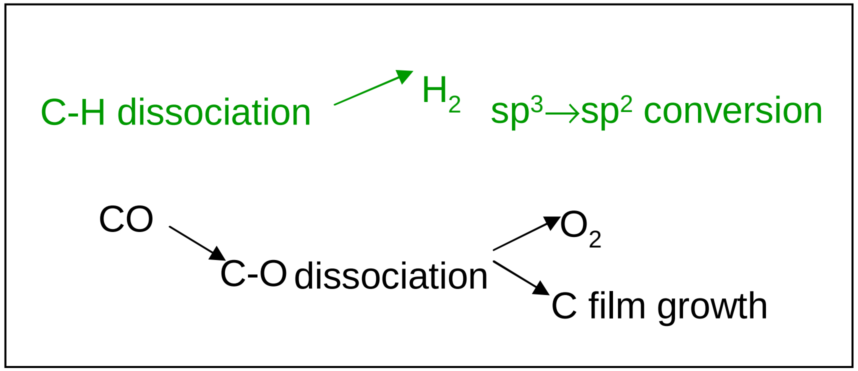
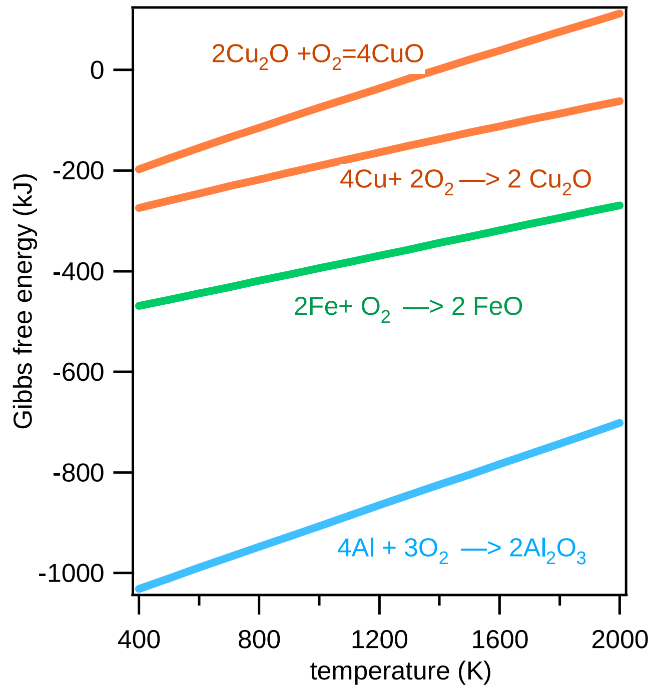
e^- beam induced surface reactions



SEY is determined by the rates of Al oxidation and reduction

reactions involving C play a minor role

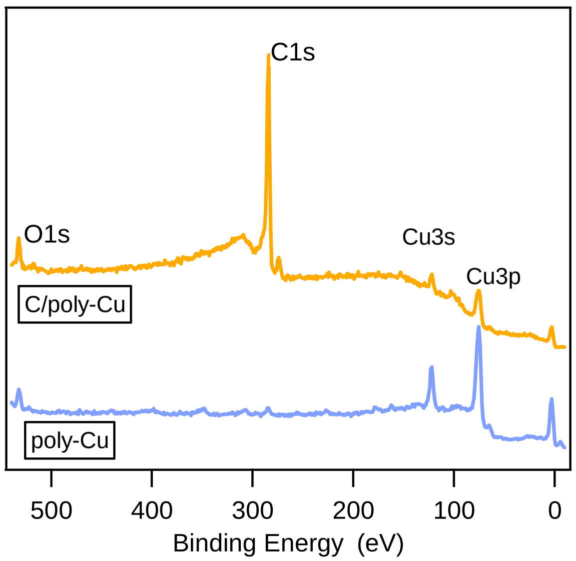


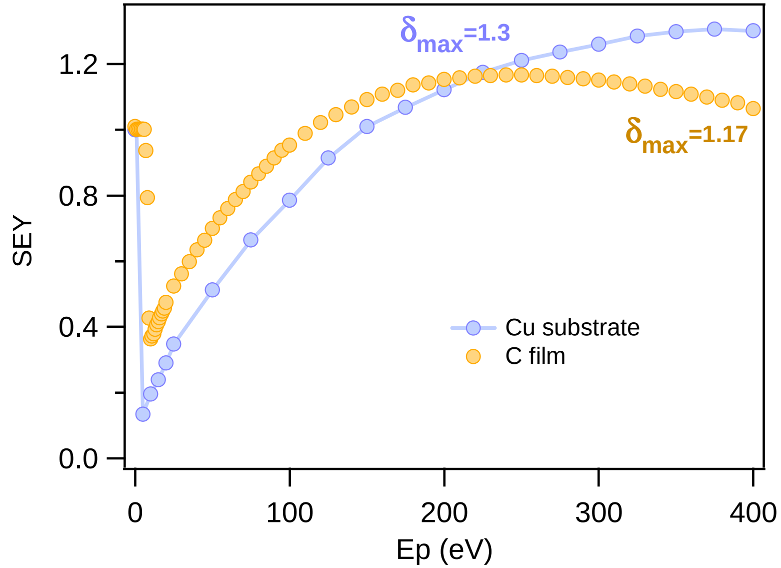


C films on polycrystalline Cu

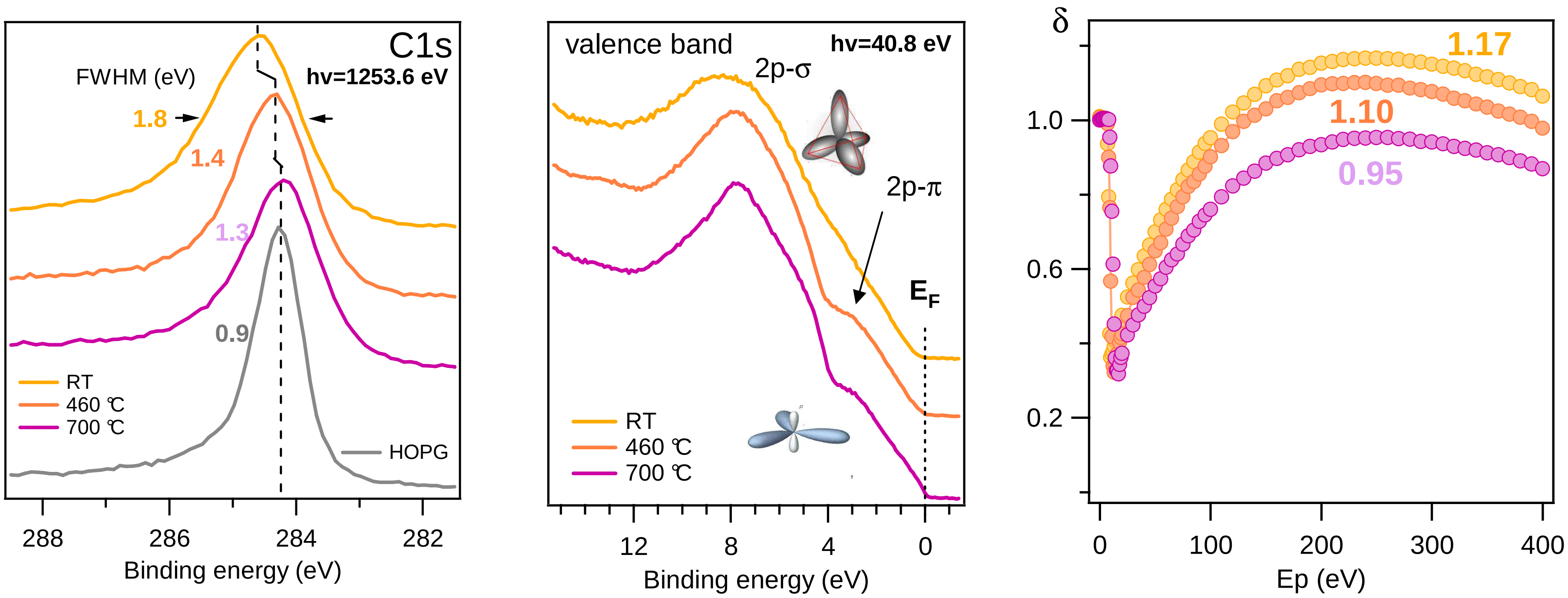
a-C films
magnetron sputtering @ RT
p(Ar)= 10^{-2} mbar
Δt = 2min

C film thickness 2-3 nm





C films on polycristalline Cu



the graphitization of the C films corresponds to a lower SEY

Conclusions

The SEY of technical samples is strongly affected by the chemical composition of the surface as the presence and the nature of contaminating adsorbates can heavily modify the effectve δ_{max} values. This determines the high variation of the experimental values.

For Cu samples electron conditioning at 500 eV reduces the SEY and lowers δ_{max} from 2.2 to 1.1 . Both direct beam and secondary electrons have a role in the chemical reactions which decrease the SEY.

Similar results were found for stainless steel samples.

On the contrary for Al samples electron conditioning at 500 eV does not succeed in lowering δ_{max} below 1.8 (1.5). In this case the composition of the residual gas in the UHV chamber is extremely importantin limiting the e^- beam induced oxidation.

For ultrathin C films deposited by magnetron sputtering on copper δ_{max} depends on the sp^3/sp^2 ratio.

The knowledge of the chemical state of a "technical" surface can elucidate the origin of the measured SEY curves and in general provide profitable information for the e-cloud mitigation.

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